ICES CM 2007/O:20

A new scientific initiative with the Pelagic RAC to develop a management plan for western horse mackerel

Maurice Clarke[1], Gerard van Balsfoort[2], Aukje Coers[3], Andrew Campbell[1], Mark Dickey-Collas[4], Afra Egan[1], Marc Ghiglia[5], Ingvild Harkes[3], Ciarán Kelly[1], Sean O' Donoghue[6], Christian Olesen[7], Beatriz Roel[8], Andrew Tait[9] and Andres Uriarte[10].

1. Marine Institute, Rinville, Oranmore, Co. Galway, Ireland
2. Pelagic Freezer Trawler Association, Treubstraat 17 P.O. Box 72, 2280 AB Rijswijk, The Netherlands
3. Pelagic RAC, P.O. Box 72, 2280 AB Rijswijk The Netherlands
4. IMARES, Ijmuiden, Netherlands
5. Union des armateurs à la pêche de France
6. Killybegs Fishermen's Organisation, Bruach na Mara, Killybegs, Co. Donegal, Ireland.
7. Danmarks Pelagiske Producentorganisation, Postbox 104, Nordsøcentret, 9850 Hirtshals
8. CEFAS, Pakefield Road, Lowestoft, Suffolk, England, UK.
9. Scottish Fisherman's Federation, 24 Rubislaw Terrace, Aberdeen, AB10 1XE
10. AZTI, Herrera Kaia Portu alde z/g, 20110 Pasaia, Basque Country, Spain

Authors after corresponding author, appear in alphabetical order. Corresponding author: Maurice Clarke, Marine Institute, Rinville, Oranmore, Co. Galway, Ireland. Tel. + 353 91 387200; Fax +353 91 387201; E mail: Maurice.Clarke@marine.ie.

Abstract

The western horse mackerel stock is currently managed by annual TACs covering only part of its distribution area. No stock assessment has been accepted and recent ICES advice has consistently been for *status quo* catches. In 2006, the Pelagic Regional Advisory Committee asked scientists to help with developing a harvest control rule for the stock that would both meet conservation and stability objectives. An initial questionnaire was circulated to the industry, to elicit feedback on possible management options. A series of Harvest Control Rules were developed. These were tested by simulation and presented to the RAC at a number of meetings. Results will be presented within the ICES advisory process and elsewhere in the scientific literature. This is a developing approach involving scientists and stakeholders in an iterative process. The problems encountered and lessons learned, are discussed.

Keywords: Pelagic Regional Advisory Committee, western horse mackerel, harvest control rule

Introduction

Atlantic Horse mackerel *Trachurus trachurus* is a widely migratory pelagic fish species, inhabiting waters in the northeast Atlantic, from Iceland to Cape Verde, in the Mediterranean Sea and Sea of Marmara. It supports both artisanal and highly mechanised fisheries in the NE Atlantic. Horse mackerel in this region (ICES area) is divided into a number of separate stock assessment units, as follows:

- Western stock: Divisions IIa, IIIa (western part), Vb, IVa, VIa, VIIa–c,e–k;VIIIa-e.
- North Sea stock: Divisions IIIa (eastern part), IVb,c and VIId.
- Southern stock: Division IXa

The spatial boundaries of the Western stock (Fig. 1) are not the same for assessment and management purposes. For management purposes, all of Sub-area IV is combined, along with Division IIa. However, for assessment purposes, Division IVa and the western part of Division IIIa are included in the "Western stock". For management purposes, Division VIId is combined with the "Western stock", but is included in the North Sea stock for assessment purposes. Based on the results of the HOMSIR project (Abaunza *et al*., 2003), Division VIIIc is considered by ICES to be part of the western stock for assessment purposes. However, for management purposes, this Division is combined with Division IXa. ICES has repeatedly advised that the management areas should correspond to the assessment areas, though this has not yet happened.

Stock characteristics and distribution

The western horse mackerel stock is one of the best studied horse mackerel stocks in the world. Yet, there are large gaps in the information base. It is considered to be a migratory shelf edge pelagic species, with longevity of about 35 years, maturing around the age of 3 or 4. Fecundity has been recently considered to be indeterminate. The nature of recruitment in western horse mackerel is highly spasmodic with a single extraordinary large (20 times the average) 1982 year class which reached its maximum in 1988 (ICES, 2005a). The 2001 cohort is stronger than recent cohorts.

Western horse mackerel is a highly migratory pelagic stock that spawns along the shelf break from Scotland, along the west coast of Ireland, to the Bay of Biscay in early spring. This stock migrates in a northerly and easterly direction towards southern Norway and the North Sea.

Egg surveys in western and southern areas are carried out every third year, the last one in 2004. This survey covered the spatial range of mackerel and horse mackerel and included fecundity sampling for both species. The total seasonal stage 1 egg production was calculated for southern and western areas separately (ICES, 2005b). The 2007 egg surveys are currently underway. Preliminary results from the Irish survey conducted in March have identified as yet unquantified amounts of horse mackerel eggs present throughout the survey area.

The horse mackerel spawn from January-July. The southern horse mackerel starts spawning in January. The distribution of the eggs in 2004 demonstrates that the fish spawn later in the season further north. Larvae are regarded to have a similar distribution area to the eggs.

The main juvenile distribution area is on the continental shelf from the north of Spain in the south, to Ireland in the north, in ICES Divisions VIIa,e,f,g,h and VIIIa,b,c,d. Usually the newly spawned fish (0-group) horse mackerel are observed along the Norwegian coast and in the fjords, during a survey which has been carried out in the 4th quarter since 1969. Juveniles are occasionally observed in high numbers in the Kattegat (IIIaS) and western Baltic (IIIc). Section 4.2 provides information on percentage of juveniles (ages 0-3) in the catches by ICES Division. Spawning in the western area takes place from April to July and this spawning is indicated by the egg distribution. Figure 2 shows the distribution of the western horse mackerel in the feeding area as indicated by location of the landings taken in the 2nd, the 3rd and the 4th quarter.

The Western stock migrates into the feeding area in the second and third quarters. Some fish move into the northern North Sea and western Skagerrak at this time, though the full distribution of the stock at feeding time is unknown. The distribution of the adults during the over-wintering period is not clearly indicated by commercial landings because these fish are scattered at this time of the year.

Horse mackerel is considered to be an indeterminate spawner, with spawning taking place over a protracted spawning season. The number of eggs produced is not determined in advance of spawning and additional maturing unfertilised eggs (oocytes) develop during the spawning season to enhance fecundity (ICES, 2003). Fecundity is likely to be regulated by factors such as total body energy content prior to spawning, and uptake of energy from feeding during spawning (Van Damme, *et al* 2005). The annual egg production method can therefore not be applied to horse mackerel.

The fishery

Broadly speaking, there are three fisheries for western horse mackerel. Dutch, German and French pelagic freezer trawlers target the stock, mainly in the western English Channel, and Sub-area VII,. There is an Irish fishery, prosecuted by pelagic RSW trawlers, mainly in coastal and shelf waters along the northwest and west coasts of Ireland, in Sub-areas VI and VII. In some years, Norwegian purse-seiners catch western horse mackerel in the northern North Sea. There has also been a small Danish fishery for industrial purposes, mainly in Sub-area VII.

Figure 2 shows the seasonal distribution of horse mackerel landings in 2005. Figure 3 shows long term trends in ICES' estimates of landings by ICES area and official landings data by country.

Current stock status

ICES (2006) considered that, in the absence of defined reference points and an analytical assessment, the state of this stock is unknown. In other words, SSB, recruitment and F cannot be reliably estimated. Data exploration suggests that the SSB has decreased since the 1980s, as the outstanding 1982 year class has been depleted. The 2001 year class is stronger than other recent ones. ICES also considers fishing mortality to be low. The 2005 stock status is shown in Figure 4.

There are no reference points for this stock. In the past $F_{0.1}$, could be considered the highest rate of fishing mortality consistent with the Precautionary Approach. This was considered as a target in the past, but cannot be used now, as no reliable estimate is available. Assumed natural mortality may be too high, and there is a perception that overall fishing mortality is moderate.

Furthermore, current F cannot be compared with those pre-2002 because age range has changed. A limit reference point for SSB (B_{lim}) could be set at the level that produced the strong 1982 year class (B_{lim} = SSB 1982). But once again, the absence of an estimate of SSB precludes the use of this reference point.

Advice

Given that F, SSB and recruitment are poorly estimated, ICES produced precautionary advice on the basis that catches should be constrained below 130,000 t. Advice for 2005 and subsequent years augmented this by 20,000 t, corresponding to average landings from Division VIIIc, on account of the findings of Abaunza et al. (2003). This advice was on the basis that, in the absence of a strong year class sustainable yield is probably not >130,000 t for the traditional stock areas (plus 20,000 t for Division VIIIc). In 2006, ICES advised that despite indications of a strong 2001 year class and given the uncertainty in stock levels, ICES recommends catches less than 150,000 t. ICES also pointed out that preliminary simulations in 2006 suggested that risk rose with catches > 150,000 t.

In addition to this main advice, ICES has also noted the following points:

- an increasing juvenile fishery at a time when the adult stock is declining and there is no analytical assessment as to the size of the stock (ICES, 2001).
- a management strategy should be developed that takes into account fisheries for both adults and juveniles (similar to North Sea herring) (ICES 2006, Section 9.4.3).
- the TAC area and stock distribution areas do not agree (ICES, 2006, Section 9.4.3).
- catches considerably overshot the TAC from 1988 to 1997, but have been below or close to the TAC since (ICES, 2004).
- the decrease in the TAC overshoot for the western area (ICES, 2006 Section 9.4.3) corresponds with an increase in North Sea horse mackerel catches (ICES 2006 Section 6.4.21).

It should be noted that the juvenile fishery overlaps the stock boundary between the North Sea and western areas, and that the TAC for the North Sea is not precautionary (Anon. 2005).

There are no defined reference points. Exploitation boundaries in the past have been based on $F_{0.1}$, but this is not considered to be well estimated anymore.

Current management regime

The stock is managed by means of Total Allowable Catch (TAC) and some Technical Conservation Measures (TCMs) for European Community vessels, and in Community waters. The spasmodic Norwegian fishery is unregulated. For the EU fishery, a precautionary TAC is set, that in recent years has been around 150,000 t. This TAC is not based on an analytical assessment or forecast, since none is available.

In addition to the EU TAC, there are a number of technical conservation measures (TCMs) relevant to the stock. In the EU, a minimum landing size of 15 cm applies. There are no closed areas applicable to horse mackerel fisheries, in EU or Norwegian legislation (Anon. 2005).

Need for a management plan

The current management system as it applies in the EU does not serve the horse mackerel situation very well. The lack of an analytical assessment or forecast precludes the implementation of the implicit EU management strategy. The implicit strategy is to set the TAC one year ahead, based on forecasted population size in an intermediate year, from an assessment in a given year.

The lack of predictive power in the assessment means that the stock may not be optimally harvested. For example, in periods of elevated stock productivity, due to pulse recruitment, optimal catches cannot be advised for in the current fisheries system.

Currently, there is a move towards developing discrete management plans for individual stocks. It was in the light of the problems above that the Pelagic RAC identified the need to develop a management plan for western horse mackerel. In light of this request, an informal consortium of scientists was formed to develop a series of management strategies, for presentation to the RAC. Due to the lack of predictive power in the assessment, the Pelagic RAC is seeking alternative ways to manage the stock and has sought help from the scientists.

Materials and methods

The following data were identified as being available.

- Catch data 1982 to present.
- Egg production estimates from egg surveys every third year 1983,1986, 1989, 1992, 1995, 1998, 2001, 2004.
- Catch at age data 1982 to present.

Process

In September 2006, the Pelagic RAC approached the scientists and asked them to convene a group to investigate the development of a management plan. The first initial meeting took place on the 3rd November 2006, in Brussels. At this meeting the latest ICES advice was presented. The strengths and weaknesses in the knowledge base were discussed. Preliminary results of simulations (Kelly and Campbell, in prep.), were presented, showing two constant catch strategies. Further preliminary simulations Röel (in prep.) were presented. These showed three-year TAC strategies. In one scenario, the TAC was adjusted based on the slope in the last 3 egg survey egg abundance estimates. A second scenario, showed a TAC adjusted by a proportion of SSB in the assessment year, derived from an analytical assessment. Roel's third scenario was for a hybrid TAC, based on a combination of fixed proportion of the previous TAC and a TAC adjusted by the slope of egg abundances.

A questionnaire (Appendix I) was presented to the RAC at the November meeting. The aim of the questionnaire was to get feedback from the industry stakeholders about important components of future management viz. TAC range, TAC variability, preferences for flexibility vs. stability and preferences for particular size grades. Responses were sought by the 7th January 2007.

The response to the questionnaire was limited, and not comprehensive nor representative of the wider membership of the RAC. In particular, one main player did not respond. A presentation on the answers received was given at the RAC workshop on the 6th February. A number of issues were identified as being more or less representative of the stakeholders' concerns:

- Industry prefer minimal year to year variation in TAC
- Markets are available for all size grades of fish.
- Fat content, not size is an important factor on price.
- There is a desire in certain parts of the industry to protect juveniles.
- There is no ceiling on marketing capacity below 250,000 t.

On the 6th February 2007, the consortium of scientists met the membership of the RAC at the scheduled RAC workshop in Edinburgh. The results of further developments of the above scenarios were presented by Ciarán Kelly and Andrew Campbell and Beatriz Röel. A detailed discussion took place.

On the 7th February, Working Group II of the Pelagic RAC met and identified further work that needed to be done, and discussions required with scientists. It was noted that these questions needed to be answered, before further progress could be made. It was agreed to convene a focus group, consisting of a smaller membership of Working Group II of the RAC and scientists. This group met on the, 20th April 2007, to consider the refined results of further simulation work.

The Pelagic RAC working group meeting of the 6th February was observed by social scientists. The aims of this process were to observe the interaction of science and stakeholders, and to investigate ways to incorporate stakeholders' concerns to the management process. This work was carried out under the SAFMANS project and will be reported in the report of that project and in the scientific literature (Wilson and Hegland, in prep.).

The focus group met on the 20th April 2007, in Dublin. Results of further developments of the simulations were conducted. Scientists and stakeholders discussed these results and then considered aspects of the developing management plan. It was agreed to make further scientific presentations at Working Group II of the Pelagic RAC on 16th May. A maximum of three strategies would be presented at that meeting. Each strategy would be accompanied by a hindcast. It was agreed to show results of simulations showing constant catch strategies using a range catches between 150,000 and 250,000 t. Consideration would be given to the consequences of different trigger points. Finally, it was considered important to provide information on the acceptable risk adopted by ICES of going below reference SSB.

On the 16th May, a single presentation was given by Ciarán Kelly, to Working Group II of the Pelagic RAC. This contained the results of simulations on two scenarios only:

- hybrid between a constant yield and proportional catch strategy (slope strategy, Roel and De Oliveira 2007)
- modified constant yield strategy

All simulations were conducted using FPRES software (Codling and Kelly, 2006) and the results were presented in a standard format that allowed stakeholders to compare and contrast the performance of each. No firm decision was taken on any one scenario. It was agreed that the results would be further refined and presented at the Pelagic RAC Working Group on the 27th June.

Management plan development

From the outset, TAC control was identified as the only option. This is because it is embodied in the current management regime, and is thought to offer the best means to regulate F. For pelagic species it is considered preferable to effort control. Within a catch constraint framework, the following themes were identified, during the science/stakeholder consultations as potential points for a management plan:

- TAC to encompass the entire spatial distribution of the stock
- Consideration of measures to regulate F separately for juveniles and adults.
- Optimal harvesting of most profitable size grades or other product types
- Ability to adjust management to take advantage of periods of elevated productivity.
- Stability in TAC vs. large increases/decreases.
- Ability to carryover unused quota to the following year.

Outline of management plan

The process closely matches best practice, as outlined in reports of SGMAS (ICES, 2007). As such, the involvement of stakeholders began at an early stage and is continuing. This paper describes a process that is still not yet complete.

Harvest Control Rules

A Harvest Control Rule is a rule designed to allow the TAC to be set in such a way as to achieve management objectives for the yield whilst safeguarding the stock from biological risk. Such biological risk is usually defined as recruitment impairment. Given the uncertainty in future stock states and the uncertainty in estimating the virtual stock size relative to the recruitment impairment point, as well as possible biases in implementation; a trigger point is often defined in a HCR. Below the trigger point the exploitation is reduced such that there is a low risk to the stock being below or at the recruitment impairment point. An HCR designed in such a way and applied rigorously should safeguard against stock depletion. However as simulations are based on past stock dynamics, and cannot guarantee future developments, it is a normal condition of most management plans with HCRs, that they be reevaluated on a regular basis.

Results

Simulated HCRs

Details of the simulation work will be presented elsewhere in the scientific literature (Anon. 2007; Roel et al. *in prep*)

Separate management for juveniles and adults

The issue of protection of juveniles has been mentioned in previous scientific meetings (Anon. 2005), and was brought up at several stages in the current process. The most recent ICES advice (ICES, 2006) mentioned that a management strategy dealing with juveniles and adults separately could be developed, as is used for North Sea herring. In order to investigate this matter further, mean weight and mean length at age in the catches for 2005 were plotted along with the proportion mature at age. Figure 5 shows the mean length and weight at age in the catches for 2005. Figure 6 shows proportions mature at age. The stock displays relatively slow growth, both in terms of length and weight, with little definition between ages. It can be seen that length and weight at age increase markedly from 4 to 5 years of age. However, fish of 200 g weight span a wide range of ages from juveniles to much older adults. The preliminary results suggest that there is little use in pursuing this further. It is not included in any of the simulations.

Final management plan adopted by Pelagic RAC

The plan is divided into general provisions (Section 1) and a specific harvest control rule (Section 2). The normal harvest control rule may be adjusted in periods of elevated productivity (Section 3).

1. General provisions

The parties agree on a management plan for the western horse mackerel stock, with the following general provisions:

- The plan provides for conditions for sustainable long term yield for the stock.
- The plan provides for achievement of acceptable year to year stability in the TAC.
- A unified management regime across all areas where the stock is distributed
- That there are not additional catches to those covered by the TAC.
- The industry agrees to partake in studies to demonstrate that there are no additional catches above the level of the TAC.
- Productivity of the stock assumed to reflect the conditions for the period 1982 to 2005. However, the plan was tested under conditions where no strong year-classes of the magnitude of the 1982 year-class occurred.
- That the TAC is set on a triennial basis based on egg abundance from the most recent three surveys
- Target fisheries will proceed with minimum ecological impact. The industry undertakes to partake in studies to quantify the levels of non-target by-catch.

2. Normal decision rule

For 2008 and subsequent years the TAC will be set according to the following rules;

1. *The TAC will be set for 3 years following the year of the most recent survey*
2. *The TAC will be fixed at the set level for a period of 3 years*

3. *In the event of the TAC being overshot in any year in the fixed period, the overshoot (as estimated by ICES) will be subtracted from the following years TAC. The impact of this needs to be tested by simulation*
4. *In the event of a survey result not being available,ICES will be asked to advise on the state of the stock and on exploitation boundaries consistent with the Precautionary Approach.*
5. *The TAC will be set according to the following rule*

$$TAC_{y-y+2} = 1.07\left[\frac{TAC_{ref}}{2} + \frac{TAC_{y-3}sl}{2}\right]$$

Where TAC_{ref} *=150,000 t and*

sl is a function of the slope of the most recent egg abundance estimates from surveys that can take values between 0 and 1.4 (see Appendix II).

Arrangements for reviewing the decision rules;

The plan will be reviewed and re-evaluated in 2009 and on three yearly intervals thereafter to ensure that;

1. SSB has been maintained above SSB_{1982}
2. That the uncertainties and bias in the fishery and biological system remain within the bounds of those tested
3. The assumptions made in the simulation testing phase are still valid

If either of the above has been violated the plan will be modified to adapt the decision rule to make it consistent with the precautionary approach.

3. Special conditions to apply in times of high stock productivity

If a recruitment event is the same or greater than that which occurred in 1982, as determined by ICES, the following will apply;

The detection of the recruitment event will be established no sooner than 4 years after its occurrence. The level of the recruitment will be established based on ICES interpretation of the most valid assessment.

After verification of such an event, by ICES, the decision rule will be adapted for as long as that year class contributes to the stock and the fishery .ICES is asked to develop a metric to determine the duration of this period of elevated productivity. Such a metric would identify when the terms of the normal decision rule above will be reverted to.

.

Discussion

The work presented above is not the end of the process, but a stage in an ongoing consultation with stakeholders.

In order for a management plan to be effective it needs to be implemented in accordance with the assumptions of the simulations. The recruitment, natural mortality, growth and maturity need to represent the full range of plausible dynamics, and the fishery dynamics need to be adequately represented. The simulations presented here represent only a first stage in what will be required with regard to robustness testing. Other factors which will need to be evaluated include sensitivity of the results to

- Error in maturity, and weights
- Bias in the assessment and implementation (to account for discards and historical overshoot).
- Overshoot due to mismatch between assessment and management areas.

The reason that a “stress-testing” approach was taken, is because there is too much uncertainty in the operational model, to be adequately dealt with in any other way. This is considered a novel approach for stocks with high uncertainty.

The simulation work conducted in this project assumes that total removals from the stock are accounted for. In particular, the simulated catches are inclusive of discards. If discarding or other unaccounted removals are made, in addition to the advised catches, then a central assumption of the work is violated.

This paper describes the first management plan for a European fish stock that has been developed through the Regional Advisory Committee structures. The process by which the plan was developed was iterative and lessons were learned along the way. It was important to note that several stakeholder consultations were required , and that stakeholder interaction is an ongoing process. Because stakeholders and scientists do not necessarily share the same concept of the issues involved, nor even the same vocabulary to describe these issues it is necessary to have open discussions. Thus, questionnaires, on their own will not elicit the information that scientists require from stakeholders. Overall the process was a success and it is hoped that this approach can be followed for other stocks.

The process by which stakeholders and scientists interacted in this work will be further considered, ina sociological framework by Wilson and Hegland (in prep).

The plan that has been developed does not require a reliable stock assessment. This is, we believe, also a new departure in the northeast Atlantic. It illustrates what can be achieved with available data, being mindful of the deficiencies in the knowledge base.

Acknowledgements

Attendance of participants at the meetings and workshops that formed the basis of this work was funded by a number of organisations: Irish Marine Institute; SAFMANS Project, coordinated by Dr. Doug Wilson of the Danish Institute of Fisheries Management; Pelagic RAC; Scottish Executive. Scientists from CEFAS, Lowestoft, UK and Marine Institute, Galway, Ireland conducted the simulation work and their contributions were funded by those institutes.

References

Abaunza, P., Campbell, N., Cimmaruta, R., Comesaña, S., Dahle, G., Gallo, E., García Santamaría, M.T., Gordo, L., Iversen, S., MacKenzie, K., Magoulas, A., Mattiucci, S., Molloy, J., Murta, A., Nascetti, G., Pinto, A.L., Quinta, R., Ramos, P., Ruggi, A., Sanjuan, A., Santamaría, M.T., Santos, A.T. Stransky, C., Zimmermann, C, 2003. Final Report of the EU funded project HOMSIR: “A multidisciplinary approach using genetic markers and biological tags in horse mackerel (*Trachurus trachurus*) stock structure analysis”. Code: QLK5-Ct1999-01438.

Anon., 2005. Report of the ad hoc scientific working group on management measures for sandeel, Norway pout, anglerfish and horse mackerel. Unpublished report. DIFRES. Charlottenlund. 78 pp.

Anon. 2007. A new scientific initiative with the pelagic RAC to develop a management plan for western horse mackerel. Working Document to ICES Assessment Working Group for Mackerel, Horse Mackerel, Sardine and Anchovy.

Codling, E.A, & Kelly, C.J., (2006) F-PRESS: a stochastic simulation tool for developing fisheries management advice and evaluating management strategies. Irish Fisheries Investigation Series No. 17 2006 34pp ISSN 05787476.

ICES, 2001. Report of the ICES Advisory Committee on Fisheries Management, Advisory Committee on Marine Environment, and Advisory Committee on Ecosystems 2001 Section 9.4.3.

ICES, 2003, Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. ICES CM 2003/G:7 Ref D. Living Resource Committee.

ICES, 2004. Report of ICES working group on Mackerel, Horse Mackerel, Sardine and Anchovy ICES:2004 ACFM:08

ICES, 2005a. Report of ICES working group on Mackerel, Horse Mackerel, Sardine and Anchovy ICES:2005 ACFM:08

ICES 2005b, Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. ICES CM 2003/G:09 Ref D. Living Resource Committee.

ICES, 2006. Report of the ICES Advisory Committee on Fisheries Management, Advisory Committee on Marine Environment, and Advisory Committee on Ecosystems 2006, Book 9, Section 9.4.3 and 6.4.21.

ICES, 2007. ICES Study Group on Management Strategies. ICES CM 2007/ ACFM:04 2006

Roel, B. A. and J. A. De Oliveira. 2007 - Harvest Control Rules for the western horse mackerel (*Trachurus trachurus* L.) stock given paucity of fishery-independent data. ICES Journal of Marine Science **64**

Van Damme, C.J.G., Dransfeld, L., Eltink, A.T.G.W., Kruger-Johnsen, M., Perez, J.R., Ullweit, J., Witthames, P., 2005. Horse Mackerel Fecundity in relation to lipid content. ICES CM 2005/Q:03

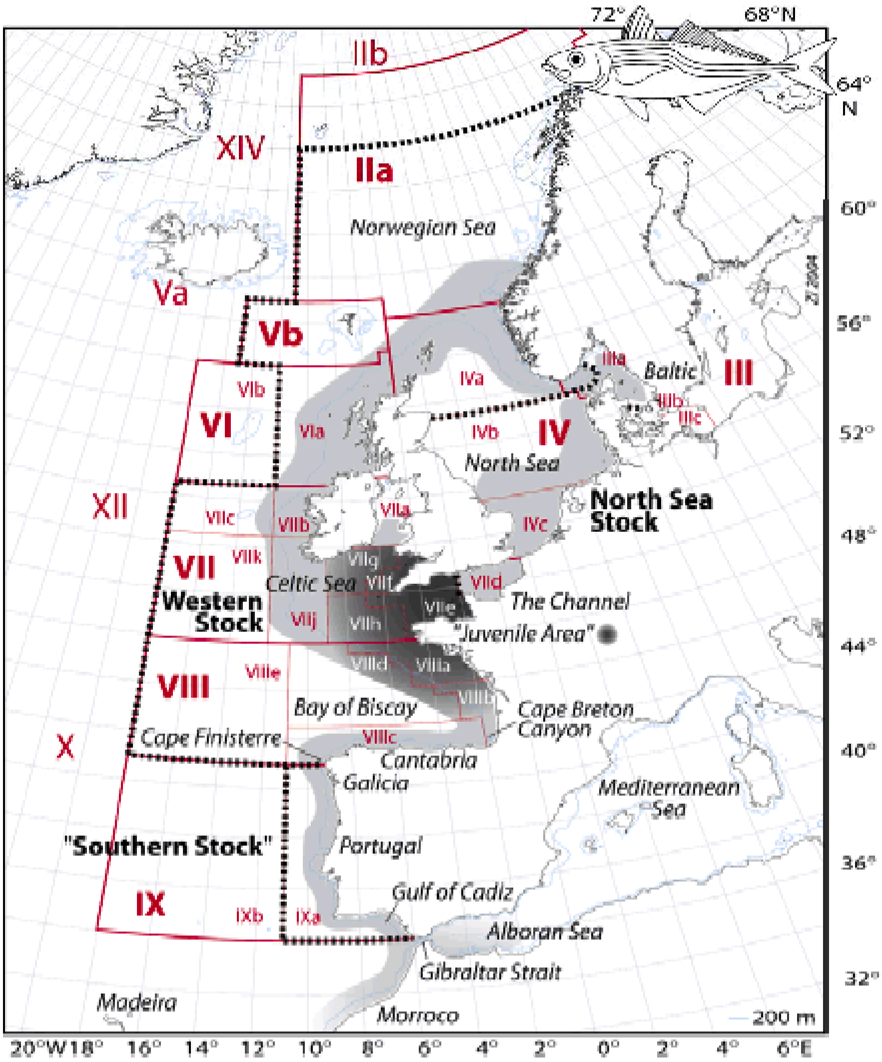


Figure 1. Distribution of horse mackerel in the Northeast-Atlantic: Stock definitions as used by the 2004 ICES WGMHSA (Anon., 2005). Note that the "Juvenile Area" is currently only defined for the Western Stock distribution area – juveniles also occur in other areas (like in Div. VIId). Map source: GEBCO, polar projection, 200 m depth contour drawn. Map by C. Zimmerman.

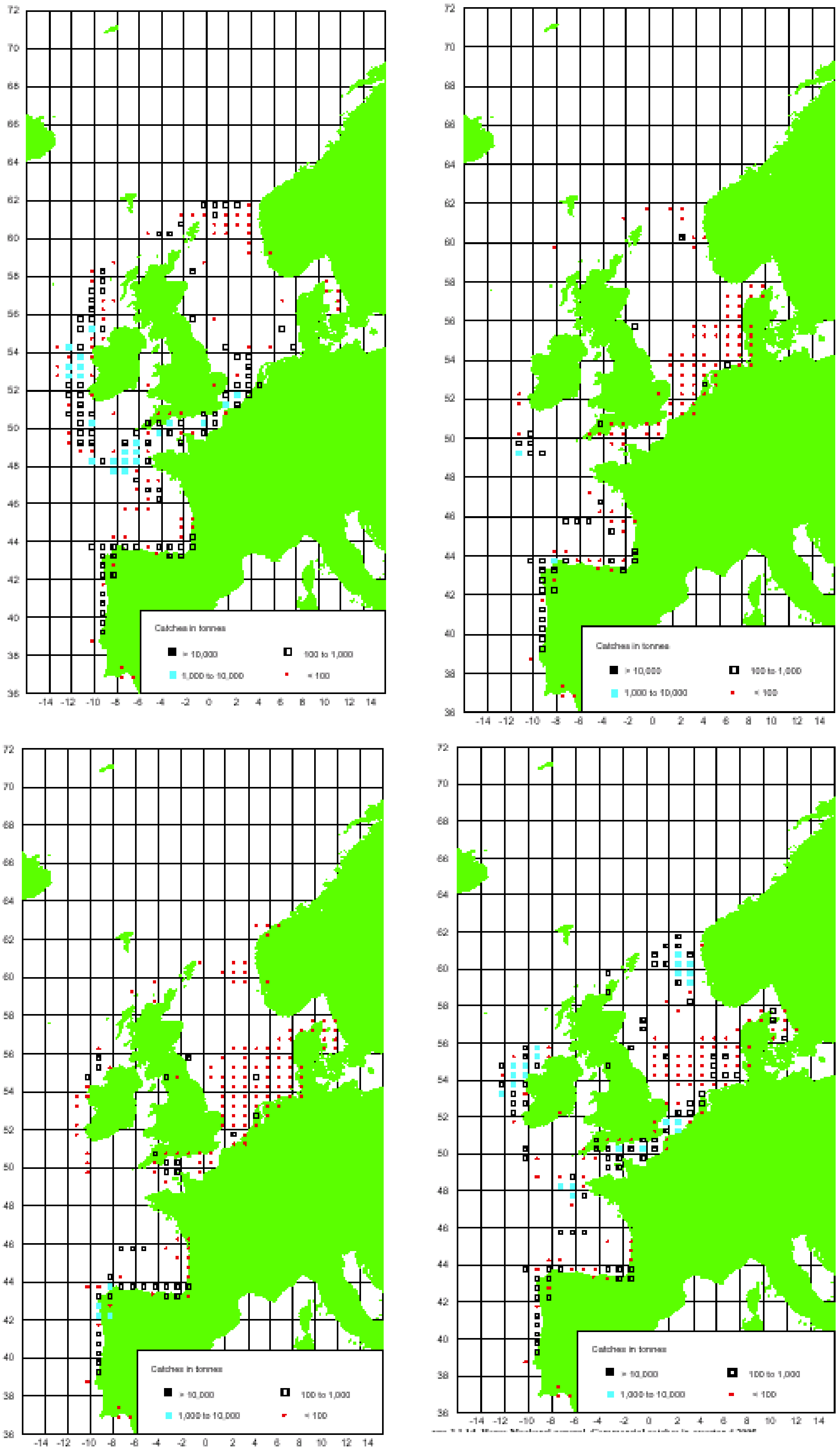
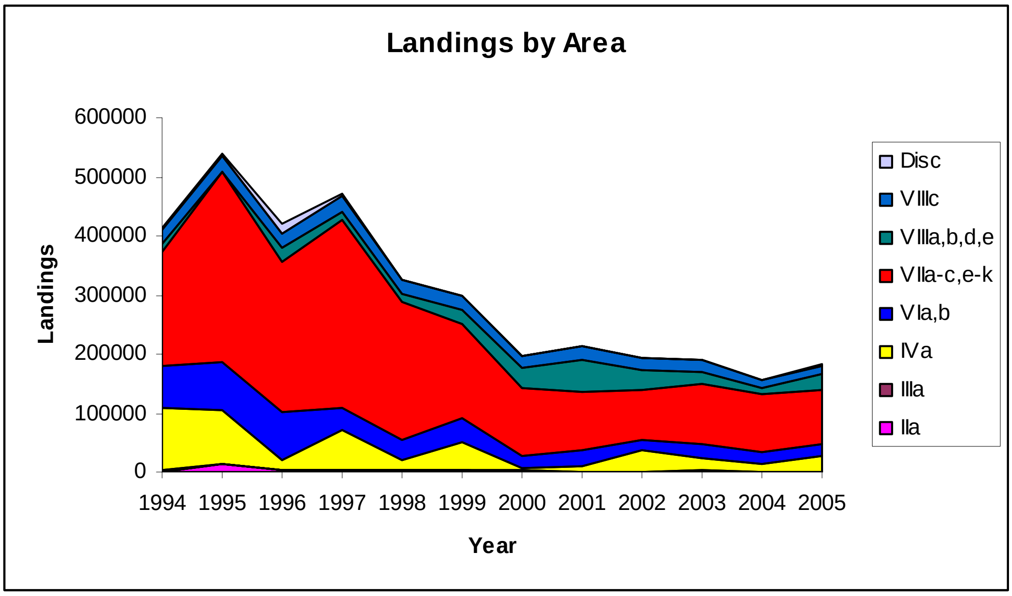


Figure 2. Horse Mackerel commercial catches by quarter 2005. Redrawn from ICES (2005).



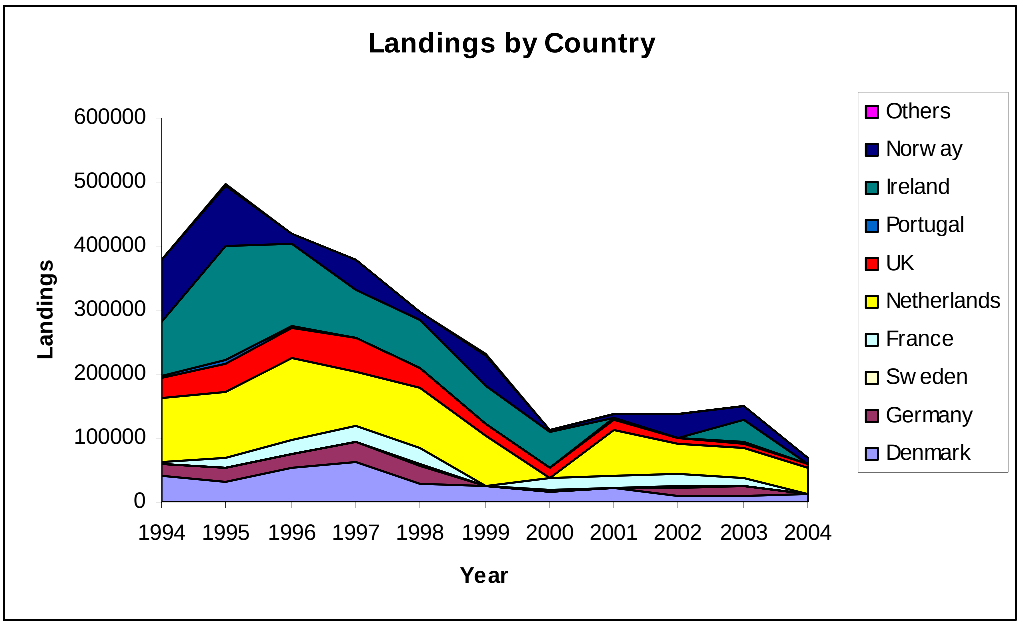


Figure 3: Landings by year from the western stock. ICES estimates of landings (above) from ICES (2006), official landings by country (below) from Anon. (2005).

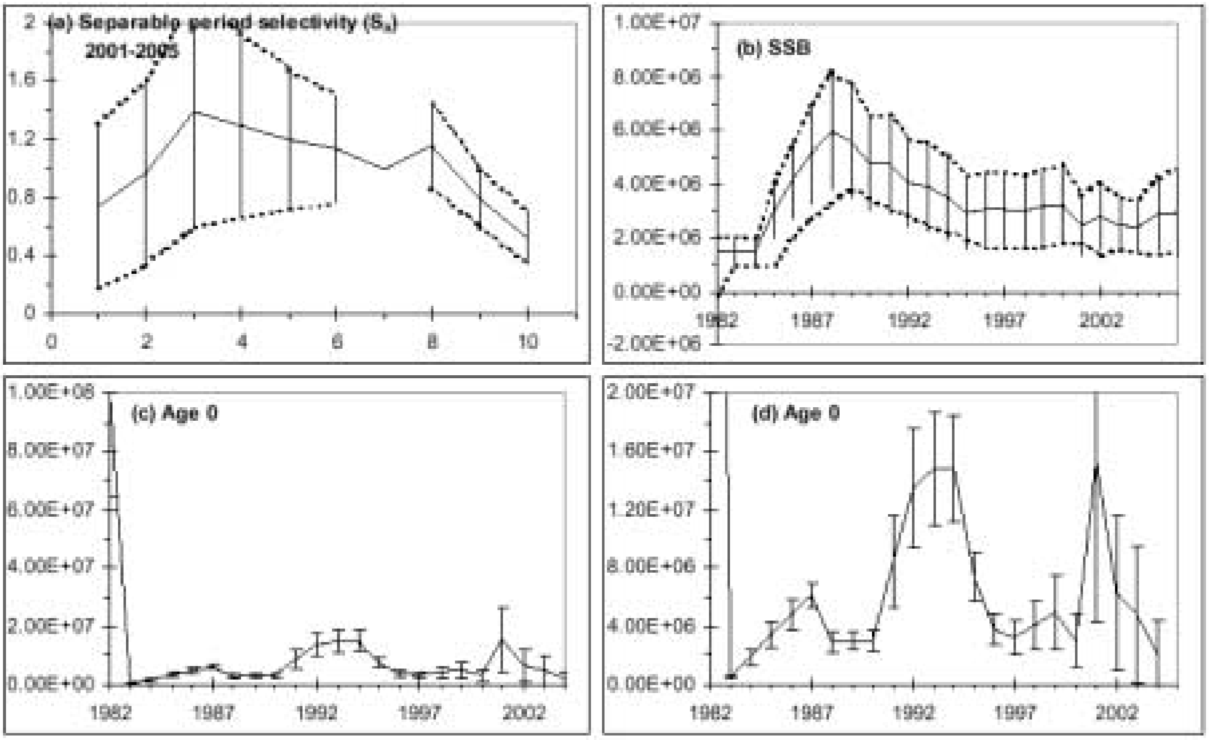


Figure 4. State of the stock in 2005. Taken from ICES WGMHSA (ICES, 2006). The selectivity S_A is the normalised Fishing mortality, i.e. in this case fishing mortality relative to F at age 7.

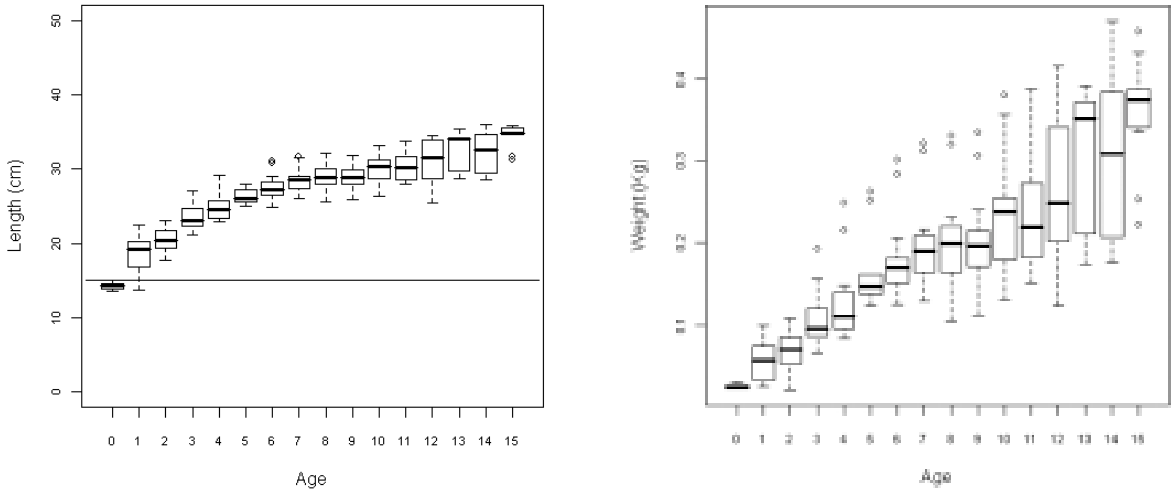


Figure 5. Box plots showing mean length at age (left) with minimum landing size indicated, and mean weight at age for western horse mackerel catches in 2005. Data from ICES WGMHSA (ICES, 2006).

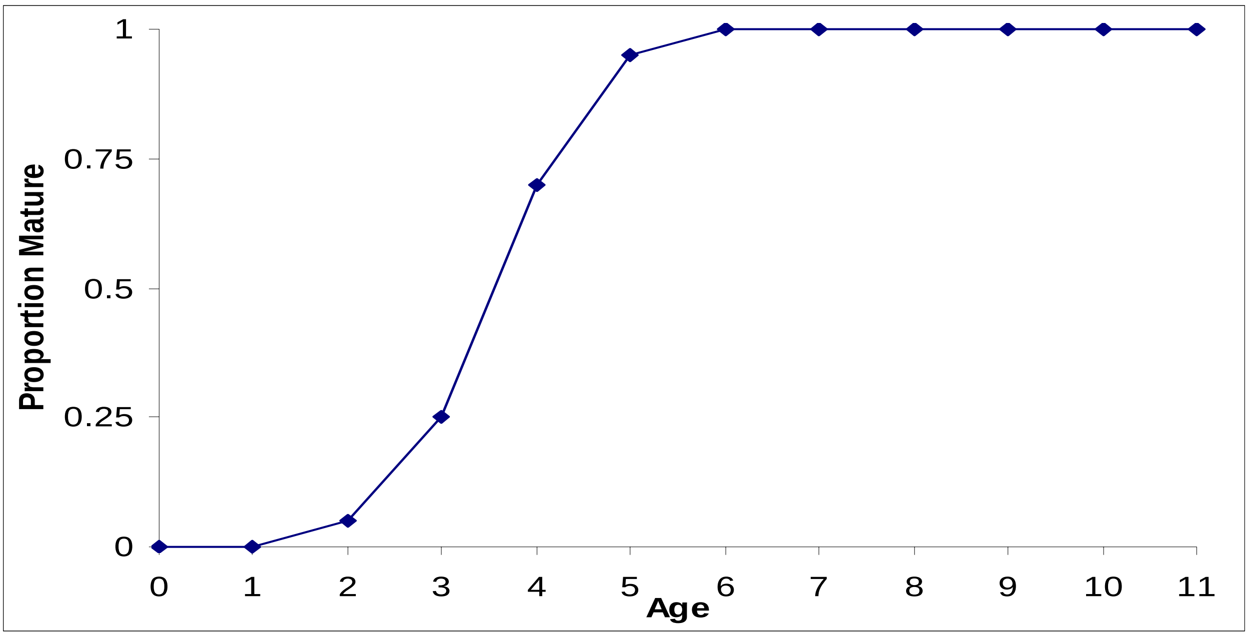


Figure 6. Maturity ogive for western horse mackerel, showing proportions mature at age in the stock at the beginning of the year. Data from ICES WGMHSA (ICES, 2006).

Appendix I Industry questionnaire

The following questions, were posed to the Pelagic RAC:

1. For western horse mackerel, what average catch would you be happy with?
2. What is, in your view, the minimum and maximum annual TAC for industry viability?
3. What would be the maximum catch above which there may be marketing difficulties?
4. Is there, in your view, a ceiling on processing capacity?
5. Would you prefer a lower but stable TAC or a more variable but higher one, on average?
6. Is there, in your view, a market preference for smaller or bigger fish? How variable is this between area and fleet?

Appendix II Computations to estimate the f(slope) parameter (*sl*)

1) Divide the last three egg estimates from the triennial survey by 10^{15};
2) Compute the slope (*b*) for years 1, 2 and 3;
3) If

$$b \le -1.5 \Rightarrow sl = 0$$
$$-1.5 < b < 0 \Rightarrow sl = 1 - (1/-1.5 * b)$$
$$0 \le b \le 0.5 \Rightarrow sl = 1 + (0.4/0.5 * b)$$
$$b > 0.5 \Rightarrow sl = 1.4$$