JRC Scientific and Technical Reports

Scientific, Technical and Economic Committee for Fisheries (STECF)

Impact Assessment of multi-annual plans for Southern hake, angler fish and Nephrops (STECF-11-06)

Edited by John Simmonds, Santiago Cerviño, Jose Maria Da Rocha
M. Paz Sampedro and Cristina Silva.

This report was reviewed by the STECF during its 37th plenary meeting held from 11 to 25 July, 2011 in Copenhagen, Denmark.

EUR 24900 EN - 2011

JRC
EUROPEAN COMMISSION

ipsc
Institute for the Protection and Security of the Citizen

The mission of the Institute for the Protection and Security of the Citizen (IPSC) is to provide research results and to support EU policy-makers in their effort towards global security and towards protection of European citizens from accidents, deliberate attacks, fraud and illegal actions against EU policies

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

European Commission
Joint Research Centre
Institute for the Protection and Security of the Citizen

Contact information
Address: TP 051, 21027 Ispra (VA), Italy
E-mail: stecf-secretariat@jrc.ec.europa.eu
Tel.: 0039 0332 789343
Fax: 0039 0332 789658

https://stecf.jrc.ec.europa.eu/home
http://ipsc.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC 66050

EUR 24900EN
ISBN 978-92-79-20806-5
ISSN 1831-9424 (online)
ISSN 1018-5593 (print)

doi:10.2788/40340
Luxembourg: Publications Office of the European Union

Printed in Italy

TABLE OF CONTENTS

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF)

Impact Assessment of multi-annual plans for Southern hake, angler fish and Nephrops (STECF-11-06)

This report was adopted by the STECF during its 37th plenary meeting held from 11 to 15 July, 2011 in Copenhagen, Denmark.

Request to the STECF

STECF is requested to review the report of the **EWG-11-07** held from June 20 – 24, 2011 in Hamburg, Germany evaluate the findings and make any appropriate comments and recommendations.

Introduction

A joint ICES / STECF meeting was held in Hamburg 20-24 June 2011, to prepare impact assessments for Southern hake, Nephrops and Angler fish and Baltic cod and an Evaluation of existing plans for Kattegat, North Sea, West of Scotland and Irish Sea cod. The meeting involved STECF, ICES scientists dealing with Economy and Biology and included Observers (Commission staff, Managers, Stakeholders). Three separate reports to the STECF were prepared by the EWG-11-07, one on the Impact Assessment of Southern hake, Nephrops and Angler fish and another on the Impact Assessments for Baltic cod and the third on the Evaluation of Cod in Kattegat, North Sea, West of Scotland and Irish Sea2. All reports were reviewed by the STECF during its 37th plenary meeting held from 11 to 15 July 2011 in Copenhagen, Denmark. The following observations, conclusions and recommendations represent the outcomes of that review for Southern hake, Nephrops and Angler fish report.

STECF observation

STECF commends the EWG-11-07 for its excellent work with the Impact Assessment of fisheries on Southern hake, Nephrops and Anglerfish (ICES areas VIIIc and IXa) and the report provided. STECF considers that the work provides some useful outputs that can contribute to an improved plan, but is concerned that some analyses, and therefore some information that could inform policy choices, have been hampered by a lack of fleet data from some MS. STECF draws the following conclusions from the report.

Biological status by species: Based on information from various sources STECF concludes the following regarding stock status relative to Fmsy objectives.

Nephrops

Nephrops in northern FUs (FUs 25, 26, 27 and 31): In the absence of an analytical assessment, it is not possible to assess the distance from current F to a potential F_{MSY} level. Given the very low biomass level of *Nephrops*, the catch should remain as low as possible (ICES, 2010b).

Nephrops in FUs 28 and 29: Fishing mortality has decreased in the last five years, and is presently considered to be at a record low. The stocks are considered underexploited at present with respect to any F_{MSY} proxy (ICES, 2010a, 2010b).

Nephrops in FU 30: The stock appears to be low compared to historic levels. Landings and effort have decreased substantially in recent years (ICES, 2010a).

Angler Fish

L. budegassa: Fishing mortality has decreased since 1999 and is in 2010 below F_{MSY}. Biomass has increased since 2002, and is presently 91% of B_{MSY} (ICES, 2011).

L. piscatorius: The update assessment for white anglerfish has identified a large decrease of F in 2010, being below F_{MSY} in contrast to the 2010 assessment. Biomass in 2011 is estimated to be approximately at 30% of B_{MSY} (ICES, 2011).

Southern hake

M. merluccius: Fishing mortality is more than twice the F_{MSY}.

Management options: Various management options were considered by STECF

Nephrops

Management of *Nephrops* stocks by Functional Unit would better respond to the conservation measures required for each FU unit. This is justified by the fact that *Nephrops* stocks in independent FUs are often at different status requiring different management measures.

Separate hake and *Nephrops* management is feasible for FU 28 and 29 provided appropriate *Nephrops* TAC is allocated at the FU level, and the fishery is spatially regulated and enforced through monitoring using VMS. This approach requires that sufficient hake quota is allocated to this fleet to cover hake bycatch.

For all other *Nephrops* FUs Separate hake and *Nephrops* management is not feasible without solutions based on species separator gears. STECF has not been able to evaluate gear-related solutions for species separation. Grids (e.g. Swedish grid) have been used in other areas to separate gadoids and *Nephrops*, and could be investigated to see if they are applicable here. Given the low biomass of northern *Nephrops* FUs, measures taken to reduce F for hake should have the effect of also reducing fishing pressure on *Nephrops.* The same is true for FU 30, although the stock is thought to be in a better condition.

Angler Fish

Considering the present state of both anglerfish stocks and their exploitation ($F< F_{MSY}$), it will not be necessary to apply F reductions in these fisheries to achieve F_{MSY}. However, part of the fleets catching anglerfish are already covered by the current hake management plan. Currently there is separate management for the "RASCO" fleet. This fleet does not catch sufficient quantities of hake to require regulation under a hake fishery management plan, and should continue to be managed separately.

All other fleets catching anglerfish catch sufficient hake that they must currently be managed within the regulation under the hake management plan.

The stock assessment is carried out separately for both angler species. Currently the advice is given for the combined stock and a single TAC for both species. The spatial pattern in the distribution of the two species of anglerfish in Divisions VIIIc and IXa could allow the possibility to manage each species separately, but additional research would be required before developing this further.

Southern hake

For Hake in the Gulf of Cadiz this is part of the definition of the stock area of southern hake and there is no scientific reason to exclude it from the effort regulations.

If the TAC is overshot the current plan and none of the alternative HCRs considered for exploitation of hake will achieve $F2015 \leq F_{MSY}$.

There are recent reports of improvements in enforcement of TACs in 2010, the situation needs to improve further if the fishery is to be managed effectively.

The current EU plan for hake and *Nephrops*, (with a 10% yearly F reduction and a 15%TAC constraint), is not expected to reduce the exploitation rate on hake to F_{MSY} by 2015; the probability of achieving this objective is only 12%. With previously observed levels of recruitment and if implemented in full the current plan will achieve F_{MSY} only by 2017 with a probability of 50%.

Replacing the existing plan with an HCR "F_{MSY} in 2015" with either a ±15% or ±25% TAC constraint will achieve F_{MSY} in 2015 for the southern hake stock. The HCR with 15% TAC constraint produces faster recoveries than the HCR 25% TAC constraint. The F reduction in this plan is always higher than the 10% F reduction in the current plan.

Alternatively additional technical measures would be required to achieve F_{MSY} in 2015 with the current plan. These technical measures could result in a change in the hake exploitation pattern. The analyzed measures to reduce the exploitation pattern were 1) changes in trawl gears and (2) closed areas.

- Mesh changes: The simulations performed show that a small change in mesh size (about 10 mm increase in mesh size for all trawlers) does not produce any substantive improvement. If mesh changes are to be used to improve the current plan, larger changes are needed. These larger changes in mesh size help by changing the F_{msy} value and thus the F_{target}, reducing the relative change in F required from current F to achieve F_{msy} in the medium term. The result in the long term of such a change would be increased landings, reduced discards and a slightly reduced SSB. In order to define the mesh changes that would be acceptable and evaluate in detail their impact on the stock, fishery and ecosystem, a definition of fleets and gears that should be changed needs to be provided by MS.
- Closed Areas: The analysis of the Portuguese and Spanish surveys (both in October) does not provide relevant additional information to extend the current closed areas in time or space. Furthermore, the impact of extending these areas on F will not be effective in reducing the exploitation pattern if the fishing effort is transferred to other areas.

There is currently a legal obligation to record soak time, and overall length of net deployed. STECF considers that this would be an appropriate metric to determine effort for static gears.

With the available data, the group is not able to assess the impact of including or excluding the vessels under 10 m in the plan. MS are required under the DCF to provide estimates of total catch from vessels under 10m. In addition to the formal data call, EWG 11-06 MS was requested to provide data during the scoping meeting for management plans. No data were available for Spain.

With the available information, it is not possible to evaluate the impact of the introduction of real time closures.

Fishing at F_{MSY}, it is expected that hake and anglerfishes biomasses will increase towards B_{MSY}. As these species are top predators in the ecosystem, the mortality of their prey could be expected to increase. The expected change in the exploitation pattern resulting from increases in mesh size and or area/season closures may reduce unwanted bycatch and consequently result in less discards.

Economic consideration:

The economic simulations show that a policy that allows reallocation of total allowed effort to a smaller number of vessels would bring an increase in average profitability per vessel. This reduction in vessel numbers could also be expected to improve profitability and profit amount in absolute terms at the fleet level. Simulations suggest that F_{MSY} can be obtained by reducing the fleet less than proportionally to the required reduction in fishing mortality.

The introduction of ITQs in this fishery is likely to result in concentration of the total amount of fishing days in the most efficient vessels. The simulations show that at F_{MSY} the total price per kg of hake and fleet profitability will both increase. STECF is uncertain about the robustness of these results, but implementation of ITQs in fisheries have in several instances resulted in increased profitability of fleets, when comparing to the previous management system.

In terms of the trade-off between employment and profitability at fleet level, if fishing mortality is not to be reduced, then in order to generate an increase in fleet profitability employment (number of persons) must decline and vessels have to leave the fishery.

Finally, the simulations suggest that introducing ITQs will allow the possibility of reducing the current fleet size while maintaining the number of licence holders but not all of them are likely to be actively fishing. In the simulations those non-fishing licence holders are supported through leasing of quota.

Overall STECF considers more work is required before the conclusions if the simulations could be used to inform policy.

STECF conclusions

STECF endorses the findings of the STECF EWG report on the Impact Assessment Southern hake, Nephrops and Angler fish report (EWG 11-06).

STECF recommendations

Forward look to Evaluation

STECF considers 5 years minimum time for data to be available for review

REPORT TO THE STECF

EXPERT WORKING GROUP MULTI-ANNUAL PLANS FOR SOUTHERN HAKE, ANGLER FISH AND NEPHROPS (STECF-11-06)

Hamburg, Germany. 20-24 June 2011

1. Executive summary

A joint ICES / STECF meeting was held in Hamburg 20-24 June 2011, to prepare an impact assessment for Southern hake, Nerphrops and Angler fish. The meeting involved STECF, ICES scientists dealing with Economy and Biology and included Observers (Commission staff, Managers, Stakeholders). Three separate reports to the STECF were prepared by the EWG-11-07, one on the Impact Assessment of Southern hake, Nephrops and Angler fish and another on the Impact Assessments for Baltic cod (STECF 11-05) and the third on the Evaluation of Cod in Kattegat, North Sea, West of Scotland and Irish Sea (STECF 11-07).

Biological status: From various sources of information STECF concludes the following stock status relative to Fmsy objectives. *Nephrops* in northern FUs (FUs 25, 26, 27 and 31): status unknown; *Nephrops* in FUs 28 and 29: F is at a record low. The stocks are considered underexploited relative to F_{MSY}. *Nephrops* in FU 30: The stock is low compared to historic levels, with decreasing landings and effort. Both angler fish are being exploited below Fmsy. Southern Hake is being exploited at more than twice the F_{MSY}.

Nephrops Management: Management of *Nephrops* stocks by Functional Unit is recommended. Except for FU 28 and 29, separate management of *Nephrops* in other FUs is not feasible without solutions based on species separator gears.

Angler Management: It is not be necessary to apply F reductions in these fisheries to achieve F_{MSY}. However, part of the fleets catching anglerfish is already covered by the current hake management plan. Currently there is separate management for the "RASCO" fleet, this could continue. All other fleets catching angler cannot currently be separated from fleets catching hake and will need to be regulated within a hake plan.

Hake Management: Gulf of Cadiz is part of the definition of the stock area of southern hake and there is no scientific reason to exclude it from the effort regulations. None of the HCRs considered for exploitation of hake will achieve F2015≤ F_{MSY} if the TAC is overshot. The current EU plan for hake and *Nephrops*, with a 10% yearly F reduction and a 15%TAC constraint (no change), does not allow the exploitation rate on hake to reduce to F_{MSY} in 2015 but if implemented full will achieve F_{MSY} in 2017. A HCR "F_{MSY} in 2015" with either a ±15% or ±25% TAC constraint will achieve F_{MSY} in 2015 for the southern hake stock. 15% TAC constraint produces faster recoveries than 25%. Additional technical measures are needed to get F_{MSY} in 2015 with the current plan. These technical measures could impose a change in the hake exploitation pattern. Detailed analyses were not possible due primarily to the shortage of detailed fleet data. Preliminary investigations suggest that only a substantial change in selection, perhaps associated with the inclusion of a 65mm square mesh panel would be sufficient to make a difference.

Economic simulations show that a policy that allows movement of number of days to a smaller number of vessels brings an increase in fleet profitability. The introduction of ITQs in this fishery may allow concentration of the total amount of fishing days in more efficient vessels. The simulations show that at F_{MSY} the total value of landings per kilo of hake and fleet profitability will increase. In terms of the trade off between employment and profitability, if fishing mortality is not to be reduced, employment (fleet size) must diminish for an increase in fleet profitability.

2. CONCLUSIONS OF THE WORKING GROUP

Biological status: From various sources of information STECF concludes the following stock status relative to Fmsy objectives.

Nephrops in northern FUs (FUs 25, 26, 27 and 31): In the absence of an analytical assessment, it is not possible to assess the distance from current F to a potential F_{MSY} level. Given the very low biomass level of *Nephrops*, the catch should remain as low as possible (ICES, 2010b).

Nephrops in FUs 28 and 29: Fishing mortality has decreased in the last five years, and is presently considered to be at a record low. The stocks are considered underexploited at present with respect to any F_{MSY} proxy (ICES, 2010a, 2010b).

Nephrops in FU 30: The stock appears to be low compared to historic levels. Landings and effort have decreased substantially in recent years (ICES, 2010a).

L. budegassa: Fishing mortality has decreased since 1999 and is in 2010 below F_{MSY}. Biomass has increased since 2002, and is presently 91% of B_{MSY} (ICES, 2011).

L. piscatorius: The update assessment for white anglerfish has resulted in a large decrease of F in 2010, being below F_{MSY} in contrast to the 2010 assessment. Biomass in 2011 is estimated to be approximately at 30% of B_{MSY} (ICES, 2011).

M. merluccius: Fishing mortality is more than twice the F_{MSY}.

Management options: Various management options were considered by STECF and are presented by stock

Nephrops

Management of *Nephrops* stocks by Functional Unit would better respond to the conservation measures required for each FU unit. This is justified by the fact that *Nephrops* stocks in independent FUs are often at different status requiring different management measures.

Separate hake and *Nephrops* management is feasible for FU 28 and 29 provided enough *Nephrops* TAC is allocated to these FUs, and VMS is used to define the location of the fisheries to FU and sufficient hake quota is allocated to this fleet to cover hake bycatch.

For all other *Nephrops* FUs separate hake and *Nephrops* management is not feasible without solutions based on species separator gears. STECF has not been able to evaluate gear related solutions for species separation. Grids (e.g. Swedish grid) have been used in other areas to separate gadoids and *Nephrops*, and could be investigated to see if they are applicable here.

Given the low biomass of northern *Nephrops* FUs, measures taken to reduce F for hake should have the effect of also reducing fishing pressure on *Nephrops*. The same is true for FU 30, although the stock is in a better condition.

Angler

Considering the present state of both anglerfish stocks and their exploitation ($F< F_{MSY}$), it will not be necessary to apply F reductions in these fisheries to achieve F_{MSY}. However, part of the fleets catching anglerfish is already covered by the current hake management plan. Currently there is separate management for the “RASCO” fleet. This fleet does not catch sufficient quantities hake to require regulation under a hake fishery management plan, and should continue to be managed separately.

All other fleets catching angler cannot currently be separated from fleets catching hake and will need to be regulated within a hake plan.

Hake

Gulf of Cadiz is part of the definition of the stock area of southern hake and there is no scientific reason to exclude it from the effort regulations.

None of the Harvest Control Rules (HCRs) considered for exploitation of hake will achieve $F2015 \leq F_{MSY}$ if the TAC is overshot.

The current EU plan for hake and *Nephrops*, with a 10% yearly F reduction and a 15%TAC constraint (no change), does not allow the exploitation rate on hake to reduce to F_{MSY} in 2015 but if implemented full will achieve F_{MSY} in 2017. With previously observed levels recruitment and no overshooting of TAC the probability of achieving F_{MSY} in 2015 is 12%.

A HCR “F_{MSY} in 2015” with either a ±15% or ±25% TAC constraint will achieve F_{MSY} in 2015 for the southern hake stock. 15% TAC constraint produces faster recoveries than 25%. This F reduction in this plan is always higher than a 10%, which is the F reduction in the current plan.

Additional technical measures are needed to get F_{MSY} in 2015 with the current plan. These technical measures could impose a change in the hake exploitation pattern. The analyzed measures to reduce the exploitation pattern were (1) changes in trawl gears (WD 1 and WD 2) and (2) closed areas (WD 2 and WD 3).

1. Mesh changes: The simulations performed show that a small change in mesh size (about 10 mm increase in for all trawlers) does not produce any substantive improvement. If mesh changes are to be used larger changes are needed. These larger changes in mesh size help to by changing the F_{msy} value and thus the F_{target}, reducing the relative change in F required to achieve F_{msy} in the medium term. The result in the long term is increased landings, reduced discards and a slightly reduced SSB. In order to define the mesh changes that would be acceptable and evaluate in detail their impact on the stock, fishery and ecosystem, a definition of fleets and gears that should be changed should be provided by MS.
2. Closed Areas: The analysis of the Portuguese and Spanish surveys (both in October) does not provide relevant additional information to extend the current closed areas in time or space. Furthermore, the impact of extending these areas on F will not be effective in reducing the exploitation pattern if the fishing effort is transferred to other areas.

There is currently a legal obligation to record soak time, and overall length of net deployed. STECF considers that this would be an appropriate metric to determine effort for static gears.

With the available data, the group is not able to assess the impact of including the vessels under 10 m in the plan. MS are required under the DCF provide estimates of total catch from under 10m. In addition to the formal data call EWG 11-06 MS were requested to provide data during the scoping meeting for management plans. No data are available for Spain. No new fleet proposals were received.

With the available information, it is not possible to evaluate the impact of the introduction of real time closures.

***Effectiveness:* STECF make the following points regarding approaches that are best placed to achieve the objectives**

If complied with the HCR2 ("F2015 ≤ F_{MSY}"), the recovery of the southern hake stock (SSB) will be faster than with the current plan. The yield has a high reduction in the first year, but will increase afterwards.

The economic simulations show that a policy that allows movement of number of days to a smaller number of vessels brings an increase in fleet profitability. Simulations suggest that F_{MSY} can be maintained by reducing the fleet less than proportionally to the reduction in fishing mortality.

The introduction of ITQs in this fishery may allow concentration of the total amount of fishing days in more efficient vessels. The simulations show that at F_{MSY} the total value of landings per kilo of hake and fleet profitability will increase.

Fishing at F_{MSY}, it is expected that hake and anglerfishes biomasses increase towards B_{MSY}. As these species are top predators in the ecosystem, the mortality of their preys should increase. The change in the exploitation pattern through increases in mesh size and or area/season closures may introduce a reduction in discards.

***Consistency:* limiting trade-offs across the economic, social and environmental domains**

In terms of the trade off between employment and profitability, if fishing mortality is not to be reduced, employment (fleet size) must diminish for an increase in fleet profitability. An increase in fleet profitability and employment is possible by reducing fishing mortality to F_{MSY}. By introducing changes in mesh size, trade-offs among the CFP three main objectives (economic, social and environment) are less severe. Finally, introducing ITQs allows maintaining the current fleet size, in terms of permit output holders.

3. Recommendations of the working group

Evaluation of any future plans should be set not earlier than after 5 years of implementation, because before this time too little information will be available to allow for both biological and economic reviews.

4. Introduction

EWG 11-07 met in Hamburg 20-24 June 2011, The WG was organised with STECF members, and invited experts, and observers from Baltic NS, NWW and SWW RACs, and managers from some MS.

4.1. Terms of Reference for EWG-11-07

The Workshop on Management plans Pt 2 (ICES - WKMPROUNDMP2011 STECF – EWG 11-07) Chaired by John Simmonds, Italy, will meet at VTI, Hamburg, Germany 20–24 June 2011 to:

1. provide Impact Assessment reports (2 reports) for
    - Baltic Cod
    - Southern hake, anglerfish and Nephrops
2. provide a combined Evaluation report on cod plans for the following areas:
    - Kattegat

- North Sea
- West of Scotland
- Irish Sea

3. provide a Clarification on NS whiting advice

WKMPROUND2001/EWG 11-07 will provide a complete draft report by 1 July to the attention of the STECF and ACOM and a final draft by 6 July.

Procedures and work will follow the work plan specified in the ICES STECF report WKMPROUND2001 EWG11-01, March 2011 for cod plans and the ad hoc meeting 29-30 March, Brussels for Southern hake anglerfish and Nephrops.

4.2. Agenda

The approach to the meeting was to hold discussions on each TOR separately in order to allow Observers and Commission Staff to organise their attendance efficiently.

Monday 20 June Open the meeting 1400
Report requirements, Section responsibilities and agree Section structure, admin details.
Discussion in subgroups to provide detailed timed agendas for Tuesday and Wednesday
Tuesday 0900 - 1800
Presentations on Southern hake, angler, *Nephrops*, Baltic cod
Discussion for conclusions
Wednesday 0900 - 1800
Presentations on Kat, NS, IS and WoS cod and NS whiting.
Discussion for conclusions
Thursday
Draft text and first drafts of conclusions
Friday
Draft text and final drafts of conclusions
Friday 1500 Meeting close

4.3. Reports

The TOR requires separate reports of the meeting for each task. This report deals specifically with Impact Assessment of multi-annual plans for Southern hake, angler fish and Nephrops STECF-11-07c. Three other reports are prepared, an overall ICES STECF report containing details of the whiting response, and separate reports one for Evaluation of cod plans for Irish Sea, Kattegat, North Sea and West of Scotland and the other for the Impact Assessment on multi-annual plans for Baltic cod.

4.4. Participants

The full list of participants at EWG-11-07 is presented in section 14.

5. Overview Impact Assessment multi-annual plans for Southern hake, angler fish and Nephrops

5.1. Problem statement

The report (COM(2011) 260 final) from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions on the application of the southern hake and Norway lobster recovery plan (Council Regulation (EC) No 2166/2005) reveals that this plan has not been effective in reducing fishing mortality and rebuilding the spawning stock biomass to the desired levels. The same report concluded that besides implementation issues that need to be thoroughly investigated and urgently corrected where necessary, the effort regime must also be improved and it may be appropriate to introduce certain conservation measures.

As a summary, the problem is perceived at two levels:

(i) A concrete problem…

> The application of the southern hake and Norway lobster recovery plan has not been effective in reducing fishing mortality and rebuilding the spawning stock biomass to the desired levels.

(ii) …that raises two questions

> - Would the existing legal framework suffice to bring down fishing mortality and rebuild the spawning stock biomass to the desired levels by 2015, as prescribed by the current plan, (a status quo option) or
>
> - is it appropriate to revise the existing measures and possibly introduce new measures in order to achieve F_{msy} by 2015 and at the same time address identified shortcomings? In this case, which measures should be introduced?

In light of the aforementioned, it is appropriate to assess the biological and social-economic impact of the following possible management measures discussed in advance with the Member States concerned and the South Western Waters RAC:

– Introducing an effort regime that takes account of the fleet segments engaged in the fishery, whether with active or passive gears, and possibly to enlarge the application of the effort regime to the Gulf of Cadiz and to smaller vessels.

– Introducing seasonal/spatial and real-time closures and/or increase the mesh sizes of certain gears to control fishing pressure.

– Managing the Norway lobster stocks by FU (Functional Unit).

– Including other species such as anglerfish in the plan to minimise the impact of this mixed fishery on stocks caught in the same fishery.

– Reviewing the current harvest control rule.

The management options should be tested against different levels of compliance with the legal obligations and stock recruitment scenarios and take into account the biological reference points of the stocks concerned as well as the objective to achieve F_{msy} by 2015. Discard practices need to be thoroughly assessed to quantify its impact on fishing mortality.

5.2. Objectives

5.2.1. General objective

The objective of the CFP (the Common Fisheries Policy) is to provide for sustainable exploitation of living aquatic resources in the context of sustainable development, taking into account of the environmental, economic and social aspects in a balanced manner. This objective is more effectively achieved through a multi-annual approach to fisheries management, involving multi-annual management plans for stocks at or within safe biological limits. For stocks outside safe biological limits, the adoption of multi-annual recovery plans is an absolute priority. The 2002 CFP reform included for the first time this possibility to manage under EC legislation for the long-term. Many stocks were then gradually brought under long-term plans in the period from 2003 onwards. Today, however, the EU has dropped this distinction between recovery and management plans and refers only to "long-term" or "multi-annual" plans. Whatever the situation of the stock, the goal is ultimately to reach maximum sustainable yield by setting an appropriate exploitation rate. The conservation (i.e. measures required to maintain or restore natural habitats and the populations of species of wild fauna and flora) objectives laid down in EU environmental legislation as well as the objective to achieve the stock maximum sustainable yield by 2015, as agreed by the Member States at the 2002 UN World Summit on Sustainable Development, should be followed.

5.2.2. Specific objective

The specific objective is to achieve F_{msy} as defined by ICES by 2015.

Objective of MS and SWWRAC's ad hoc group:

Continuation of fisheries which depend primarily on species not included in the recovery plan for hake or *Nephrops*. These are predominantly fisheries for pelagic stocks that catch hake as (salable) bycatch and other fisheries with low dependence (<5%) on hake.

6. CHOICE OF TACTICAL METHODS

The Commission requests STECF to provide guidance for utility and effectiveness of the following management approaches.

1. Introduction of an effort regime that takes account of all of the fleet segments engaged in the fishery, whether with active or passive gears. Active gears would be limited in kW.days whereas passive gears such as gillnets would be limited in extension of nets and soaking time.
2. Enlargement of the application of the effort regime to the Gulf of Cadiz and to smaller vessels (<10m).
3. Introduce seasonal and real-time closures, in particular on spawning grounds.
4. Allowance of additional effort for vessels under scientific observer programmers or with CCTV cameras on board, or fully documented fisheries, demonstrating low catches of hake.
5. Introduction of a range of mesh sizes in line with Member States and SWWRAC proposals.

In addition it would also be useful to assess the impact of:

1. Managing *Nephrops* stocks by Functional Unit.
2. Including anglerfish in the plan.

The RAC requested the STECF to consider the utility of the following measures:

1. Fleet based effort including different measures for different fleets
2. Technical measures
   i. for mesh size
      1. 70mm mesh size with square mesh in the top of the trawl,
      2. An 80mm mesh size for trawlers not targeting pelagic species (limit to be discussed with MS, it could be boats that land more than x% of hake; x being a number to test, it could be 5 or 10%).
      3. Minimum mesh size of 100mm for passive gears (gillnets and trammels)

   ii. Spatial and temporal closures
      1. Real time closures: when a % of juveniles (to be defined) is found in an area by a vessel, fishing in this area would be forbidden for a defined period of time (to be defined).
      2. Rotating closures: Apply to all boats which fished more than 1t of hake in 2010, a 2 month closure. In order to mitigate effects on the market, this closure should be implemented in the various Member States (France, Spain and Portugal) in different quarters of the year.
      3. Temporal closure of 45 days.
3. TAC Control
4. Managing *Nephrops* by functional unit
5. Managing anglerfish by species

The above measures involve identification and specification of fleets, areas, based on existing information.

Setting TACs for *Nephrops* by FU is a technical issue of allocation and monitoring for Member States and is fully supported by STECF but implies no further work in the Impact Assessment.

Proposals have already been made for some spatial management of Anglerfish by species. This has been dealt within WKSHAKE2 report (ICES, 2010b) and is presented below.

All the mesh size and area closure technical measures suggested essentially impact on the stock and the fishery through a change in exploitation pattern in the fishery. Currently it is not possible to parameterise these changes so detailed specific evaluations were not possible.

For Technical Measures to be implemented fleet segments need to be identified. The current regulatory groups may not be suitable, if not others would need to be identified. Insufficient data has been supplied by MS and this task is examined in a limited way which cannot be used directly to set a plan.

7. OVERRIDING CONSIDERATIONS OF THE OPTIONS

It is not currently possible determine the effectiveness of different tactical approaches (TAC, Effort, catch, mesh and area restrictions). TAC control is uncertain, though indications are that landings control is improving. Provided discarding does not increase, control of catches may be possible through control of landings. In the absence of control through TAC, effort controls may help, though control of catch may only be possible through direct monitoring of catch.

Directly assessing the extent of mesh changes as a regulatory approach has not been possible, because detailed information on fleets was not available for most of the fisheries. Indications from example studies (see below) are that substantial changes would be needed.

Current closed areas appear to be applicable, additional closed areas have not been identified (see below)

8. ENVIRONMENTAL EFFECTS OF THE OPTIONS

8.1. Methodology and Scenarios to be tested

Methodology

The methodology used is the same used by WKSHAKE2 (ICES, 2010b).

The numerical basis of the evaluations is the 2010 ICES assessment output (ICES, 2010a). The update assessment for white anglerfish has resulted in a high decrease of F in 2010, being below F_{MSY} in contrast to the 2010 assessment (ICES, 2011).

A description of the methodology used to obtain the simulations and the way they were implemented are available in WKSHAKE2 Report. The performance of HCRs 1-3 defined in WKSHAKE2 (ICES, 2010b) as: "10% Annual Decrease", "F_{MSY} in 2015" and "F_{MSY} since 2011", with the 3 TAC constraint options (15% constraint, 25% constraint and no TAC constraint), have been tested by conducting forward projections from 2010 to 2020. Three different scenarios for recruitment during projection years are considered (Average, Low and High recruitment). Each recruitment scenario is combined with no TAC overshoot and with the 4 TAC overshoot scenarios: Overshoot Type 1 or 2, each combined with Medium or Very high overshoot level). Hence, the performance of each HCR-TAC constraint combination is tested under 15 different recruitment-TAC overshoot scenarios. HCR 0 ("$F_{status\ quo}$" or "F_{sq}") is considered only without TAC constraint and TAC overshoot, but under the 3 recruitment scenarios).

HCR equations are defined in two steps which are applied every year from 2010 to 2015 to correct deviations in F_{y-1} caused by TAC constraint or TAC overshooting. The first step is presented in the following table

HCR name	**HCR Equation**
HCR 1 ("10% Annual Decrease"):	$F_{\mathrm{HCR,first}}(y) = \max\{0.9F_{\mathrm{HCR}}(y-1), F_{\mathrm{MSY}}\}$
HCR 2 ("F_{MSY} in 2015"):	$F_{\mathrm{HCR,first}}(y) = \max\left\{F_{\mathrm{HCR}}(y-1)\left(\frac{F_{\mathrm{MSY}}}{F_{\mathrm{HCR}}(y-1)}\right)^{1/(2015-y+1)}, F_{\mathrm{MSY}}\right\}$
HCR 3 ("F_{MSY} in 2011"):	$F_{\mathrm{HCR,first}}(y) = F_{\mathrm{MSY}}$

In the second step the TAC constraint is checked and F is corrected accordingly.

The projections of the southern hake were carried out using a length-based assessment model (GADGET). The GADGET population dynamics was specifically programmed in R software for this work (Annex 3 of ICES, 2010b). Uncertainty in the projections was simulated with different recruitment scenarios. The projections for anglerfish stocks were carried out with a Schaefer biomass dynamic model, a non-equilibrium stock production model incorporating covariates with bootstrapping. Projections were performed separately for each anglerfish species.

In addition to the main simulations, some technical measures were also evaluated with the aim of analyzing their impact on exploitation pattern. The first step to address the issue (decided in the scoping meeting) was for "MS to identify fleets and evaluate if catches by fleet are available". MS did not provide any fleet proposals different from those defined in the current regulation so the second option (decided in the Scoping meeting) was followed, i.e. "… some approximation to change in selection" will be presented and tested to show the generic effect.

The methodologies developed to explore these change in selection measures were presented in 3 different WDs:

- Changes in trawl gears (WD 1). Results for selectivity experiences (Campos and Fonseca, 2003) with 3 scenarios different mesh sizes (D70, D80, S65) were used to evaluate the impact of change in mesh size trawlers on Southern hake stock. The GADGET model used to assess Southern hake stock is structured with two "fleets", one for landings (trawlers, gill-nets, long-liners and artisanal) and another for discards (trawlers). In this work we assume that the current baseline can be considered to be equivalent to trawlers fishing with D70, and then D80 and S65 are considered as relative change in exploitation pattern with respect to D70. Thus effectively the D80 scenario implies an approximate 10mm increase in mesh size for all trawlers (irrespective of their actual mesh size) from their current gear to larger mesh gears. The changes in landings selection pattern (due to the 10mm shift) are applied to the fraction of total catch corresponding to all trawls. The change in discards selection pattern is applied to all discards. F_{MSY} was re-estimated for the 3 scenarios and projections achieving F_{MSY} in 2015, continuing until 2030 (equilibrium), were performed to evaluate the impact on yield, discards and SSB.
- Changes in trawl gears and closed areas (WD 2).
    - Gear Changes: We simulated the effect of using the 70mm+100mm SMP trawl used in French *Nephrops* fishery in order to decrease hake catches. Changes in selection pattern were simulated for those fleets not targeting pelagic species (Castro et al, 2007): "pareja" fleet and "baca" gear from the otter trawl Spanish fleet. Others theoretical shifts in selection pattern were also tested.
    - Closed Areas: It was requested to evaluate possible changes in exploitation pattern resulting from closed periods/areas. No fisheries relevant data could be used to assess this point but scientific surveys data (P-GFS October survey from 2003 to 2010) were used in order to investigate:
        - If hake juveniles aggregate so that implementing closures to protect those grounds could be relevant.
        - If trawlers main target species distribution (Mackerel, horse mackerel, blue whiting, etc…) overlaps with the distribution of hake juveniles. Catches of these target species in hauls with high abundance of hake <20cm were compared to catches of hauls with low abundance of hake <20cm to assess this overlap.
- Closed areas analysis is detailed in WD 3. Hake recruits distribution in North of Spain were analyzed with data coming from IBTS Cantabrian Demersal Surveys carried out every year between September and October in the Spanish coast from Portugal to France. The survey methodology used is the IBTS standard for the western and southern areas. Overlaps in spatial distribution between hake recruits and other target species for the trawl fleet were provided by comparing the survey catches of commercial species (hake $\geq$ 27 cm, horse mackerel, blue whiting and megrims $\geq$ 15 cm and anglers $\geq$ 30 cm) in nursery area hauls (defined as hauls with $\geq$ 100 hakes < 20cm)

with the survey catches of commercial species in other areas (defined as hauls with < 100 hakes < 20cm).

8.2. Evaluation of the effects of the multi-annual plan options on the fishery

Anglerfish

The choice of an HCR among those that achieve with 95% probability the target of F being equal to or below F_{MSY} in 2015 (Table 8.1) should take into account the resulting levels of biomass in 2015 or 2020 and the amount of cumulative yield. The choice must result from a compromise between these indicators. The effect of TAC constraint is dominant; all HCRs examined perform in the same way when the same TAC constraint is applied. The yield obtained will be unaffected by the F targets in the HCR and depends only on the inter-annual TAC constraint of 15 or 25%. For example, the most restrictive TAC tested, 15%, would allow a faster recover of the biomass but with the lowest level of cumulative yield. The TAC constraint of 25% increases the cumulative yield faster maintaining the biomass of *L. piscatorius* in the longer term (2020).

Table 8.1. For *L. piscatorius* and *L. budegassa*: probability of $F < F_{msy}$; cumulative yield over the period to 2015; and biomass in 2015 and 2020 over B_{msy} for different HCRs including inter-annual constraints in change in TAC.

	L.piscatorius				*L.budegassa*				*L.pis+L.bud*
Scenarios	F2015≤Fmsy	Ycum2015	Brel2015	Brel2020	F2015≤Fmsy	Ycum2015	Brel2015	Brel2020	Ycum2015
HCR 10%AnnualDecrease & TACc=15%	0.98	8471	0.76	1.35	1.00	3126	1.79	1.84	11600
HCR 10%AnnualDecrease & TACc=25%	0.97	11092	0.68	0.94	1.00	4121	1.74	1.69	15347
HCR Fmsyin2015 & TACc=15%	1.00	8471	0.76	1.35	1.00	3129	1.79	1.84	11600
HCR Fmsyin2015 & TACc=25%	0.99	11092	0.68	0.94	1.00	4122	1.74	1.69	15347
HCR Fmsyin2015	1.00	13813	0.42	0.73	1.00	6622	1.58	1.67	20633
HCR Fmsyin2011 & TACc=15%	1.00	8471	0.76	1.35	1.00	3096	1.79	1.84	11600
HCR Fmsyin2011 & TACc=25%	0.99	11092	0.68	0.94	1.00	4062	1.74	1.69	15347
HCR Fmsyin2011	1.00	13853	0.50	0.78	1.00	6009	1.62	1.67	20023

Taking into account the mixed nature of part of the fisheries affected by this Management Plan, using the hake fishing mortality in excess of MSY, as the key driver for the management of the anglerfish stocks would lead to a significant loss in yield for the angler stocks. The fact that an important part of the anglerfish catches comes from “RASCO”, a “clean” fleet without hake catches, would allow considering different effort measures by fleet. “Rasco” fleet is regulated by Spain with a single gear license (Real Decreto 410/2001), that would ensure the possibility of the implementation of specific effort measures only for this fleet targeting anglerfish. In order to analyse the effect on anglerfish stocks of different F reductions by fleet, a small number of simulations were tested during the WKSHAKE2. Because not all possible combinations of F reduction have been explored, more simulations should be carried out to offer a complete study of this option.

Enlarge the application of the effort regime to smaller vessels (<10m)

The present recovery plan includes only hake and *Nephrops* and the effort regulations cover the vessels with overall length ≥ 10 m operating with trawls with mesh ≥ 32 mm, gillnets with mesh ≥ 60 mm and bottom longlines.

Answering to a request from EC to ICES to evaluate the current recovery plan and including anglerfish in a new plan, WKSHAKE2 (ICES, 2010b) makes a description of the fleets and fisheries catching hake, *Nephrops* and two anglerfish species, showing the proportion of each fleet in the Iberian total landings of these species. However, the description of metiers is based on the type of gear used (Castro et al, 2007) and does not consider the size of the vessel.

Leaving out of the effort regulations the fishing vessels under 10 m, part of the artisanal effort catching these species is unaccounted and unregulated and, if a significant part of the catch comes from these vessels, this may affect the success of the plan. At present due to a shortage of data we are unable to quantify the proportion of total catch by these vessels. If MS wish to exclude small vessels from the plan it is important to allocate sufficient TAC to cover the catch of these fleets. However, this will increase the regulatory burden on the remaining vessels.

STECF-SGMOS 10-05 report (STECF, 2010) on the evaluation of effort regimes makes some considerations on the gears definition in the Annex IIB. The trawl category with mesh size ≥ 32 mm includes 2 different Portuguese fleets, one targeting demersal species with mesh size 65-69mm, and the other targeting crustaceans using two different mesh sizes (shrimps with mesh size 55-59mm and *Nephrops* with mesh size ≥70mm) with different licenses, operating in different fishing grounds and depth ranges. The same happens with the Spanish métiers. “Baca”, “jurelera” and pair bottom trawl are mixed in the trawl classification, “volanta” and “rasco” operating with different mesh sizes are included in the same gillnet group and longlines targeting different species are considered as a single group. All these metiers catch different proportions of the species aimed by the recovery plan or intended to be included in the future management plan (ICES, 2010b).

A more detailed classification of the gears in the effort regulation may provide more focused and efficient effort management.

Following the discussions of the scoping meeting, in March 2011, and according to the data call issued by EC in February 2011 (Ref. Ares(2011)200418 - 23/02/2011), MS should provide detailed data by fleet/segment (including the vessels under 10m) to allow the evaluation of the contribution of each fleet/segment to the total effort exerted on these stocks. Only Portugal and France presented data under the Effort Data Call. As Spain catches most hake, the catch proportions by fleet are unaltered from SGMOS 10-06. However, it had been requested that MS provided data on any new fleet proposals at the scoping meeting in March. No data has been made available at the finer metier level to allow for a more detailed analysis and this more detailed analysis was not possible.

Enlarge the application of the effort regime to the Gulf of Cadiz

Annex IIB excludes the Gulf of Cadiz although this area is included in the recovery plan regulation (EC Regulation 2166/2005). However, Gulf of Cadiz is part of the definition of the stock area of southern hake and should be included in the hake effort management. The same argument is applicable for *Nephrops* FU 30.

Spatial management of anglerfish species

The scientific sampling programs from Portugal and Spain observe that the percentage of *L. piscatorius*, in the commercial catches of anglerfish, is very high in the Cantabrian Coast (Division VIIIc); this percentage decreases southwards from the Galician to Portugal West coast (Division IXa) and on the South Coast of Portugal where the percentage of *L. budegassa* is more than 90%.

Although the stock assessment is carried out separately for each species, the advice is given for the combined stock. There is a single TAC for both species. The spatial pattern in the distribution of the two species of anglerfish in Divisions VIIIc and IXa could allow the possibility to manage each species separately, but additional research will be required before developing this further (ICES, 2010).

Manage Nephrops by Functional Unit.

Nephrops are limited to a muddy habitat. This means that the distribution of suitable sediment defines the species distribution which is not continuous. Although the stocks are assessed as separate functional units, the TAC is set by ICES Division. The northernmost stocks (FUs 25, 26, 27 and 31) continue to be at very low abundance levels. The southern stocks (FUs 28-29 and FU 30) remain low despite some increase in recent years. In these FUs, since 2006 part of the multispecies fleet effort was directed at rose shrimp, reducing the pressure on *Nephrops*.

The practice of managing distinctive *Nephrops* stocks by a joint TAC may lead to unbalanced exploitation of the individual stocks. This is particularly true for Division IXa where the state of the individual stocks is quite different. ICES has been proposing the implementation of a fine scale management of catches and/or effort at a geographic scale that corresponds to the *Nephrops* stock distribution (ICES, 2010a, 2010b, 2011a) and consequently, different catch levels have been proposed for the various FUs.

The EWG 11-07 considers that ICES proposal is in agreement with the characteristics of *Nephrops* distribution and that separate catches/effort management by *Nephrops* FU can be implemented (see below).

Hake

Additional days for vessels catching low proportions of hake

The allocation of additional days is already considered in article 8 of Annex IIB, on the basis of an enhanced programme of observer coverage in partnership between scientists and the fishing industry.

The SWW RAC proposed to exclude from the effort limitation scheme the days at sea of vessels not targeting hake. Days at sea not counting would be days when catches of hake are <5% of the total or <50kg, whichever is lower.

Currently the data on the total catch by fleets that would be expected to operate under such a regulation has not been provided and it is not possible to determine the proportion catches and therefore F that would be included under this type of regulation. The data needed are the catches by trip for the fleets to be considered. The setting of a maximum amount of hake per day may result in an increase of discards. If such derogation was to be applied for low catches it would need to conditional on appropriate demonstration of compliance such as by onboard sampling or CCTV cameras. The coverage of the fleet by observers is currently limited and the results could be biased due to a different behaviour of the crew in the presence of observers. The use of electronic monitoring equipment such as the CCTV cameras has already been tested in Denmark, Sweden and Scotland. More fishing days could be used as incentives for vessels that accept to join a programme to fully document the fishery.

None of the Harvest Control Rules (HCRs) considered by ICES are expected to achieve F_{MSY} in 2015 if the TAC is exceeded. The TACs for southern hake have been exceeded every year since 2004. The TAC constraint has the effect of increment the reduction of F the first year of implementation. The more restrictive the TAC constraint is, the lower is the F in the first year. In this situation the more restrictive TAC constraint explored (15%) provide always the highest probabilities of getting F_{MSY} in 2015.

The HCR, "F_{MSY} in 2015") with either a ±15% or ±25% TAC constraint will always achieve F_{MSY} in 2015, in case of not TAC overshoots. The F reduction produced by this HCR is always higher than a 10%, which is the F reduction in the current plan.

The current EU plan for hake and *Nephrops*, with a 10% yearly F reduction and a 15%TAC constraint, do not allow reaching F_{MSY} in 2015. The simulations show that without overshooting and with mean recruitments, the probability of achieve F_{MSY} in 2015 is 12% and F_{MSY} is not achieve with >50% of probabilities until 2017 (Table 8.2)

Table 8.2. Probability Freal (2015) ≤ F_{MSY} for southern hake, with three recruitment scenarios (high, average and low).

HCRs	TAC constraint option	High recruitment				
		No TAC overshoot	TAC Overshoot: Type 1		TAC Overshoot: Type 2	
			Medium	Very high	Medium	Very high
HCR0	No constraint	0	Not applicable	Not applicable	Not applicable	Not applicable
HCR1	15%	0.24	0	0	0.01	0
	25%	0	0	0	0	0
	No constraint	0	0	0	0	0
HCR2	15%	1	0.03	0	0.01	0
	25%	1	0	0	0	0
	No constraint	1	0	0	0	0
HCR3	15%	1	0.92	0	0.49	0
	25%	1	0.8	0	0.26	0
	No constraint	1	0	0	0	0
HCRs	**TAC constraint option**	**Average recruitment**				
		No TAC overshoot	TAC Overshoot: Type 1		TAC Overshoot: Type 2	
			Medium	Very high	Medium	Very high
HCR0	No constraint	0	Not applicable	Not applicable	Not applicable	Not applicable
HCR1	15%	0.12	0.01	0	0	0
	25%	0	0	0	0	0
	No constraint	0	0	0	0	0
HCR2	15%	1	0.03	0	0.01	0
	25%	1	0	0	0	0
	No constraint	1	0	0	0	0
HCR3	15%	1	0.78	0	0.29	0
	25%	1	0.5	0	0.1	0
	No constraint	1	0	0	0	0
HCRs	**TAC constraint option**	**Low recruitment**				
		No TAC overshoot	TAC Overshoot: Type 1		TAC Overshoot: Type 2	
			Medium	Very high	Medium	Very high
HCR0	No constraint	0	Not applicable	Not applicable	Not applicable	Not applicable
HCR1	15%	0	0	0	0	0
	25%	0	0	0	0	0
	NA constraint	0	0	0	0	0
HCR2	15%	1	0	0	0	0
	25%	1	0	0	0	0
	No constraint	1	0	0	0	0
HCR3	15%	1	0.65	0	0.1	0
	25%	1	0.17	0	0.01	0
	No constraint	1	0	0	0	0

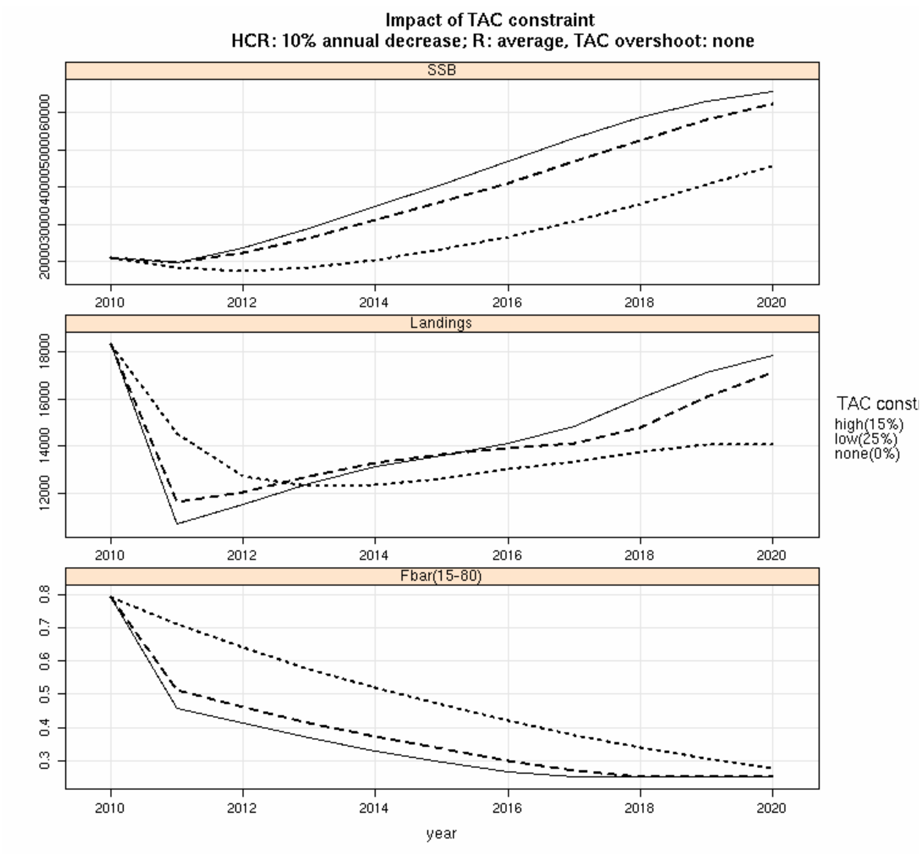


Figure 8.1. Effect of TAC constraint on performance of HCR 1 on southern hake.

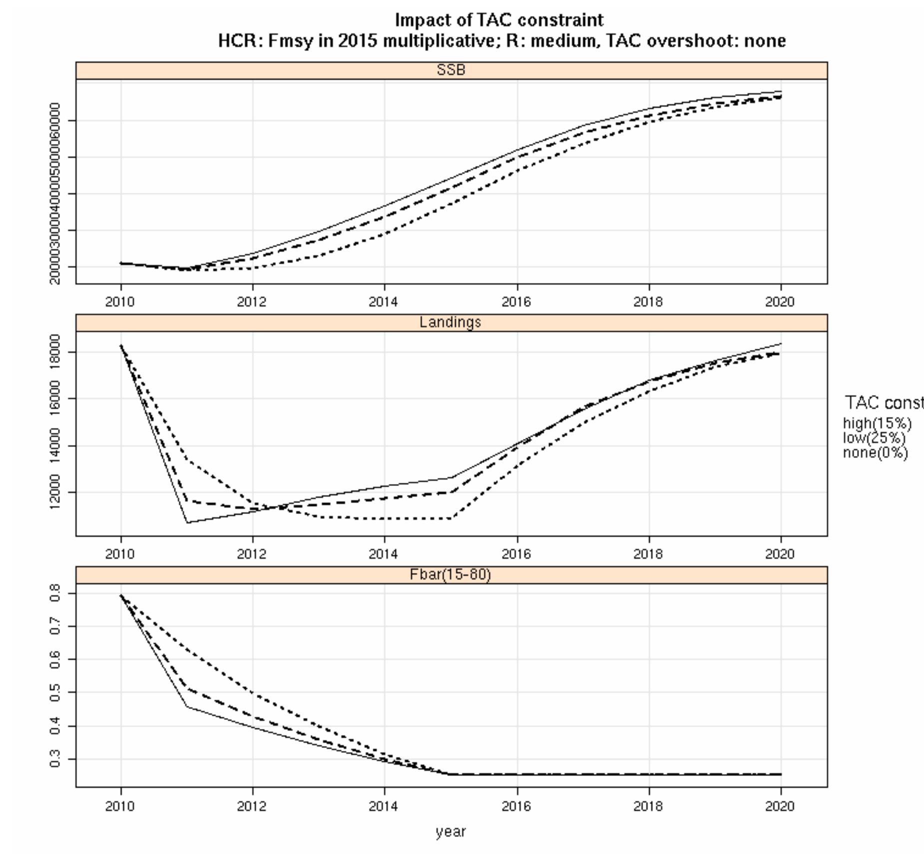


Figure 8.2. Effect of TAC constraint on performance of HCR 2 on southern hake.

Figure 8.1 and 8.2 shows the trends in SSB, landings and discards for HCR 1 and HCR 2. HCR 2 produces large reduction in yield the first year although a higher increase afterwards. The 15% TAC constraint impose a higher reduction in yield the first year although a faster recovery with highest yields afterwards.

Technical measures for hake were evaluated through the impact on the exploitation pattern of two different generic actions: (1) change in mesh (size and shape) and (2) closed areas.

1. The simulations performed (WD 1 and 2) to evaluate the impact of mesh changes have some limitation that should be considered. This limitations are caused by the need of implementing mesh size through a model not designed to deal with different fleets (WD 1) and because selective adjustment used to simulate 70mm+SMP trawl effects used catches from French selectivity study that may have leaded to an underestimation of the selective effect (WD 2).

    a. increasing the mesh size in a small amount like 10 mm (WD 1) or adding a 50 mm square mesh panel (1 * 2 meters) on the top of the gear (WD 2) do not produce substantive differences in the landings or discards and does not change the probability of achieving F_{MSY} in 2015.

    b. Larger changes in the mesh size, like the introduction of a 65 mm square mesh, increase landings and reduce discards both, short and long term. The F reduction needed to achieve F_{MSY} in 2015 is reduced from 24% at year to 18 %. Though the impact of the square mesh panel on catches of other species has not been modelled.

    c. Theoretical simulations (WD 2) show that if we assume no fishing mortality under MLS (27 cm), yield may be improved by 34% (WD2), but this is a theoretical gain that may not be achieved in practice.

2. Regarding closed areas, a spatial analysis of the main species distribution was performed (WD 2 and 3). Their impact on exploitation pattern could not be quantified. According to data available from the bottom trawl surveys carried out on the North of Spain and in Portugal, it is difficult to set new fixed and well defined areas to protect hake recruits seasonally (figure 8.3 provides a map of the current protected areas).

    a. Main recruitment areas in autumn are identified. The main nursery area in Spain is in “Coruña-Celeiro” area, consistent over the years but its extension varies with the strength of the new year-class; mainly at depths ranging from 100-200 m. (WD 3). This area has been closed to trawling activity since 2001, from October to January. The spatial distribution of hake recruits in Portugal shows recent changes in the recruitment areas. The largest recruitment area is now located in the northwest, south of Galicia, in addition to the traditional southwest area (ICES, 2011a). However, the causes of these changes are unknown and it is not possible to evaluate its potential use for hake management.

    b. The areas where small hake (≤ 20 cm) is abundant overlap with the distribution of larger hake (>27cm), blue whiting, horse mackerel and black anglerfish. Areas where only hake recruitment occurs could not be identified.

c. More information on the variability of the seasonality of hake recruitment is still an important gap in the knowledge needed to approach the conservation issues of reduced fishing on hake recruitment

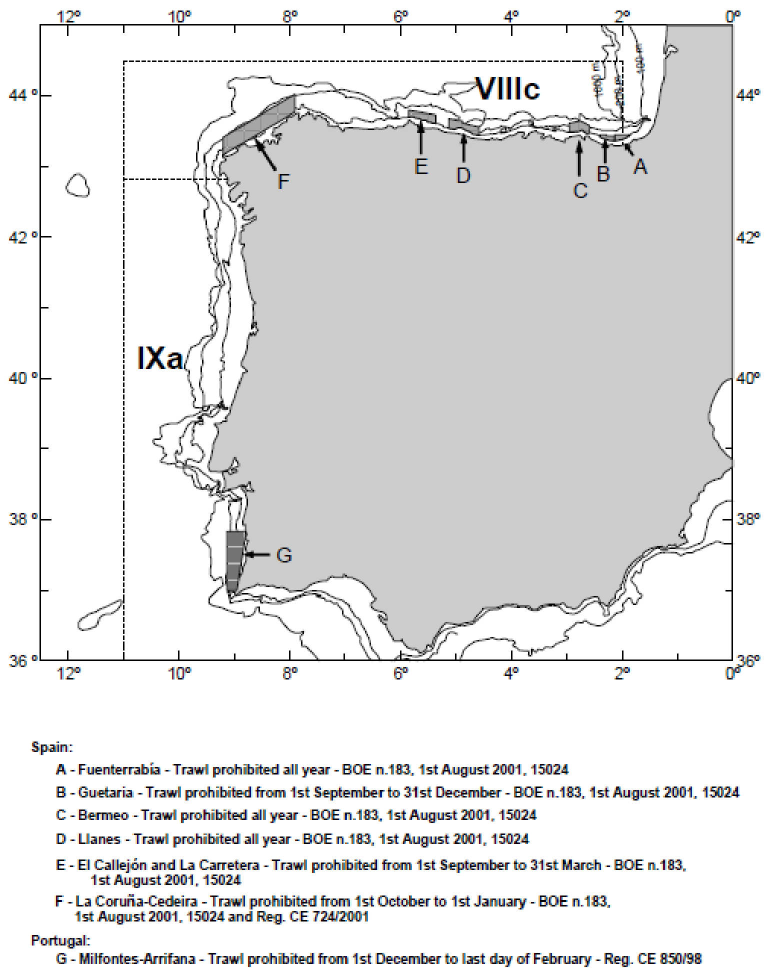


Figure 8.3. Spatial and temporal definitions of current areas closures.

9. EVALUATION OF THE EFFECTS OF THE OPTIONS ON THE STOCK

For FUs 25, 31, 26, 27 and 30:

These stocks have no analytical assessment and it is not possible to assess the distance from current F to a potential F_{MSY} level.

Given the very low biomass level of *Nephrops* in the northern FUs (FUs 25 and 31 in Area VIIIc and FUs 26 and 27 in Area IXa), the catch should remain as low as possible, but the mixed nature of the Spanish bottom trawl fishery, for which *Nephrops* is no longer a target species, makes this difficult to accomplish. Nonetheless, measures taken to reduce F for hake and anglerfish should have the effect of also reducing fishing pressure on *Nephrops*. In what concerns the Gulf of Cadiz (FU 30), the bottom trawl fleet of this FU consists of only one, highly multi-specific metier. Any F reduction measures applied to the fleet catching hake should also cause a reduction on the fishing pressure applied to *Nephrops* (ICES, 2010b).

For FUs 28 and 29:

Although the analytical assessment has been accepted only for trends, it is considered under-exploited at present with respect to any F_{MSY} proxy and with the potential for F to increase. Given the fact that *Nephrops* is caught in a mixed crustacean fishery which main target species is rose shrimp and that the F reduction observed on *Nephrops* stock in recent years was the result of the shift of effort towards rose shrimp, an increase in F on *Nephrops* is to be expected in the future if rose shrimp abundance decreases, as have already happened before (ICES, 2010b). Considering the level of landings of hake and anglerfish by the crustacean trawl fleet, this fleet has a low impact on hake and anglerfish stocks (ICES, 2010b). The total catch of hake by this metier is not identifiable to functional unit but the available data indicate that the Crustacean fleet which fishes in FUs 28 and 29 catches less than 9% of Portuguese catches of hake (as reported to STECF) or less than 2% of total Southern hake catch (ICES, 2011a), see Table 9.1 below. If desirable, this fleet could be allocated sufficient quota to ensure they did not exceed an allocation of hake catch quota (landings and discards). Total catch of hake by the fleet would need to be estimated. This *Nephrops* fishery could then be managed through an allocation of *Nephrops* TAC for these FUs and requirement for detailed VMS monitoring giving limits on location of operation for each FU and its TAC. Managers would need to show that hake catches remain below some agreed upper limit for the vessels.

Table 9.1 ICES estimated catches of hake by country (000 t) and percentage contribution of the Crustacean fleet to Portuguese and ICES total catch of Southern hake (estimated from data submitted to STECF).

	ICES Catches		Hake % taken by Crustacean Fleet in FUs 28-29	
Year	Spain	Portugal	relative to PT catches	relative to ICES total hake
2006	11.33	2.73	2.2	0.4
2007	13.99	3.44	1.6	0.3
2008	16.02	3.07	2.0	0.3
2009	17.81	4.31	8.5	1.7
2010	14.04	2.92	6.1	1.0

Effects of the two seasonal closed areas (in FUs 26 and 28) have not been evaluated.

Anglerfishes

The present exploitation of both anglerfish stocks ($F_{2010} < F_{MSY}$) means that it is not necessary to apply F reductions to reach F_{MSY} in 2015 in these fisheries (ICES 2011a). Some scenarios using the 2010 assessment as numerical basis were carried out to assess the effect of harvest control rules in these stocks.

Due to the starting conditions of *L. budegassa*, with F_{2009} below F_{MSY}, all scenarios tested keep F below F_{MSY} and lead total biomass of the stock to be above any potential biomass target values. For all scenarios performed any TAC overshoot reduces the probability of F in 2015 being equal to or below F_{MSY}, and slows down the recovery of the biomass. Assuming no TAC overshoot, all the HCR tested (with or without TAC constraint) lead F to be equal or below F_{MSY} in 2015 with a high probability, over 70% in all cases.

Taking into account the mixed-species nature of some fleets catching anglerfish, an anglerfish-hake linkage analysis was tested. This analysis consisted in applying to anglerfish a combination of F reductions appropriate for hake and F reductions appropriate for anglerfish (Table 9.2). The “Rasco” fleet, without hake catches, does not need to undergo a reduction in F in order to bring the F of *L. piscatorius* to F_{MSY} in 2015 with a high probability (78%) for all scenarios). The *L. piscatorius* biomass will be close to B_{MSY} in 2020 in all scenarios without a reduction in F in "Rasco" fleet. H

Table 9.2. For *L. piscatorius* and *L. budegassa*: probability of F < Fmsy; cumulative yield over the period to 2015; and biomass in 2015 and 2020 over Bmsy, for different HCRs including links with hake management.

	L. piscatorius				*L. budegassa*				L.pis+L.bud
Scenarios	P|F2015≤ Fmsy|	Ycum2015	Brel2015	Brel2020	P|F2015 ≤Fmsy|	Ycum2015	Brel2015	Brel2020	Ycum2015
All Fleets: Hake HCR 2, TACc: 15%	0.99	9635	0.66	1.32	1	3778	1.75	1.86	13404
All Fleets: Hake HCR 2, TACc: 25%	0.99	9918	0.64	1.30	1	4020	1.74	1.85	13917
All Fleets: Hake HCR 2, TACc: NA	0.99	10277	0.58	1.26	1	4427	1.72	1.85	14677
"Rasco": Fsq & Other Fletts: Hake HCR 2, TACc: 15%	0.78	12541	0.53	0.96	1	5380	1.66	1.74	17872
"Rasco": Fsq & Other Fleets: Hake HCR 2, TACc: 25%	0.78	12583	0.52	0.95	1	5530	1.65	1.74	18046
"Rasco": Fsq & Other Fleets: Hake HCR 2, TACc: NA	0.78	12603	0.49	0.92	1	5755	1.64	1.74	18339
"Rasco": Anglerfish HCR 2, TACc: 25% & Other Fleets: Fsq	0.30	14442	0.44	0.60	1	6760	1.57	1.59	21189
"Rasco": Anglerfish HCR 2, TACc: 25% & Other Fleets: Hake HCR2, TACc:15%	0.99	10227	0.67	1.18	1	3915	1.75	1.80	14091

Hake

Current the hake stock does not have any defined biomass reference points (BRPs). The 35 000 t that is the current SSB recovery target is no longer valid taking the new assessment in consideration. However, simulations show that the B_{MSY} (74 000 t) that would result on average from long term exploitation at F_{MSY} is well above any observed historic SSB (max SSB = 44 000 t), so biomass consideration is not currently an important issue.

Figure 8.1 and 8.2 shows the trends in SSB, landings and discards for HCR 1 and HCR 2. HCR 2 produces faster SSB recoveries than HCR 1; and 15% TAC constraint produces faster recoveries than 25% and no TAC constraint. The HCR that produces the fastest recovery is HCR 2 with 15% TAC constraint.

Technical measures evaluated in WD 1 analyze the impact of the change in mesh size. Results show a slightly faster recovery of SSB in the first years; however the equilibrium SSB is slightly lower with bigger mesh size. This is because the new F_{MSY}, linked to different selection in the fishery, is higher at older ages, and this more than counterbalances the reduction in F at younger ages.

10. EVALUATION OF THE EFFECTS OF THE MULTI-ANNUAL PLAN ON THE ECOSYSTEM.

Hake in divisions VIIIc and IXa is caught in a mixed fishery by the Spanish and Portuguese fleets (trawls, gillnetters, longliners and artisanal fleets). The main species caught with hake are anglerfishes, megrims, Norway lobster, blue whiting, horse mackerel, mackerel and rose shrimp (*Parapenaeus longirostris*), among others. The impact of the different measures evaluated above for the hake fisheries have not been evaluated for all the other species although some considerations have been provided regarding anglerfish and *Nephrops* in WKSHAKE2 (ICES, 2010b).

One of the main impacts of a potential change of the trawl mesh size is the reduction of pelagic catches, mainly blue whiting, horse mackerel and mackerel, which are important catches for trawlers. There is no quantification of the impact of the plan on these stocks.

Hake is a top predator in Iberian waters occupying together with anglerfish one of the highest trophic levels (Velasco *et al.*, 2003). Hake is a highly ichthyophagous species although euphausiids and decapods are an important part of the diet for smaller hake (> 20 cm). Its diet at >30 cm is mainly composed of blue whiting, while other species such as horse mackerel and clupeids are only important in shallow waters and for smaller individuals that also feed on other small fishes. Cannibalism in the hake diet is highly variable depending on predator size, alternative prey abundance, year or season. From stomach content observations, cannibalism ranged from 0 to 30% of total volume (with mean values of around 5%) producing a high natural mortality in younger ages.

All the measures for reducing F drive to an increase of hake population. Being the hake a top predator it is expected an increase on consumption on other species, particularly pelagic stocks like blue whiting, horse mackerel and mackerel. There is no quantitative evaluation of the plan impact on these species.

Discards are important in both, Spain and Portugal. Discards are mainly driven by the MLS (27 cm). An increase in mesh size should reduce the catch of small hake and then the discards rate (WD 1)

11. SOCIAL AND ECONOMIC EFFECTS OF THE PLAN

11.1. Data and Calculation of Indicators

Detailed economic analyses of the hake fisheries have been hampered by a shortage of data from Spain, which has the main fleets that fish Southern hake. While data on economic performance a number fleet segments was supplied this year, the 2008/2009 data on catch volume and catch value by species (including hake) was not uploaded for the 2011 economic data call. Therefore the most up to date detailed economic analysis at species level is available in SGMOS 10-06. This shortage of data from the 2011 call has restricted the economic considerations to stylized and theoretical evaluations which are presented in WD 4 and summarized below

Economic analyses indicate that mesh size and area closure regulations seem to impact on profitability and fleet size through a change in number of days per vessel in the fishery. Constraints on the maximum number of days affect operating profits and vessel entry and delay-exit decisions. Therefore, the distribution of vessels is a function of fishery regulations (scenarios). Policies increasing the number of days per vessels while maintaining or decreasing the total number of days always entail a (potential) reduction in the fleet size (i.e. employment). However, introducing ITQs that can be sold and leased allows sharing among all vessels the surplus generated by an increase in the number of days and/or the fishing mortality reduction. This is due to the fact that ITQs increase the overall fleet revenue without having all vessels fishing. Some vessels sell their quota and others, more cost-efficient vessels fish on a higher quota. This means that overall costs are reduced and that the benefits can be divided between the quota sellers and quota buyers.

Currently it is not possible to parameterize these changes in a fully dynamic model. Therefore, we concentrate on the impact on the long term (stationary) fleet capacity. We build up a stationary analytically tractable fleet distribution model in which vessels value per unit is endogenous (Da Rocha and Pujolàs, WD4). An analytical solution for the vessels stationary distribution is obtained by using optimal investment/disinvestment decisions.

We calibrate the model for seizing the heterogeneity observed in the European Southern Hake multi species fishery. Data shows that there is no correlation between daily hake landings and the value per kilo of hake.

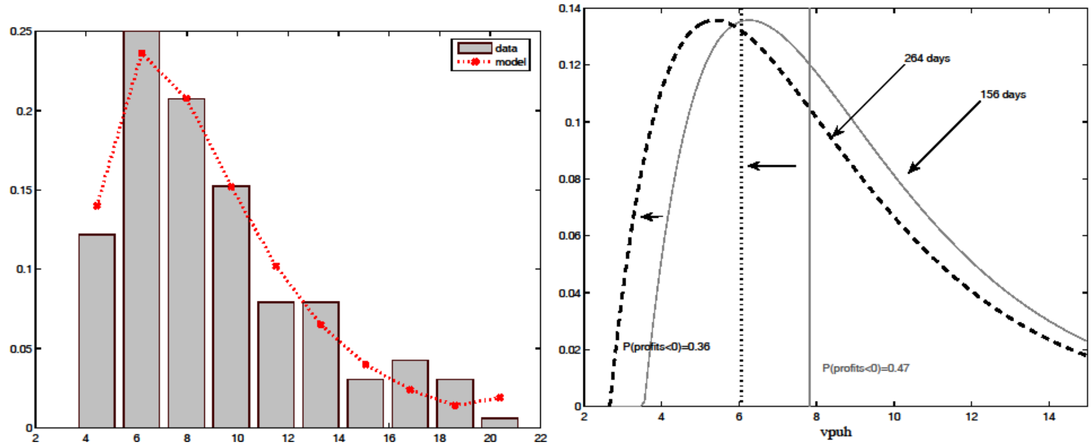


Figure 11.1. The left panel shows the value per kilo of hake partition. Right panel shows the impact on the value per unit of hake fleet distribution of an increase in the number of days per vessel.

We use the calibrated model for analyzing the impact on long term fleet size and profitability of:

- Scenario 1: an increase in the number of days per vessel (from 156 to 264) and a reduction in fishing mortality from F_{sq} to F_{MSY};
- Scenario 2 (technical measures): an increase in the number of days per vessel (from 156 to 264) and a fishing mortality reduction from F_{sq} to F_{MSY} when a square 65mm mesh is introduced.

For each scenario we compare the effects of reducing the number of vessels and the days per vessel, and we will show the trade-off between profits per vessel and fleet size.

Finally, we analysed the economic benefits of adopting a property right-based management (ITQs) in the European Southern Hake multi species fishery

11.2. Findings

Increasing days per vessel by 70% (from 156 to 264) by redistribution impacts strongly on fleet profits: on the one hand, fleet expected value increases in a 65.67%, and on the other hand, the fraction of fleet vessels having short-run losses diminishes in a 22% (see Figure 11.1).

A policy that increases the number of days per vessel (from 156 to 264) and reduces fishing mortality from F_{sq} to F_{MSY} brings an 89% increase in profits while reducing current fleet by only 25%. Therefore, the desired levels of fishing mortality F_{MSY} might be achieved reducing fleet less than proportionally to the reduction in fishing mortality. Considering the impact on hake alone the introduction of a square 65mm mesh increases profits even further and diminishes the fleet size reduction, though this may be complicated by the effect on other species.

Table 11.1. Long term indicators from the simulated scenarios. Status quo: F and number of days per vessel

	No ITQ's	ITQ's
Itq price per kilo of hake lease market		4.96
Itq price per kilo of hake stock market		99.15
Permit outputs (days)		147
Expected value per kilo of hake	8.40	12.30

The simulations suggest that the introduction of ITQs in this fishery implies allocating to a quota each vessel equivalent to 147 times its average landings per day. Under these conditions, vessels obtaining total landings in value of 4.44 euros per kilo of hake or more will remain in the fishery. On the contrary, a 4.32%of the fleet will not attain the minimum necessary total landings and will sell fishing rights (at 99.15 euros per kilo). Leasing price will be equal to 4.96 euros per kilo and day. Introducing leasing markets allows concentrating the total amount of fishing days in more efficient vessels. Therefore, the total value of landings per kilo of hake will be 12.30 euros in average, 37% greater than the current average value (see Table 11.1)**.**

11.3. Efficiency: cost-effectiveness

Table 11.2. Long term indicators from the simulated scenarios. Status quo: F and number of days per vessel equal 2011, scenario 1: F_{MSY} and maximum number of days per vessel, scenario 3: F_{MSY} and maximum number of days per vessel with Square 65mm.

Scenario	F	Yield (kTn)	Landings per day (kilos)	Days per vessel	Fleet size (Satus quo =100)	Expect Value (Satus quo =100)
status quo	0.85	11933	250	156	100.00	100.00
Scenario 1	0.25	17251	286	264	76.39	189.01
Scenario 2	0.25	19503	413	264	82.62	197.51

A policy, that increases the number of days per vessel (from 156 to 264) by redistribution and reduces fishing mortality from F_{sq} to F_{MSY} (scenario 1), increases expected value per vessel and reduces employment (fleet size). By introducing the square 65mm mesh it is possible to increase profitability and reduce, at the same time, the negative impact on fleet size.

Therefore, the desired levels of fishing mortality F_{MSY} can be achieved reducing fleet less than proportionally to the reduction in fishing mortality.

11.4. Consistency: limiting trade-offs across the economic, social and environmental domains

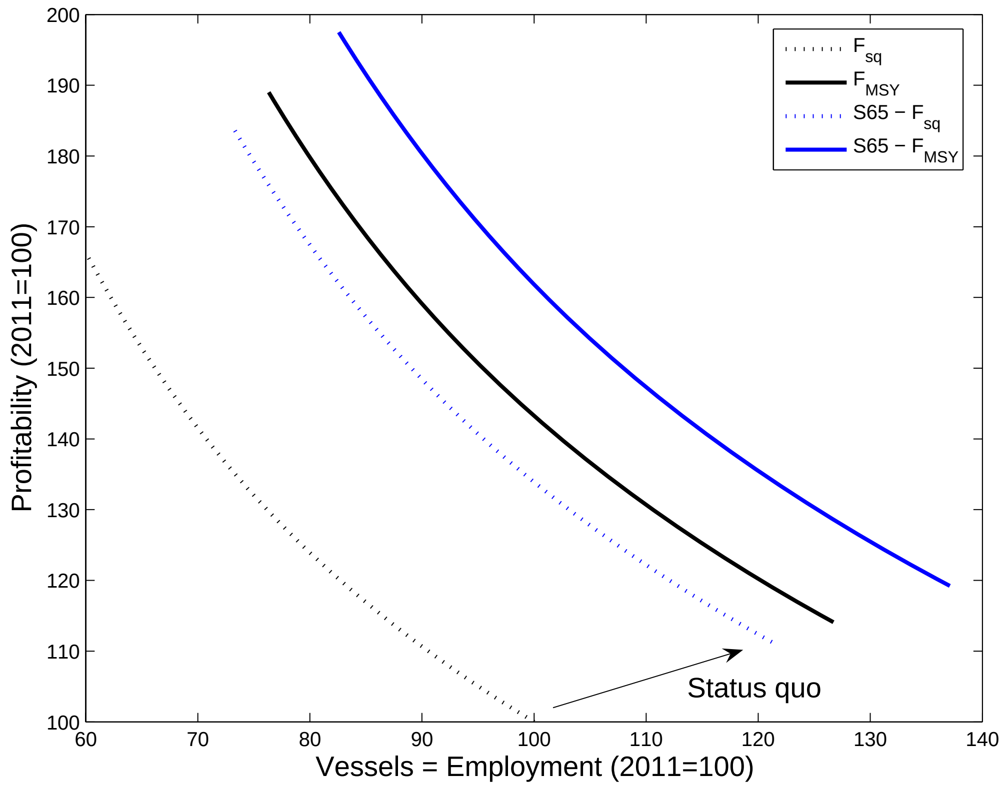


Figure 11.2. Trade-offs between fleet profitability and fleet size, for different environmental domains (dotted lines, F_{sq}: solid lines, F_{MSY}.). The introduction of S65mm shift trade–off curves to the right.

Figure 11.2 shows that there are important trade-offs between the three main objectives of the CFP (economic, social and environment) that differ among the different environmental domains. An increase in fleet profitability and employment is possible by reducing fishing mortality from F_{sq} to F_{MSY}. If fishing mortality is not to be reduced, employment (fleet size) must diminish for an increase in fleet profitability. By introducing changes in mesh size (scenario 3) trade-offs among the CFP three main objectives (economic, social and environment) are less severe, though the impact on other species has not been explicitly considered.

Finally, introducing ITQs allows maintaining the ‘current fleet size’, in terms of permit output holders, though not in active vessels. This result is possible because in making the ITQ allocation, in terms of days per vessel, the number of days is smaller than the current number of days per vessel.

12. Cost effectiveness of Control and Enforcement

There is no cost data available for enforcement so the cost effectiveness of regulations cannot be estimated, however, simulations indicate that failure to improve regulation will ensure that F_{MSY} targets are not met.

New information on enforcement

In the second semester of 2010, a limitation of Spanish landings of 100-200 kg per vessel per week (depending on the fleet segment) was established under regulation ARM/1808/2010. A closure of activity for 1 month was also established in the same period. In 2010, Spanish landings in the first semester have been 9 080 t meanwhile 3 950 t in the second semester. In 2011 there will be 2 months of closure and a system to share the Spanish quota with maximum landings per quarter and fleet segment (ARM/3361/2010 and ARM/1083/2011).

13. Conclusions to the Impact Assessment

13.1. Current situation of the stocks and fisheries

WKSHAKE2 (ICES, 2010b) carried out analyses of several different HCR for the plan. From the work carried out here and discussed above and from the information from the ICES 2011 assessment update (ICES, 2011a) the following may be concluded:

Nephrops in northern FUs (FUs 25, 26, 27 and 31): In the absence of an analytical assessment, it is not possible to assess the distance from current F to a potential F_{MSY} level. Given the very low biomass level of *Nephrops*, the catch should remain as low as possible (ICES, 2010b).

Nephrops in FUs 28 and 29: Fishing mortality has decreased in the last five years, and is presently considered to be at a record low. The stocks are considered underexploited at present with respect to any F_{MSY} proxy (ICES, 2010a, 2010b).

Nephrops in FU 30: The stock appears to be low compared to historic levels. Landings and effort have decreased substantially in recent years (ICES, 2010a).

L. budegassa: Fishing mortality has decreased since 1999 and is in 2010 below F_{MSY}. Biomass has increased since 2002, and is presently 91% of B_{MSY} (ICES, 2011).

L. piscatorius: The update assessment for white anglerfish has resulted in a large decrease of F in 2010, being below F_{MSY} in contrast to the 2010 assessment. Biomass in 2011 is estimated to be approximately at 30% of B_{MSY} (ICES, 2011).

M. merluccius: Fishing mortality is more than twice the F_{MSY}.

13.2. Comparison of Options

Options considered:

Nephrops

Management of *Nephrops* stocks by Functional Unit would better respond to the conservation measures required for each FU unit. This is justified by the fact that *Nephrops* stocks in independent FUs are often at different status requiring different management measures.

Separate hake and *Nephrops* management is feasible for FU 28 and 29 provided enough *Nephrops* TAC is allocated to these FUs, and VMS is used to define the location of the fisheries to FU and sufficient hake quota is allocated to this fleet to cover hake bycatch.

For all other *Nephrops* FUs separate hake and *Nephrops* management is not feasible without solutions based on species separator gears. STECF has not been able to evaluate gear related solutions for species separation. Grids (e.g. Swedish grid) have been used in other areas to separate gadoids and *Nephrops*, and could be investigated to see if they are applicable here.

Given the low biomass of northern *Nephrops* FUs, measures taken to reduce F for hake should have the effect of also reducing fishing pressure on *Nephrops.* The same is true for FU 30, although the stock is thought to be in a better condition.

Angler

Considering the present state of both anglerfish stocks and their exploitation ($F< F_{MSY}$), it will not be necessary to apply F reductions in these fisheries to achieve F_{MSY}. However, part of the fleets catching anglerfish is already covered by the current hake management plan. Currently there is separate management for the "RASCO" fleet. This fleet does not catch sufficient quantities hake to require regulation under a hake fishery management plan, and should continue to be managed separately.

All other fleets catching angler cannot currently be separated from fleets catching hake and will need to be regulated within a hake plan.

Hake

Gulf of Cadiz is part of the definition of the stock area of southern hake and there is no scientific reason to exclude it from the effort regulations.

None of the Harvest Control Rules (HCRs) considered for exploitation of hake will achieve $F2015 \leq F_{MSY}$ if the TAC is overshot.

The current EU plan for hake and *Nephrops*, with a 10% yearly F reduction and a 15%TAC constraint (no change), does not allow the exploitation rate on hake to reduce to F_{MSY} in 2015 but if implemented full will achieve F_{MSY} in 2017. With previously observed levels recruitment and no overshooting of TAC the probability of achieving F_{MSY} in 2015 is 12%.

A HCR "F_{MSY} in 2015" with either a ±15% or ±25% TAC constraint will achieve F_{MSY} in 2015 for the southern hake stock. 15% TAC constraint produces faster recoveries than 25%. This F reduction in this plan is always higher than a 10%, which is the F reduction in the current plan.

Additional technical measures are needed to get F_{MSY} in 2015 with the current plan. These technical measures could impose a change in the hake exploitation pattern. The analyzed measures to reduce the exploitation pattern were (1) changes in trawl gears (WD 1 and WD 2) and (2) closed areas (WD 2 and WD 3).

3. Mesh changes: The simulations performed show that a small change in mesh size (about 10 mm increase in for all trawlers) does not produce any substantive improvement. If mesh changes are to be used larger changes are needed. These larger changes in mesh size help to by changing the F_{msy} value and thus the F_{target}, reducing the relative change in F required to achieve F_{msy} in the medium term. The result in the long term is increased landings, reduce the discards and a slightly reduced SSB. In order to define the mesh changes that would be acceptable and evaluate in detail their impact on the stock, fishery and ecosystem, a definition of fleets and gears that should be changed should be provided by MS.
4. Closed Areas: The analysis of the Portuguese and Spanish surveys (both in October) does not provide relevant additional information to extend the current closed areas in time or space. Furthermore, the impact of extending these areas on F will not be effective in reducing the exploitation pattern if the fishing effort is transferred to other areas.

There is currently a legal obligation to record soak time, and overall length of net deployed. STECF considers that this would be an appropriate metric to determine effort for static gears.

With the available data, the group is not able to assess the impact of including the vessels under 10 m in the plan. MS are required under the DCF provide estimates of total catch from under 10m. In addition to the formal data call EWG 11-06 MS were requested to provide data during the scoping meeting for management plans. No data are available for Spain. No new fleet proposals were received.

With the available information, it is not possible to evaluate the impact of the introduction of real time closures.

13.3. Effectiveness: best placed to achieve the objectives

If complied with the HCR2 (“F2015 ≤ F_{MSY}”), the recovery of the southern hake stock (SSB) will be faster than with the current plan. The yield has a high reduction in the first year, but will increase afterwards.

The economic simulations show that a policy that allows movement of number of days to a smaller number of vessels brings an increase in fleet profitability. Simulations suggest that F_{MSY} can be maintained by reducing the fleet less than proportionally to the reduction in fishing mortality.

The introduction of ITQs in this fishery allows concentrating the total amount of fishing days in more efficient vessels. The simulations show that at F_{MSY} the total value of landings per kilo of hake and fleet profitability will increase.

Fishing at F_{MSY}, it is expected that hake and anglerfishes biomasses increase towards B_{MSY}. As these species are top predators in the ecosystem, the mortality of their preys should increase. The change in the exploitation pattern through increases in mesh size and or area/season closures may introduce a reduction in discards.

13.4. Efficiency: cost-effectiveness

There are no economic studies of transition phases due to data shortages

13.5. Consistency: limiting trade-offs across the economic, social and environmental domains

In terms of the trade off between employment and profitability, if fishing mortality is not to be reduced, employment (fleet size) must diminish for an increase in fleet profitability. An increase in fleet profitability and employment is possible by reducing fishing mortality to F_{MSY}. By introducing changes in mesh size, trade-offs among the CFP three main objectives (economic, social and environment) are less severe. Finally, introducing ITQs allows maintaining the current fleet size, in terms of permit output holders.

13.6. Forward look to Evaluation

STECF considers 5 years minimum time for data to be available for review

14. EWG-11-07 List of Participants

Name	Address	Tele	Email
STECF members			
Nick Bailey	FRS Marine Lab. , Victoria Road, Aberdeen, United Kingdom	0044(0)12242 95398	baileyn@marlab.ac.uk
Massimiliano Cardinale	Europeen Commission, Föreningsgatan , Lysekil, Sweden	+46 523 18750	massimiliano.cardinale@fiskeriverket.se
Ralf Döring	Institute for Sea Fisheries, Steinstr. 42, Greifswald, Germany	0049 40 38905-185	doering@uni-greifswald.de
Norman Graham	Marine Institute, Rinville, Co Galway, Ireland	+353 (0)91 387307	norman.graham@marine.ie
Eskild Kirkegaard	DTU Aqua, Charlottenlund Slot, Charlottenlund, Denmark	4533963300	ek@aqua.dtu.dk
Sarah Kraak	Marine Institute, Rinville, County Galway, Ireland	35391387392	sarah.kraak@marine.ie
Clara Ulrich Rescan	DTU-Aqua, Charlottenlund Castle, Charlottenlund, Denmark	+45 35883300	clu@difres.dk
Willy Vanhee	ILVO, Hospitaalstraat, Oostende, Belgium	+32(059)433 083	wvanhee@pandora.be

Name	Address	Telephone no.	Email
Invited experts			
Francois Bastardie	DTU-Aqua, Charlottenlund castle, Charlottenlund, Denmark	+45 35883300	fba@aqua.dtu.dk
Jörg Berkenhagen	VTI-Federal Research Institute for Rural Areas, Fo, Palmaille 9, Hamburg, Germany	+49 040 38905-206	joerg.berkenhagen@vti.bund.de
Santiago Cerviño	Instituto Español de Oceanografia, Cabo Estay - Canido s/n, Vigo, Spain	+34 986492111	santiago.cervino@vi.ieo.es
Jose Maria Da Rocha	Universidade de Vigo, Campus Lagoas Marcosende, Vigo, Spain	34986812400	jmrocha@uvigo.es

Name	Address	Telephone no.	Email
Invited experts			
Chris Darby	Cefas, Pakefield Road, LOwestoft, United Kingdom	441502524329	chris.darby@cefas.co.uk
Margit Eero	DTU-Aqua, Charlottenlund Castle, Charlottenlund, Denmark	+45 35883300	mee@aqua.dtu.dk
Steven Holmes	fisheries research services, victoria road, aberdeen, United Kingdom	+44(0)1224 295507	s.holmes@marlab.ac.uk
Tore Jakobseb	Institute of Marine Research, Nordnesg. 50, Bergen, Norway	4755238577	tore.jakobsen@imr.no
Katharina Jantzen	Institute of Sea Fisheries, vTI-SF, Palmaille 9, Hamburg, Germany	+49(0)403890 5231	katharina.jantzen@vti.bun d.de
Alexander Kempf	Institute of Sea Fisheries, Palmaille 9, Hamburg, Germany	494038905194	alexander.kempf@vti.bund .de
Sasha Maguire	Marine Scotland, Scottish Government, Victoria Quay, Edinburgh, United Kingdom	441312440563	sasha.maguire@scotland.g si.gov.uk
Rasmus Nielsen	Techn. Uni. Denmark, Nat. Inst. Aquatic Resources, Charlottenlund Castle, Jaegersborg Allé 1, Charlottenlund, Denmark	+45 35883300	rn@aqua.dtu.dk
Maris Plikshs	BIOR, Daugavgrivas str 8, Riga, Latvia		maris.plikss@bior.gov.lv
John Powell	University of Gloucestershire, Oxstalls Lane, Gloucester, United Kingdom	+44 1242 714129	jpowell@glos.ac.uk
Krzysztof Radtke	Sea Fisheries Institute, Kollataja 1, Gdynia, Poland		krzysztof.radtke@mir.gdy nia.pl
Tiit Raid	Estonian Marine Institute, University of Tartu, Mäealuse 14, Tallinn EE-12618 Estonia	+372 6718953	tiit.raid@gmail.com
M. Paz Sampedro	Instituto Español de Oceanografia, Paseo Maritimo Alcalde Francisco Vazquez, 10, A Coruña, Spain	981218253	paz.sampedro@co.ieo.es
Pieter-Jan Schon	Agri-Food & Biosciences Institute, Newforge Lane, Belfast, United Kingdom	+44 28 90255015	pieter-jan.schon@afbini.gov.uk
Cristina Silva	INRB-L/IPIMAR, Av. de Brasília, Lisboa, Portugal	+351 213027096	csilva@ipimar.pt
Chris Zimmermann	Thünen-Inst Baltic Sea Fisheries, Alter Hafen Süd, Rostock, Germany	+49 381 81161 15	czimmermann@clupea.de
JRC Experts			
John Simmonds	Joint Research Centre, Via E Fermi, Ispra, Italy	39 332 785311	john.simmonds@jrc.ec.eur opa.eu
Robb Scott	Joint Research Centre, Via E.Fermi, Ispra, Italy	390332783692	robert.scott@jrc.ec.europa. eu

Name	Address	Telephone no.	Email
European Commission			
Edgars Goldmanis	European Commission, 79 Rue Joseph II, Brussels, Belgium		edgars.goldmanis@ec.europa.eu
Rodrigo Ataide-Dias	European Commission, Rue Joseph II 79, Brussels, Belgium		rodrigo.ataide-dias@ec.europa.eu
Stuart Reeves	European Commission, 79 Rue Joseph II, Brussels, Belgium	+32229 80156	stuart.reeves@ec.europa.eu

Name	Address	Telephone no.	Email
Observers			
Michael Anderson	Danish Fishermen's Association, Nordensvej 3, DK-7000 Fredericia	+4540265040	ma@dkfisk.dk
Antonio Miguel Cunha	ADAPI – Edifício Vasco da Gama, Bloco c, 1º Piso, Rua General Gomes de Araújo, 1399-005 Lisboa	+351919360175	antonio.cunha@testacunhas.pt adapi.pescas@mail.telepac.pt
Barrie Deas	Nat. Fed. Fishermen's Orgs, 30 Monkgate, York, United Kingdom	441904635430	bdeas@nffo.org.uk
Paul Dolder	Defra, Nobel House, 17 Smith Square, London, United Kingdom		paul.dolder@defra.gsi.gov.uk
Magnus Eckeskog	The fisheries Secretariat, Åsögatan 140, Stockholm, Sweden	+ 46 (8) 25 07 90	magnus.eckeskog@fishsec.org
Kenn Skua Fischer	Danish Fishermen's Association, Nordensvej 3, DK-7000 Fredericia	+4551199537	ksf@dkfisk.dk
Caroline Gamblin	CNPMEM, 134 avenue de Malakoff , Paris, France	33172711800	cgamblin@comite-peches.fr
Kim Kaer Hansen	Fiskeriforening Oest Lendemark Hovedgade 32 DK-4780 Stege	+4540891381	kim@fisker.mail.dk
Reine Johansson	BSRAC, H.C. Andersen's Boulevard 37, DK-1553 Cph V	+4533935000	ai@bsrac.org
Lorcan Kennedy	IRISH FISH PRODUCERS ORGANISATION, 77 SIR JOHN VROGERSONS QUAY, DUBLIN, Ireland	35316401850	ifpo@eircom.net
Lianne Kersbergen	Ministry Econ. Affairs, Agriculture, Innovati on, Bezuidenhoutseweg 73, Den Haag, Netherlands	31703784154	m.c.kersbergen@minlnv.nl
Segolene Monteillier	DPMA-MAAPRAT, 3 place de fontenoy, Paris, France	330149558219	segolene.monteillier@agriculture.gouv.fr
Mike Park	SWFPA, 40 Broad street, Fraserburgh, United Kingdom	1346514545	mikeswfpa@aol.com
Yohan Weiller	SWWRAC, 6 rue alphonse rio, Lorient, France	33632026815	yweiller@ccr-s.eu

Name	Address	Telephone no.	Email
Carole White	Seas At Risk, 26 rue d'edimbourg, Brussels, Belgium	3228930968	cwhite@seas-at-risk.org

15. REFERENCES

Campos, A. and P. Fonseca. 2003. Selectivity of diamond and square mesh cod ends for horse mackerel (*Trachurus trachurus*), European hake (*Merluccius merluccius*) and axillary seabream (*Pagellus acarne*) in the shallow groundfish assemblage off the south-west coast of Portugal. SCI. MAR., 67 (2): 249-260.

ICES, 2010a. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 5-11 May 2010, Bilbao, Spain, ICES CM 2010/ACOM:11.

ICES, 2010b. ICES Workshop on Iberian mixed fisheries management plan evaluation of Southern hake, Nephrops and anglerfish (WKSHAKE2), 22-26 November 2010, Lisbon, Portugal. ICES CM 2010/ACOM:63.

ICES, 2011a. WGHMM2011 Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 5-11 May 2011, Copenhagen, Spain, ICES CM 2011/ACOM:11.

ICES, 2011b. Advice June 2011, Book 7. Bay of Biscay and Western Iberian Seas. http://www.ices.dk/advice/icesadvice.asp

STECF, 2010. Report of the SGMOS-10-05 Working Group on Fishing Effort Regimes regarding Annexes IIA, IIB and IIC of TAC & Quota Regulations, Celtic Sea and Bay of Biscay. 27 September – 1 October 2010, Edinburgh, Scotland (draft).

https://stecf.jrc.ec.europa.eu/c/document_library/get_file?p_l_id=53310&folderId=44891&name=DLFE-10103.pdf

16. LIST OF BACKGROUND DOCUMENTS

Background documents are published on the meeting's web site on: XXXXXXXX

List of background documents:

1. EWG-11-07 – Doc 1 - Declarations of invited and JRC experts.

Annex 1 Impact of mesh size change on Southern hake stock.

Santiago Cerviño[1] and Ernesto Jardim[2]

([1]) IEO. Vigo, Spain.
([2]) IPIMAR. Lisbon. Portugal.

Summary
Results for selectivity experiences (Campos and Fonseca, 2003) with 3 different mesh sizes (D70, D80, S65) were used to evaluate the impact of change in mesh size trawlers on Southern hake stock. The GADGET model used to assess Southern hake stock is structured with two “fleets”, one for landings (trawlers, gill-nets, long-liners and artisanals) and another for discards (trawlers). In this work we assume that all the trawlers fish with D70 being D80 and S65 a relative change in exploitation pattern regarding D70. Results show that the change in mesh to D80 do not has impact on the stock meanwhile changes in mesh to S65 produces: (a) a lower reduction in effort to reach Fmsy in 2015; (b) an increase in landings and reduction of discards in both, short and long term; (c) a lower SSB in long term. The main limitation of this study is the assumption of all fleets fishing at S70. Current trawl fleets in the area are quite different in mesh size (minimum 55 mm) and in gear design depending in the activity (area, season, target species, etc). However, a change in selection pattern towards larger fish, if significant should produce similar responses than those presented here.

Southern hake dynamic model (GADGET)
Southern hake dynamics follows last ICES WGHMM assessment model with GADGET. It is a length based model (1-130 cm) with quarter time steps. The model has two different “fleets” one for landings (all fleets together) fitted to a logistic curve and another for discards (only for trawlers) fitted to an Andersen function (double asymmetric normal). 8 multipliers for projections were defined to represent the current effort conditions for 4 quarters times 2 fleets, as the mean of last 3 years. Figure 1 shows the resulting exploitation pattern for projections.

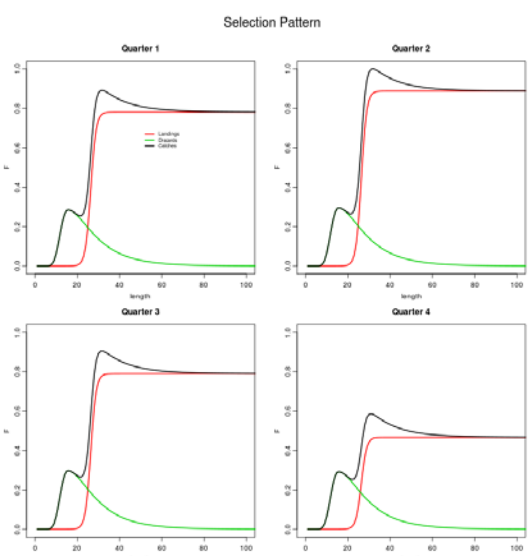


Figure 1. Current exploitation pattern by quarter before a change in mesh size. Mean of last 3 years.

Southern hake exploitation pattern

Change in mesh size.
Selectivity experiences with 3 different mesh sizes were developed by Campos and Fonseca (2003). The mesh length are D70, D80 and S65 (diamond 70 mm, diamond 80 mm and square 65 mm). Data from the experiences were fit by Campos and Fonseca (2003) to a logistic function (exp(a+b*len)/(1+exp(a+b*len)) getting the following parameters:

Mesh	**a**	**b**
D70	-12.635	0.742
D80	-9.547	0.522
S65	-8.662	0.267

The implementation of these new selectivities in current GADGET exploitation pattern was developed following the next steps:

1. Assume all trawls employ D70 mesh. The change to other mesh is relative, i.e. we assume that all trawlers use D70.
2. Estimate the ratios of the change (D80/D70 and S65/D70) and apply these ratios to the trawl fraction in the landings exploitation pattern and to all the discards exploitation pattern
3. Estimate new exploitation patterns for changes to D80 and S65

Figure 2 (upper plot) shows the curves for the 3 different mesh sizes. Differences between D70 and D80 are small; however S65 curve is clearly moved to the right. This movement to the right do not happen at low length levels. Figure 2 (lower plot) shows the ratios between D70 and the other two selectivities (D80 and S65). At low length levels (18 cm for D80 and 8 for S65) the ratios are higher than 1 and were cut to a maximum of 1. This means that all length class are less selected with the change in mesh size. These ratios were estimated to quantify the impact of a change on mesh on the total exploitation pattern. This will be done assuming that the current trawl selection follows the D70 mesh size for all trawling fleets.

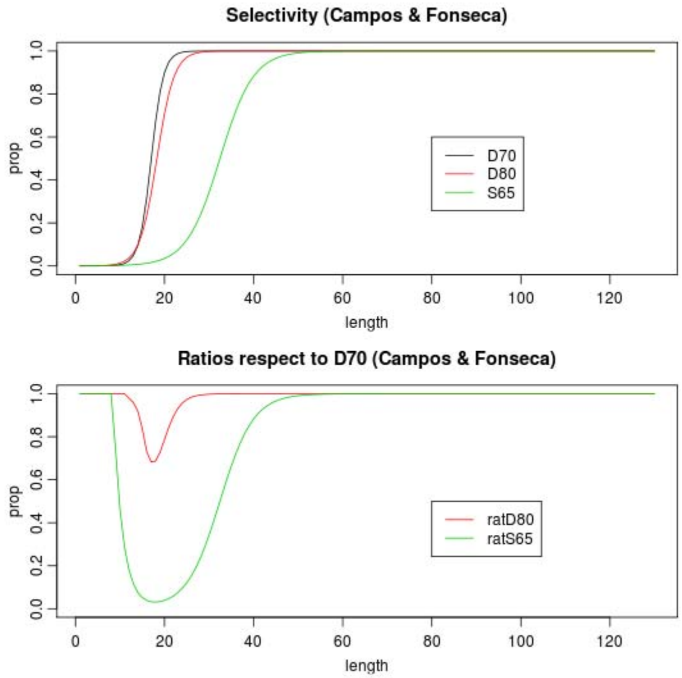


Figure 2. Selectivities from Campos and Fonseca (2003) and ratios of change regarding D70.

The ratios were applied to the GADGET exploitation pattern in the following way:

1. for the "landings" fleet the ratios multiply the landings exploitation pattern and afterwards a correction was implemented to S65 to consider the fraction of trawl landings on the total landings. This correction was estimated as the mean ratio in number (trawl landings / total landings) for the length classes where Campos and Fonseca (2003) found differences in selectivity (20 – 50 cm in S65). The correction rate was 0.75 that means that 75% of F is caused by trawlers in this length range.
2. For the "discards" fleet, the ratio was applied directly since all discards in the GADGET model belong to the trawl fleet.
3. once the corrections were applied the resulting exploitation patters were reparametrized to the corresponding GADGET functions exploitation pattern (logistic for landings and Andersen for discards).

The original exploitation patterns (before change in mesh size) were presented in figure 1. The resulting exploitation for Landings and discards, after change in mesh size are presented in figure 3.

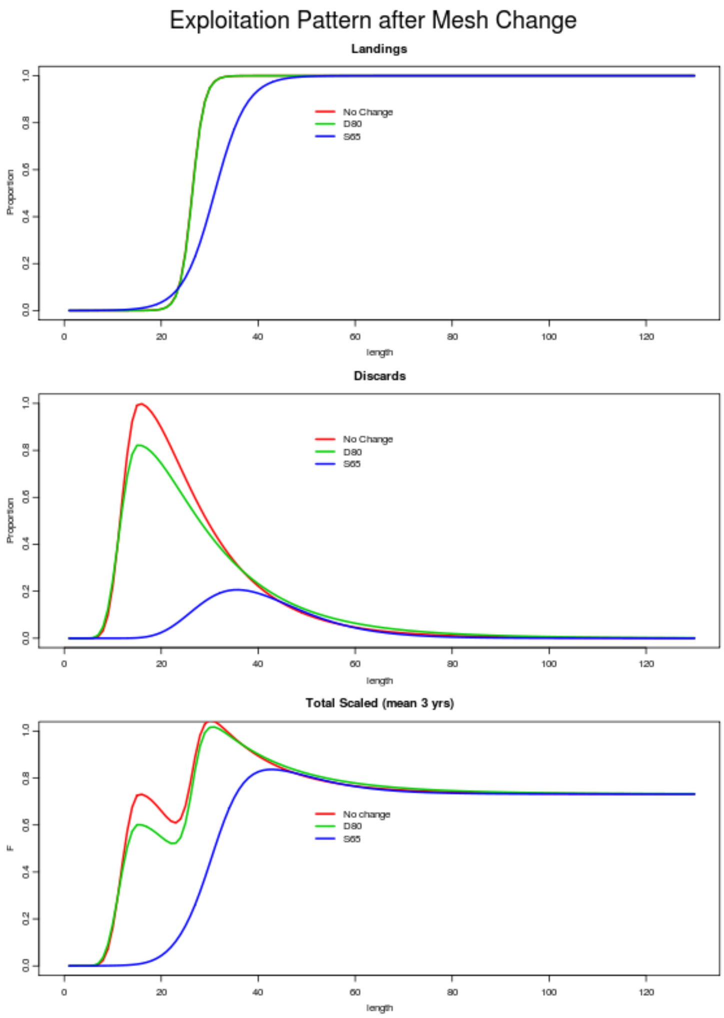


Figure 3 Change in annual (mean of 4 quarters) GADGET selection pattern with change in mesh sizes. Note that D80 overlaps "no change" in the upper plot.

Figure 3 upper plot shows the old and news exploitation patterns for landings. The change from D70 to D80 do not produce any important change. The change to S65 produce a new selection pattern moved to the right. The middle plot shows the change in discards selection. In this case the change to D80 reduces the discards, that are more reduced with the change to S65. Finally, the lower plot shows the total exploitation patters scaled to the mean of last 3 years. These are the exploitation pattern that will be used in the simulations

Southern hake dynamic simulations

After new selection was defined, next steps to quantify the impact of change in selection pattern are:

1. Estimate new target reference points (Fmax)
2. Mid term projections (to Fmsy in 2015)

1- Biological Reference Points

The change in the selection pattern imposes two different changes in BRPs. First, a change in absolute BRPs and second, a change in the current F, i.e. if selection changes to larger fish, the current F decreases.
The absolute change is presented in figure 4. Fmax, that was accepted as a proxi for Fmsy (ICES WGHMM 2010) hardly change with the change in mesh size.

	F current	Fmax
No change (D70)	0.72	0.24
D80	0.71	0.25
S65	0.48	0.24

In general there are not changes in absolute Fmax; there are not important changes from D70 to D80, neither in Fmax nor in Fcurrent. The changes from D70 to S65 however are important since there is a considerable increase in the expected yield and then in MSY. In relative terms the change from D70 to S65 are also important since the current F has been reduced from 0.72 to 0.48. In this case the reduction in F to reach Fmsy is lower.

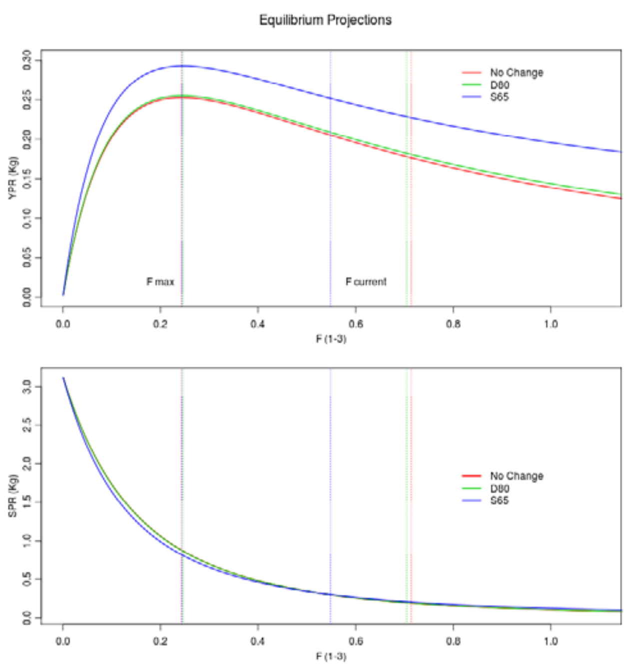


Figure 4. Absolute F vs. YPR and SPR curve for the 3 exploitation pattern

Figure 5 shows the same plot than in figure 4 with F mult instead of Fmean (ages 1-3). Fmult is a straightforward way to evaluate the distance from current F to Fmsy. To express F in relative term allow to comparison when F of reference changes with the change in the exploitation patter. In this plot Fcurrent is set to 1 for the 3 mesh size strategies and relative Fmax represent the reduction needed to reach absolute Fmax

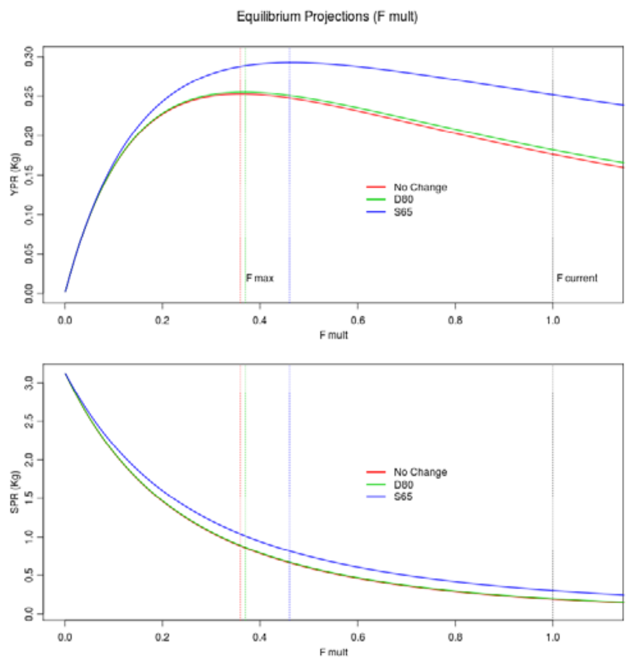


Figure 5. Relative F vs. YPR and SPR curve for the 3 exploitation pattern

2 - Medium term projections

Projections were performed for the 3 different mesh devices starting in 2010. In 2011 it was assume Fsq (mean of last 3 years) without change in mesh size. In 2012 two modifications were imposed: first a change in mesh size (no change, D80 and S65), plus a reduction in effort in order to reach Fmsy in 2015. This yearly effort reduction was estimated for every mesh as: *ratio= (Fmax/Fcur)^(1/4)*; being Fcur the F current after change in mesh size. This gives the following yearly reductions:

Scenario	**Yearly ratio**	**Yearly effort reduction**
No change	0.76	24%
D80	0.77	23%
S65	0.82	18%

After 2015 the F was set constant at Fmax until 2030 to estimate the equilibrium figures. The simulations were performed without TAC constrains and without overshooting. Recruitment was set constant as the mean of 1989-2009 being 80.8 mill.

Figure 6 shows the summary plot of the medium term projections.

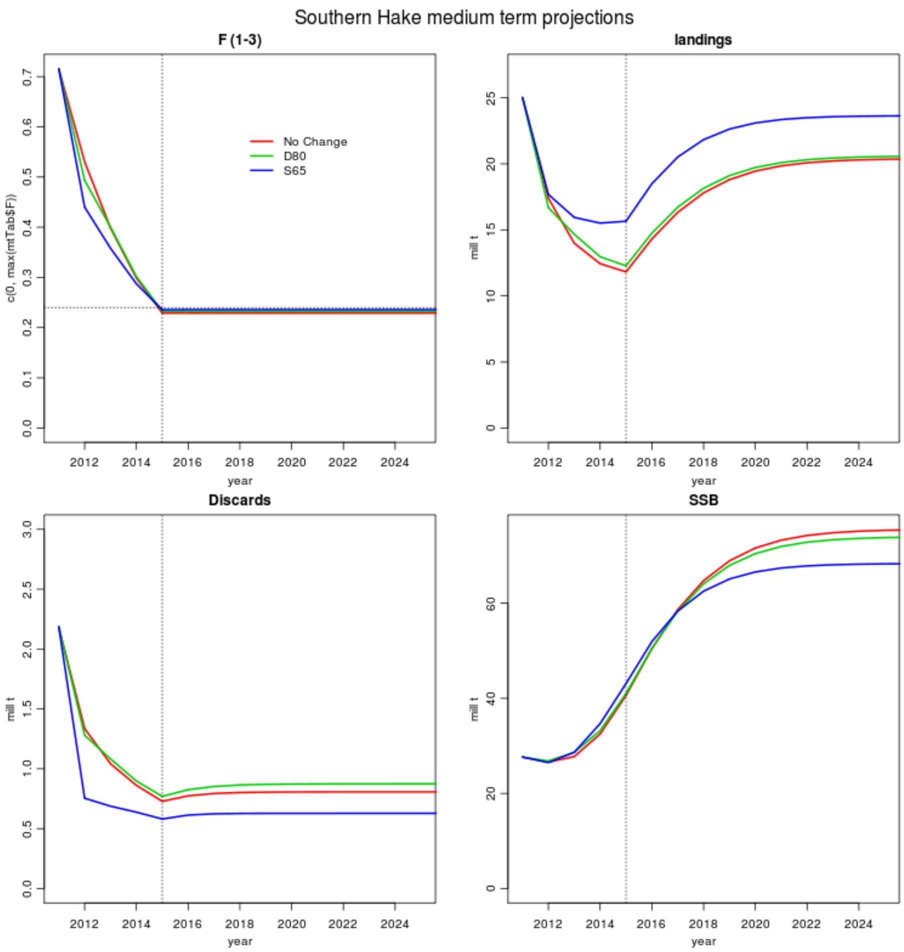


Figure 6. Summary of medium term projections. F (1-3), landings (in mill tonnes), discards (mill tones) and SSB (mill tonnes).

In general there are not differences between "No change" scenario and "D80" scenario. Main differences appear with the "S65" scenario. These differences are:

1. A lower F reduction to reach Fmsy in 2015. 18% instead of 24%
2. An increase in expected landings: 16 Kt instead of 12.5 Kt in 2015; 24 Kt instead of 20Kt in the long term.
3. A reduction in discards. Strong in 2012-2015 and from 0.6 Kt instead of 0.9 Kt.
4. A small increase of SSB after 2017 and long term decrease from 70 to 65 Kt.

Discussion and conclusions

There are some limitations in the work performed. These limitations are caused by the need to implement the changes in mesh sizes within a model that was not developed to do that. Landings and discards are modelled independently in GADGET and, furthermore, all the fleets (trawls, gillnets, long-liners and artisanals) are modelled together in the landings suitability function (logistic). Furthermore we have to consider that there are many different kind of trawls acting in this fishery. These different trawls have different mesh sizes and in this simulation we have assumed that all of them are acting with D70. The minimum legal mesh size is 55 mm for trawlers.

The assumption that all trawlers catch with D70 and that a change to D80 or S65 may change the current exploitation pattern in the direction that was described (figure 3) is not totally wrong if we interpret the results as a relative change in exploitation pattern. This relative change is driven by the ratios estimated (Figure 2). However the results cannot be seen as the expected results if a change to D80 or S65 is implemented to all trawlers since most of them use a different mesh (55 to 80 or more, depending on target species).

Taken these limitations in consideration we may conclude the following:

1. A small increase in mesh size of about 10 mm (like from D70 to D80) does not produce significative differences compared with current state. Bigger increases in mesh are needed if we have to get any kind of improving.
2. If we consider the change to S65 as a relative reference for bigger increases in mesh size we may expect:
    a. a lower reduction in effort to reach Fmsy in 2015,
    b. an increase in landings,
    c. a reduction in discards and
    d. a lower SSB in equilibrium (although higher than historic)
3. To perform a more straightforward analysis of impact of change in mesh size it is needed a model that considers:
    a. separate fleets
    b. join landings and discards for the fleets discarding hake
    c. Selectivity mesh is suggested.
    d. We need to separate the fleets units which do not catch a minimum hake.

Annex 2 Southern Hake stock selectivity simulation

EWG11-07 Hamburg meeting

Yohan Weiller-SWWRAC

Southern hake stock is managed under a recovery plan since 2006. This plan is being revised and a phase of management options evaluation is now carried out. Because of a shortage of time and as RACs are getting involved more and more in long terms management plans revision, SWWRAC has been offered a possibility to help STECF scientist in order to assess the impact of some management options for the future plan. It's in this process that SWWRAC has agreed to help by simulating an increase of selectivity in the fishery and by assessing the role that could have closure zones/period on stock health.

This document present the work being done, showing the results and the methodology used in this study.

1. Selectivity simulation

1.1. Data used

In this study we want to simulate the impact of the use of 70mm with 100mm square mesh panel (1*2m on the top part of the trawl, ASCGG 2004) on Spanish trawlers not targeting pelagic species. The idea is to simulate a change in selectivity corresponding to the effect of a real gear (here it's this 70mm + 100mmSMP trawl, used in the French nephrops fishery to catch less juveniles of hake).

In order to simulate these changes on the fleets, we had the catches in length class from Spanish and Portuguese fleet. We also had, estimated by Gadget model (ICES,2010) an estimation of the total catches in length and age classes. This allowed us to set an age-length key (ALK). In these Gadget model outputs, were also an estimation of total fishing mortality (by age and length). All Gadgets outputs are done with a trimester time step.

We also used growth parameters (VB model, Linf=130, K=0.165), natural mortality (M=0.4 for all ages) and for recruitments the geometric mean from 1998-2008: 78,700 million (ICES,2010). This recruitment was rescaled to 90,578 million to put it as if it enters the stock the 1st January (instead of entering at the end of first and second quarter).

Catches made by the selective gear (70mm+100mm SMP trawl) were used from French selectivity study (ASCGG, 2004).Catch data for Iberian fleet are disaggregated as shown in Fig 1. In blue, level of disaggregation of catches (ICES, 2010) and in red, catches for "baca" gear and "jurelera" gear, obtained by the relative % of hake catches from both gear compared to the OTB fleet one (Castro et al, 2007).

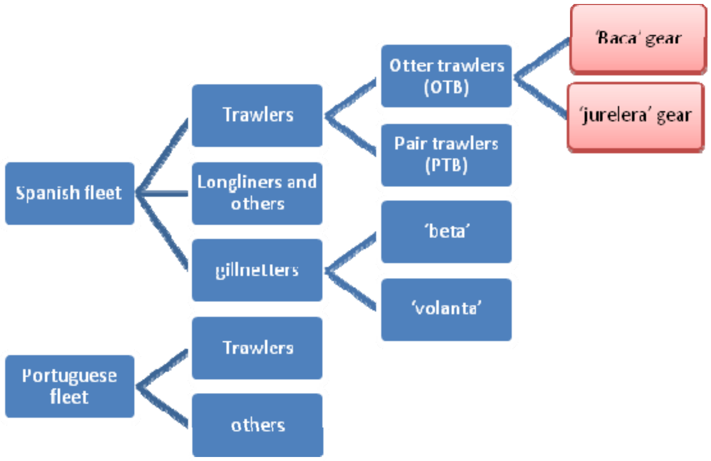


Fig. 1 fleet catches disaggregation

1.2. Methodology used in the selectivity adjustments

We wanted selectivity simulation to be as close as possible to a real effect. That is why we simulated the selective effect of the new gear to real fleet catches. As we didn't have any level of disaggregation for Portuguese trawlers fleet in order to separate the ones targeting pelagic species from the one targeting demersal ones, we only simulated the new selection pattern on some Spanish trawlers. We decided to simulate trawl selectivity change on the "baca" and "pareja" (pair trawlers) trawl fleet. These two fleets are the ones that catch the higher % of hake compared to the "jurelera" gear. In order to disaggregate within the OTB catches the ones corresponding to the "baca" gear and the ones corresponding to the "jurelera", we used their respective catch % of hake (data from IBERMIX project report, referred to as Castro et al, 2007). For discards, we disaggregated them into the different fleet proportionately to their respective effort (in kW.number of days). We also simulated the effect of using the selective gear on all Spanish trawlers.

Catch diagrams from Iberian Peninsula's fleets used to simulate selective curves are fleets mean catches diagrams 2005-2009 in order to minimize the impact of a year. To simulate catches made by the different Iberian Peninsula's fleet, we adjusted a logistic model with the least square method to the catch ratio $\frac{\text{Catches by selective gear}}{\text{Spanish fleet catches}}$.
As those catches cannot be directly compared, logistic model has an asymptotic value that is not 1. Logistic model is a function of length: $F(l) = \frac{a}{1 + e^{-b(l-c)}}$ with **a, b, c** parameters estimated with the least square method. Then logistic model F(l) are rescaled to 1 dividing by **a**: we obtain S(l).

Selectivity with logistic model and residuals from the least square adjustment:

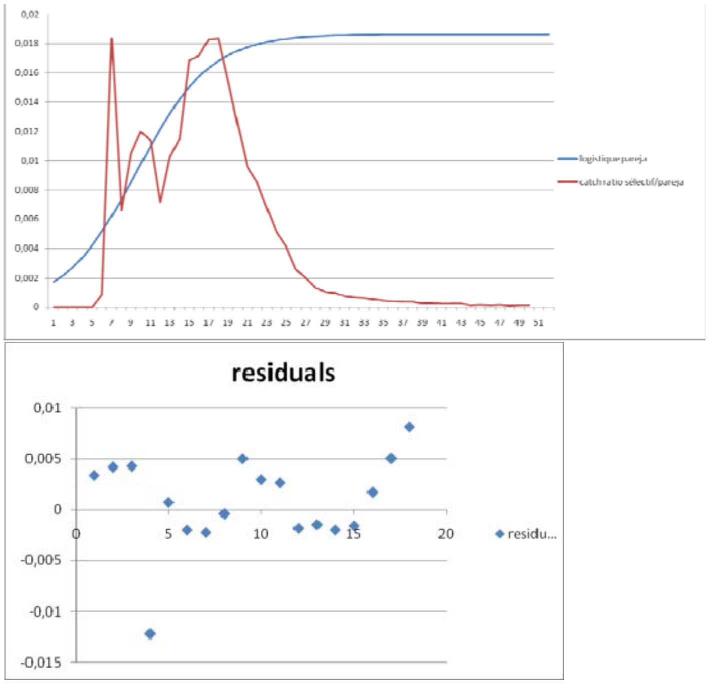


Fig. 2: Logistic model adjustment for “pareja” fleet.

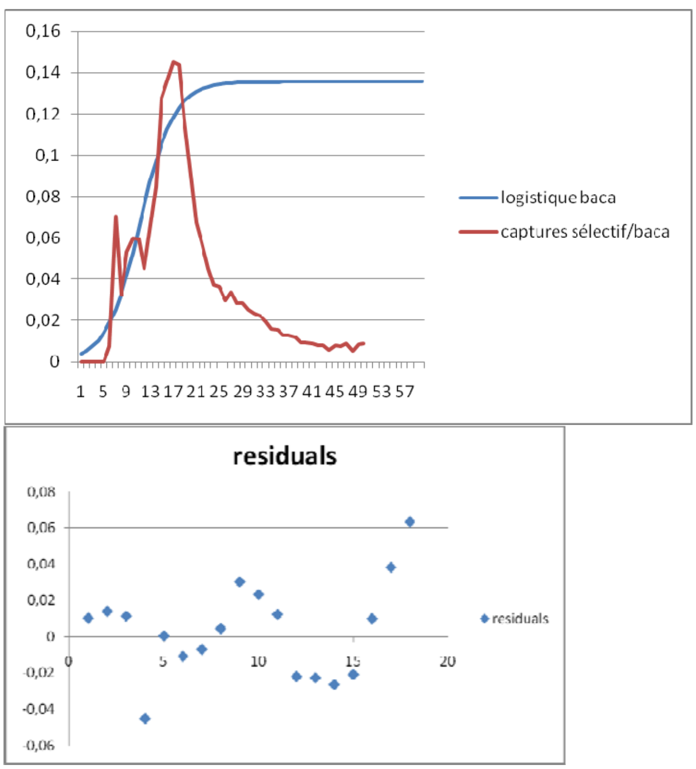


Fig. 3: logistic model adjustment for "baca" gear

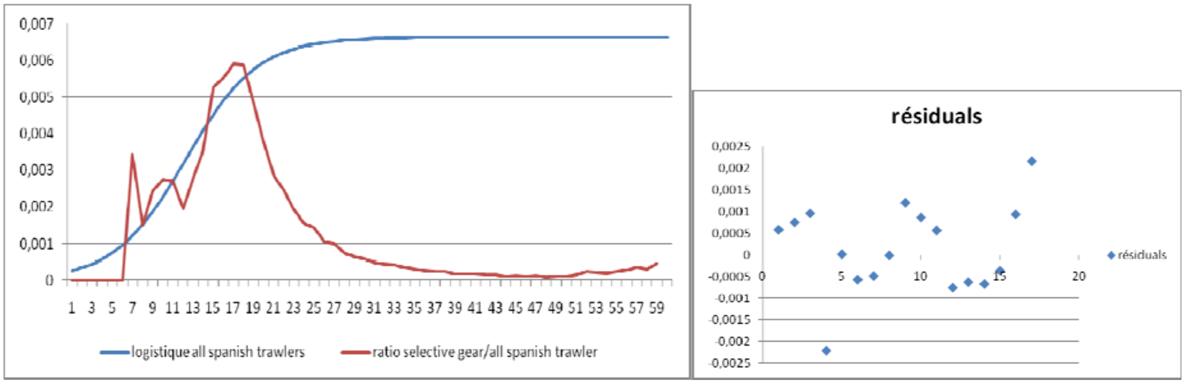


Fig. 4 : logistic adjustment for all Spanish trawlers

We expect the ratio to remain at an asymptotic value for high lengths as selectivity effect of the more selective gear disappear. But as length increases, the ratio decreases. This can be explained by the small number of large fish presents in the catches of ASCGG program as it was conducted on “la grande vasière” area which is a nursery for hake. That can explain why the ratio decreases when L>20cm: the relative proportion of larger hake decreases compared to Spanish grounds. That’s why we made the adjustment of the logistic model on sizes under 21cm.
If the observed ratio decrease is due to a lack of large hakes in the ACSGG program’s experimental zone, the selectivity adjusted may be undersetimated. Indeed, if a higher distribution of bigger hakes would have been observed in the experimental zone (“la grande Vasière”), we could expect that the selectivity ratio would have kept increasing for lengths >20cm. A higher range of sizes would have then benefited from selectivity effects.
For discards, we disaggregated them into the different fleet proportionately to their respective effort (in kW.number of days).
Fishing mortality used in all the simulations is a mean of the Gadget evaluated mortality over the 4 semesters of the year 2009. When we had the catches of each fleet, we obtained their respective mortality F_{fleet} by multiplying total mortality by the ratio $\frac{Cfleet}{Ctotal}$. Once we have these F_{fleet} we can simulate the effect of the new selective gear: $F_{fleet}^{*} = F_{fleet} * S(l)$. We then have a new F* for the entire stock. All these data are in length class.

1.3. Methodology used to assess impacts

1.3.1. Y/R at equilibrium

In this part we present the methodology and results of selectivity increase impacts on yield per recruit (Y/R) in function of different scenarios corresponding to different selection patterns.
This simulation has been conducted in Xcel. We enter population biological parameters (VB growth model, natural mortality and length-weight relationship parameters) and fishing mortality (F*) corresponding to the scenario we want to test.
Then we calculate with the Von Bertalanffy growth model the time it takes to grow from length class l to length class l+1:

$\Delta t(l) = t(l+1) - t(l) = \frac{1}{K} * \ln\left(\frac{Linf - l}{Linf - l + 1}\right)$.

In order to have Yield per recruit analysis, we apply the total mortality (mf*F*+M) to each length class. The number of individuals of the lth length class is the following:

$N(l) = N(l-1) * e^{-(mf*F+M)*\Delta t(l)}$

Then we calculate the weight corresponding to each length class:

$w(l) = a * (l+0.5)^b, a = 0{,}00659 \text{ et } b = 3{,}01721 \text{ for weight in grammes}$. **a** and **b** being length-weight model parameters (ICES,2010).

From this we can obtain the Yield from each length class:

$Y_l = W(l) * \left(\frac{mf*F}{mf*F+M}\right) * (N(l) \quad N(l-1))$

Summing over the length those Y_l, we have the total yield per recruit corresponding to the fishing mortality mf*F* applied. We then simulate for different values of mf (effort multiplier) and we also evaluate the F_{max}* corresponding.

1.3.2. Prospective catches and Y/R

In order to realize what would be the impacts in the short term, we simulated the effect of selectivity improvement at constant recruitment rate. We simulate the evolution throughout years of Y/R and CPUE in the different scenarios of selectivity. In order to run such simulation, we first had to transform length class data into age class data. In order to do that, we produced an age-length key (ALK) from the stock abundance estimation (Gadget 2009 output) in age and length classes.

Using the ALK, we can transform F* that were in length class into F* in age class and run the simulation. We also used Gadget 2009 stock numbers evaluation of the beginning of the first semester to begin the simulation. As said before, the simulation is run with a constant recruitment for the age 0 class, being the geometrical mean from 1998-2008 rescaled to be entered 1st january.

We enter F* corresponding to the different selectivity scenarios we want to test, mean weight at age and 2009 stock numbers evaluation and we can then evaluate stock numbers along the years at F* constant. For a year y and age a:

$N(y|a) = N(y-1|a-1) * e^{-(F(a-1)+M)}$

From the stock numbers at age we can determine the catches:

$Y(y|a) = W(a) * N(y|a) * \frac{F(a)}{F(a)+M} * \left(1 - e^{-(F(a)+M)}\right)$

We can then have the global yield for a year by summing over the ages all the Y(y|a).

1.4. Results

1.4.1. Scenario simulated:

1) The use of selective gear in “baca”+“pareja” fleet and all Spanish trawlers.

2) We simulated the effect of no fishing mortality on fish under minimum landing size (MLS) and no fishing mortality on fish of age 0 and 1.

3) We also simulated two others scenarios called F2009* and F2009**. For these scenarios, we applied on the total fishing mortality (F 2009) a theoretical change: a shift of the entire selection pattern of a proportion which is the same than the one we simulated on Spanish trawlers. This scenario called F2009* corresponds to a selective improvement of all the fleets at a same level than the one applied to Spanish trawlers. We also simulated a scenario of the same type where we double this selectivity improvement. This scenario is called F2009**. These two scenarios are, here again, really theoretical but they correspond more to a real selective improvement, even if we don't know what type of gear needs to be used in each fleet in order to achieve this change.

1.4.2. Results at equilibrium

All scenarios tested results shown in fig. 5 under:

Fig. 5: Y/R (in g) in function of mf

	Fbar15-80 msy	Y/R (mF=1)	Y gained in %
Y/R status quo	0,254	156,6	0
Y/R baca	0,254	156,7	0,05
Y/R pareja	0,255	157,3	0,43
Y/R all spanish trawlers	0,256	159,4	1,80
Y/R baca+pareja	0,255	157,4	0,48
Y/R F2009*	0,260	166,0	5,98
Y/R F2009**	0,263	172,2	9,93
Y/R no catch of under MLS	0,277	209,8	33,96

Table 1: Y/R and Fmax evaluation for the different scenarios tested

We see here that the most realistic scenario (implement the selective trawl: 70mm+100mmSMP) on fleet not targeting pelagic species, has a really low effect : 1g/R more than the status quo scenario.
On the other hand increasing selectivity can be really interesting for this stock as, for example, if we simulate the no catch of individuals under MLS, yield can be improved by 34%. This is not related to any technical measure but just show that serious improvement can be reached by decreasing mortality on small individuals.

1.4.3. Prospective impact

Here we simulate the evolution of the catches and Y/R at constant R and F
Results of selective scenario 1 to 3 compared to status quo are shown in fig 6 to 8 below.

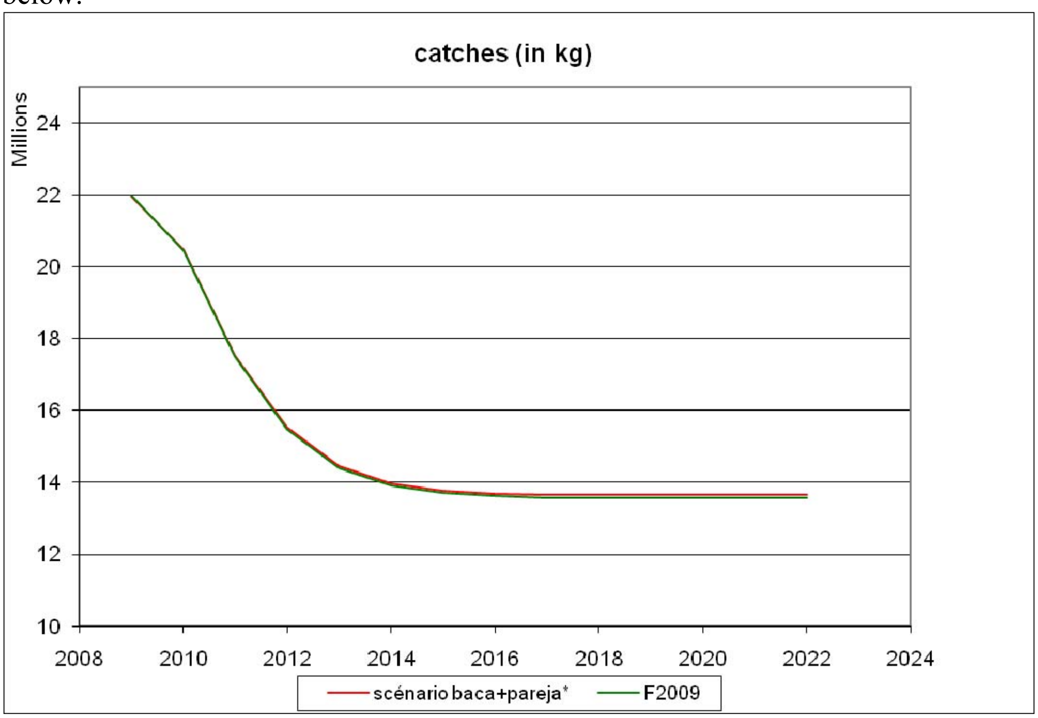


Fig. 6: selectivity effects on catches of scenario 1)

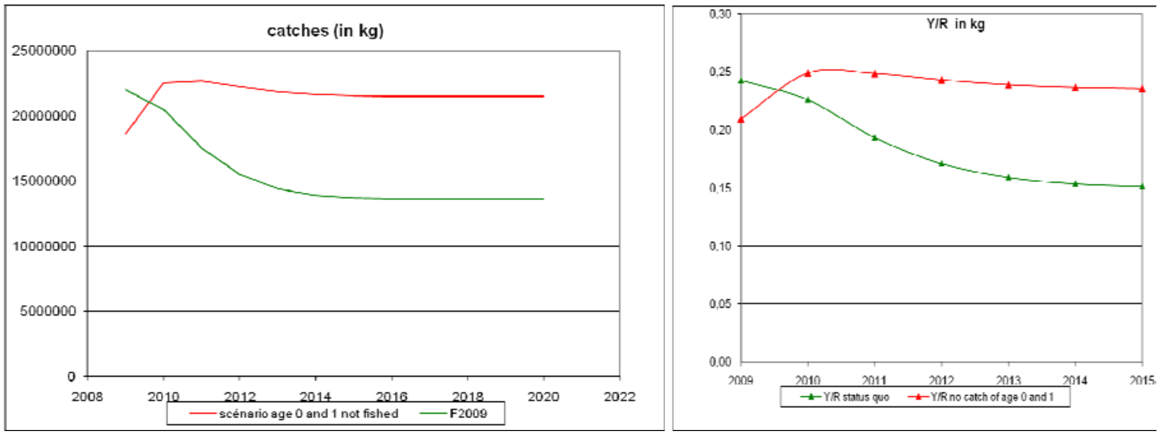


Fig. 7: Effect of non catching age 0 and 1 on catches and Y/R evolution

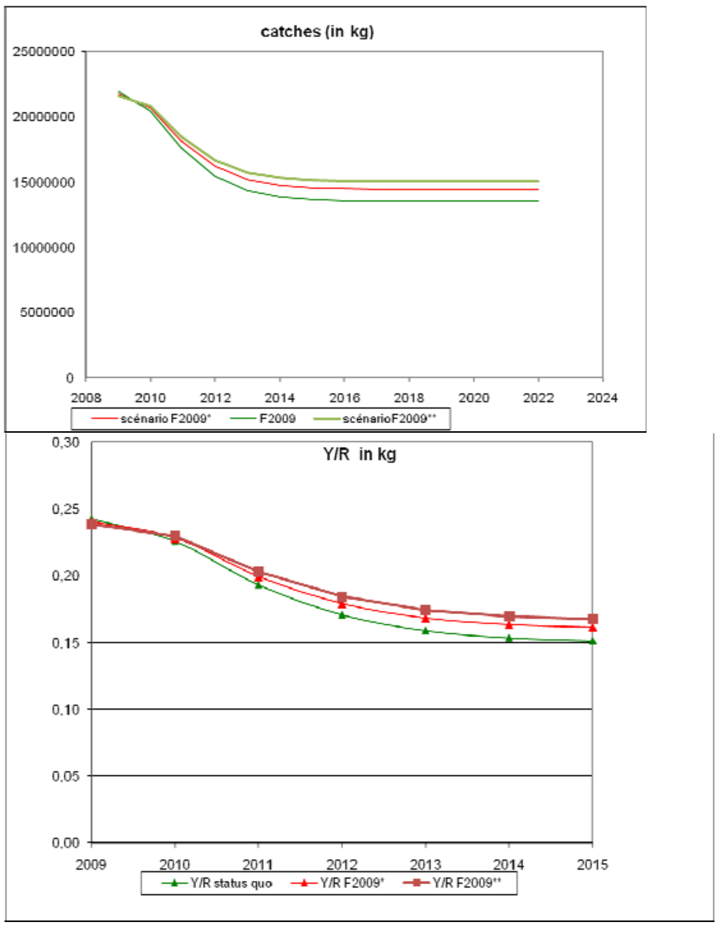


Fig. 8 Efects of Scenarios F2009* and F2009** on catches and Y/R evolution

1.5. Conclusion-Discussion

Effects on southern hake stock from selectivity improvement simulations (through the selective gear tested) are not important. This means that using 70mm trawl with

100mm SMP for “baca” and “pareja” fleet wouldn’t have a big impact on the stock. These results have to be discussed as several points of the study limit its results:

- For trawlers, the selection pattern used to simulate better selectivity is the one from ACSG program which experimental trawls were held on the “grand vasière area” which is a hake juvenile concentrated area. As said before, this could have leaded us to an underestimation of the selective effect when adjusting logistic curves.

- Regarding gillnetters, one of the ToR was to simulate the impact of mesh increase but we did not have time to lead such study as we couldn’t use logistic model for such simulation.

- We didn’t simulate any selective improvement on Portuguese fleets as we didn’t have disaggregated catch data for those fleets in order to apply selectivity on trawlers that don’t target pelagic species.

- We used as fishing mortality an evaluation from Gadget model outputs which is not the exact fishing mortality (see Gadget model).

Results from theoretical scenario show that a great improvement can be reached by decreasing fishing mortality on lower ages. Selectivity studies should be conducted in this fishery in order to assess which type of gear could provide such type of results. Bearing in mind that most of those trawlers target pelagic or smaller species (such as mackerel, horse mackerel, blue whiting) which limits the possibility of mesh increase in trawls.
Another option that could lead to decrease fishing mortality over small individuals of hake could be closures. We then have to investigate if hake juveniles are aggregated. We can also investigate the amount of overlapping of hake juvenile’s concentrated areas and other trawl target species distribution.

2. Closure zones/periods

2.1. Portuguese scientific survey results

Regarding the effect of closure period/zones on Southern hake stock, because of time and geolocalised catches at length data scarcity, we couldn’t evaluate nor simulate the direct effect of closing zones/periods on the stock. The only data available was scientific survey data. Regarding Spanish ones, IEO produced an interesting and complete WD where they investigate the preferential recruitments zones for Hake over the Cantabrian shelf and the overlap with other trawl target species (Punzon et al, 2011).

We used Portuguese scientific surveys catch data (P-GFS October surveys from 2003 to 2010), to see if some zones concentrates hake juveniles and also to see if other species overlaps with these zones.

Table 2: % of the total catches in hauls of more than 200 <20cm hakes (18,6% of total hauls) and in the 10% hauls with highest <20cm hake numbers.

		HKE <20 cm	HKE > 20cm	HOM nÂº/h	WHB nÂº/h	MAC nÂº/h	MAS nÂº/h	all pelagics
	total catches	99030	86358	542958	1991541	272791	53497	2860787
Hke<20	18,6% of highest trawl ca	79791	32921	227600	755311	77041	2754	1062705
	%of total	0,81	0,38	0,42	0,38	0,28	0,05	0,37
	10% of highest catches	62705	20609	198714	346451	57276	1001	603442
	% of total	0,63	0,24	0,37	0,17	0,21	0,02	0,21

Regarding concentration of hake juveniles:

This table show that in the 10% hauls with the highest number of small hake (<20cm), we have 63% of the total catches of hake juveniles (<20cm). This show that hake juveniles are aggregated in some areas and that they are concentrated. It shows as well that creating closed areas localized on these zones could be of interest as these zones are not too extended.

Regarding other species overlap:

Regarding the overlap with other species, those hake juveniles' high concentrated hauls have a proportion of other target species above the average. Indeed, for the 10% of trawls with the highest number of <20cm hake, all the other target species are represented in a % higher than 10% of their total catch.

This means that those hake juveniles' high concentrated zones are also preferential fishing zones for the main trawler fleet.

Figure 9 to 14 present the repartition of those species along Portuguese coast synthesizing all hauls from 2003 to 2010. They permit to identify 4 principal areas.

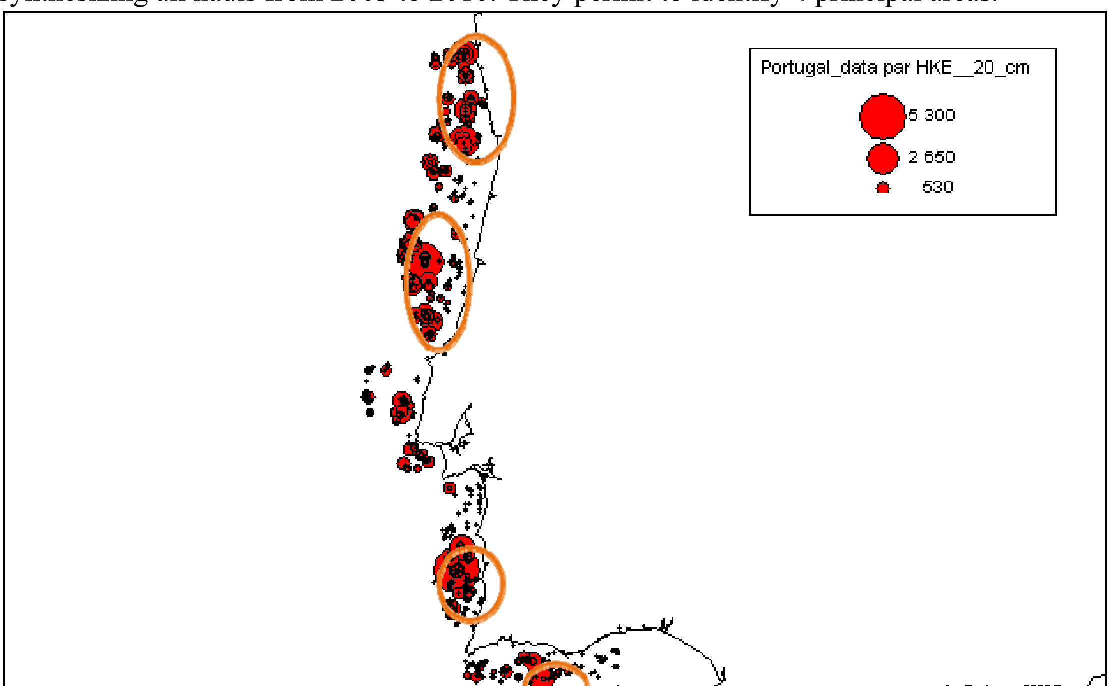


Fig. 9: <20cm hake distribution in number per hour (P-GFS survey from 2003-2010) with the main concentration areas identified along the years.

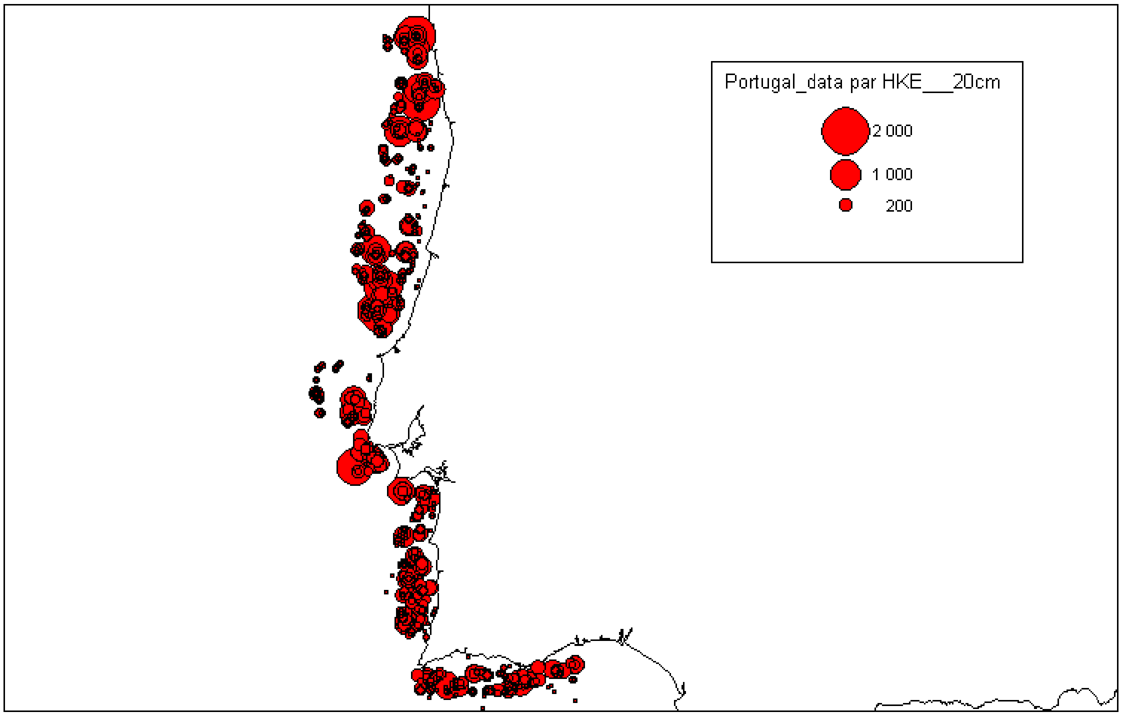


Fig. 10: >20cm hake distribution in number per hour (P-GFS survey from 2003-2010)

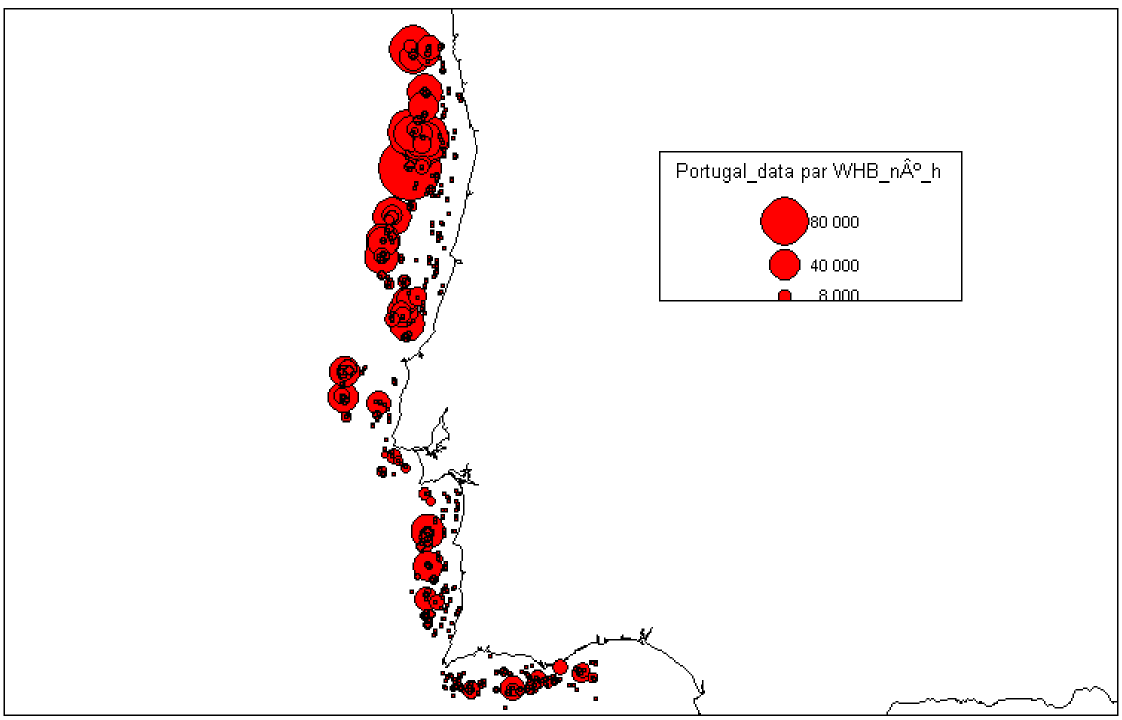


Figure 11: blue whiting distribution in number per hour (P-GFS survey from 2003-2010)

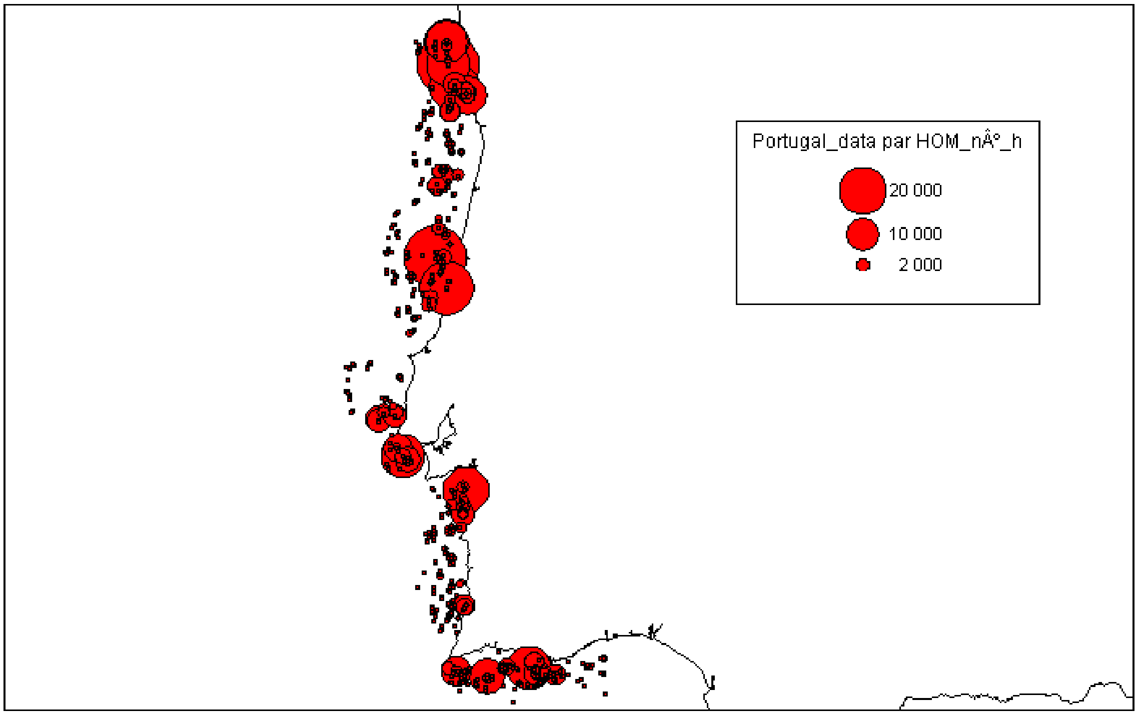


Figure 12: horse mackerel distribution in number per hour(P-GFS survey from 2003-2010)

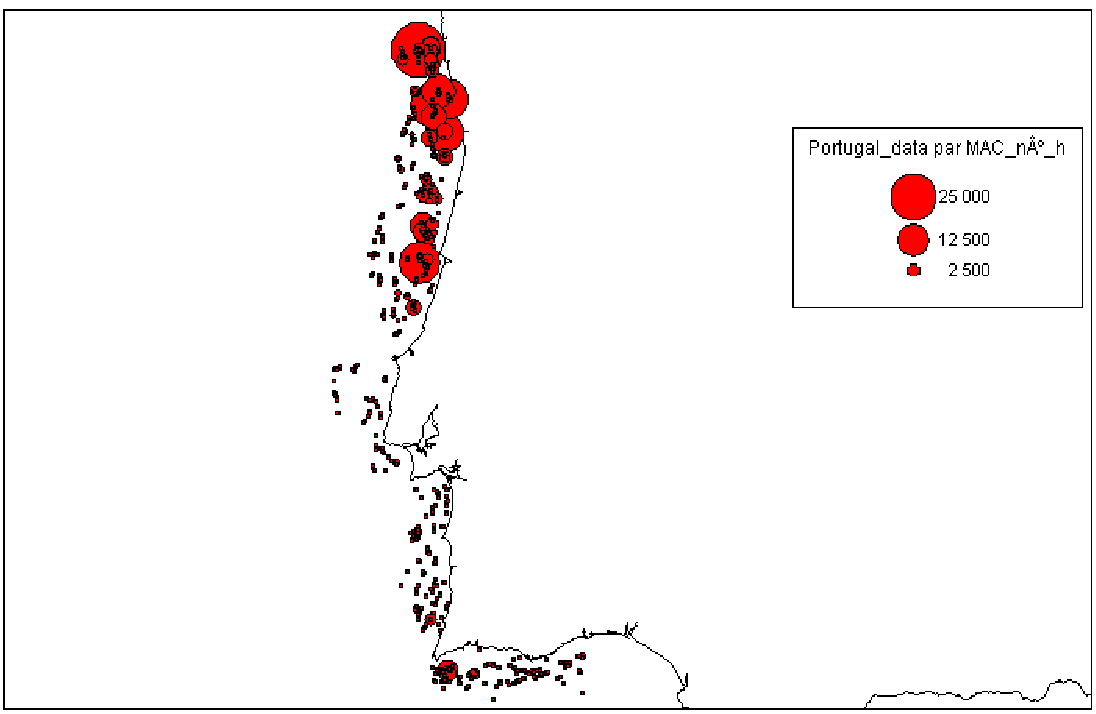


Figure 13: Mackerel distribution in number per hour (P-GFS survey from 2003-2010)

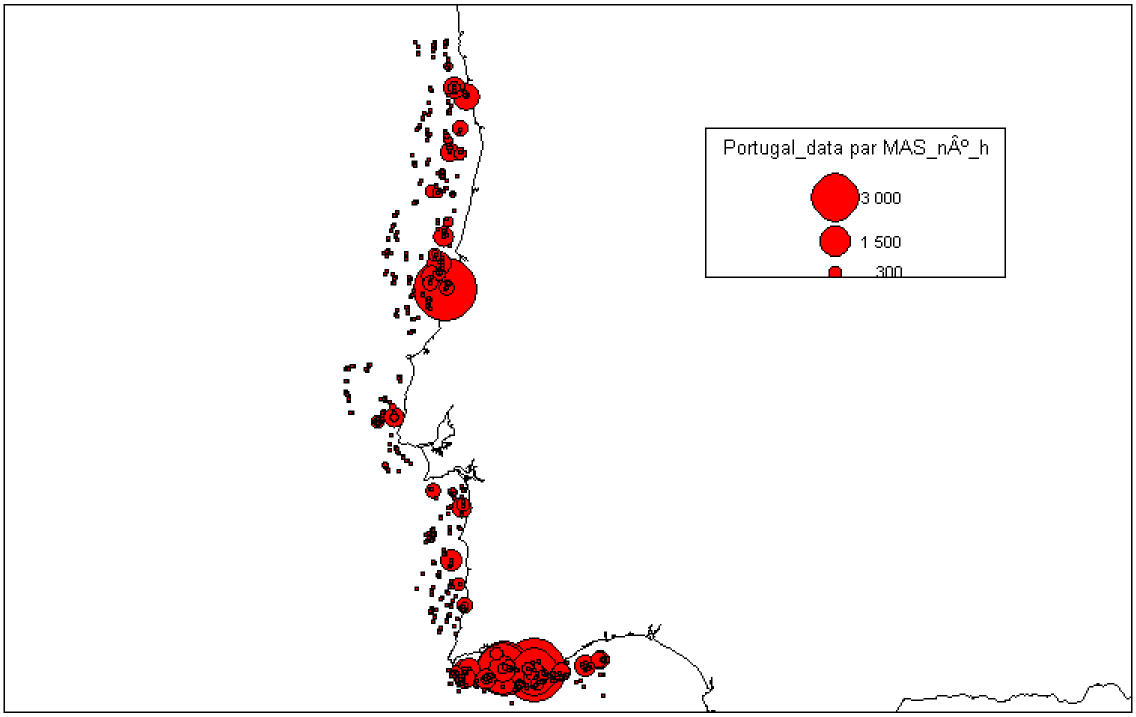


Figure 14: Shrub mackerel distribution in number per hour (P-GFS survey from 2003-2010)

In those next figures 15 to 18 we represented the overlap of trawlers main target species and juvenile hakes distribution as an illustration of what explored in table 2.

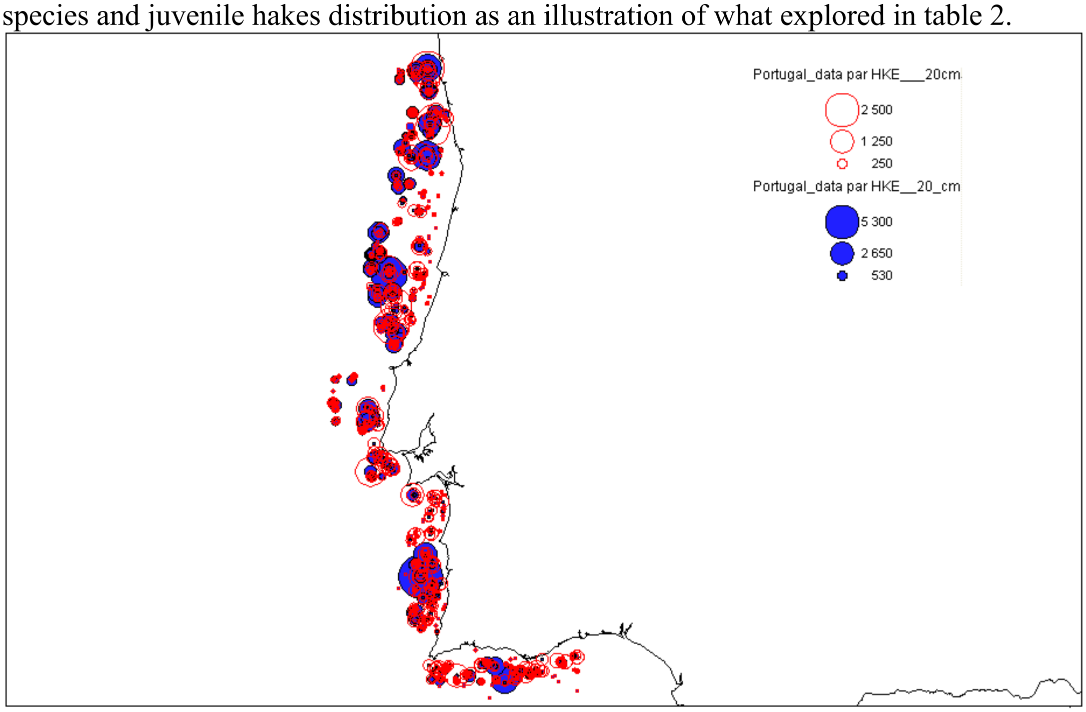


Figure 15: Distribution in number per hour of <20cm hake in blue and >20cm hake in red (P-GFS survey from 2003-2010)

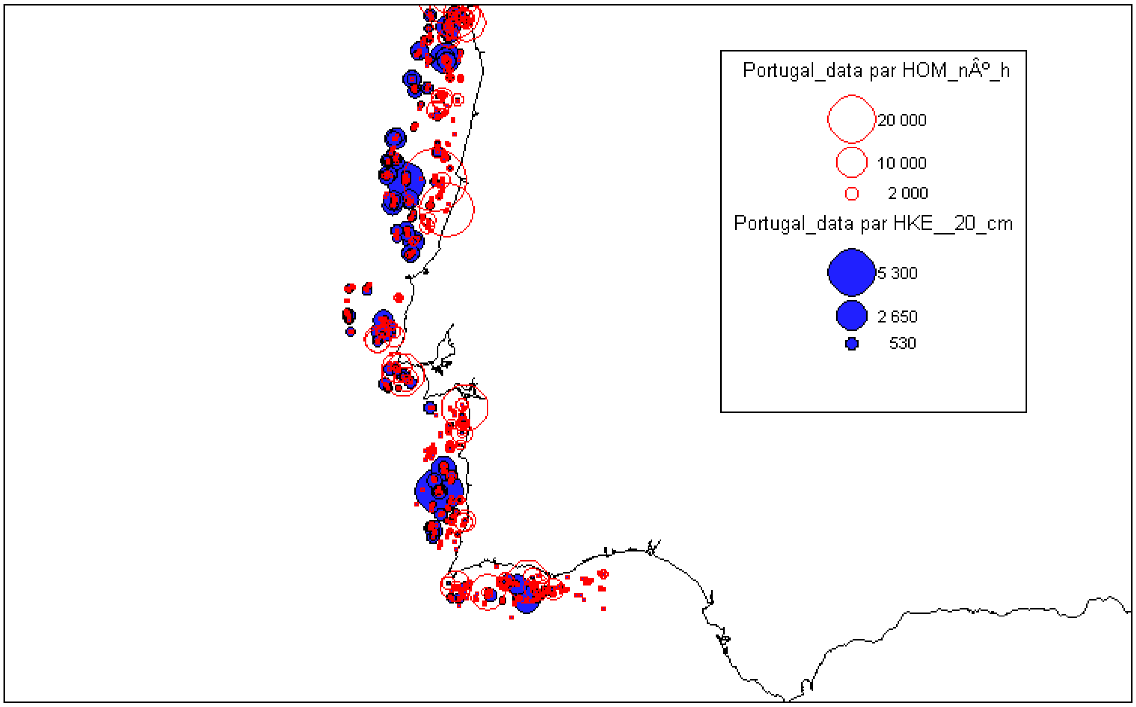


Figure 16: Distribution in number per hour of <20cm hake in blue and horse mackerel in red (P-GFS survey from 2003-2010)

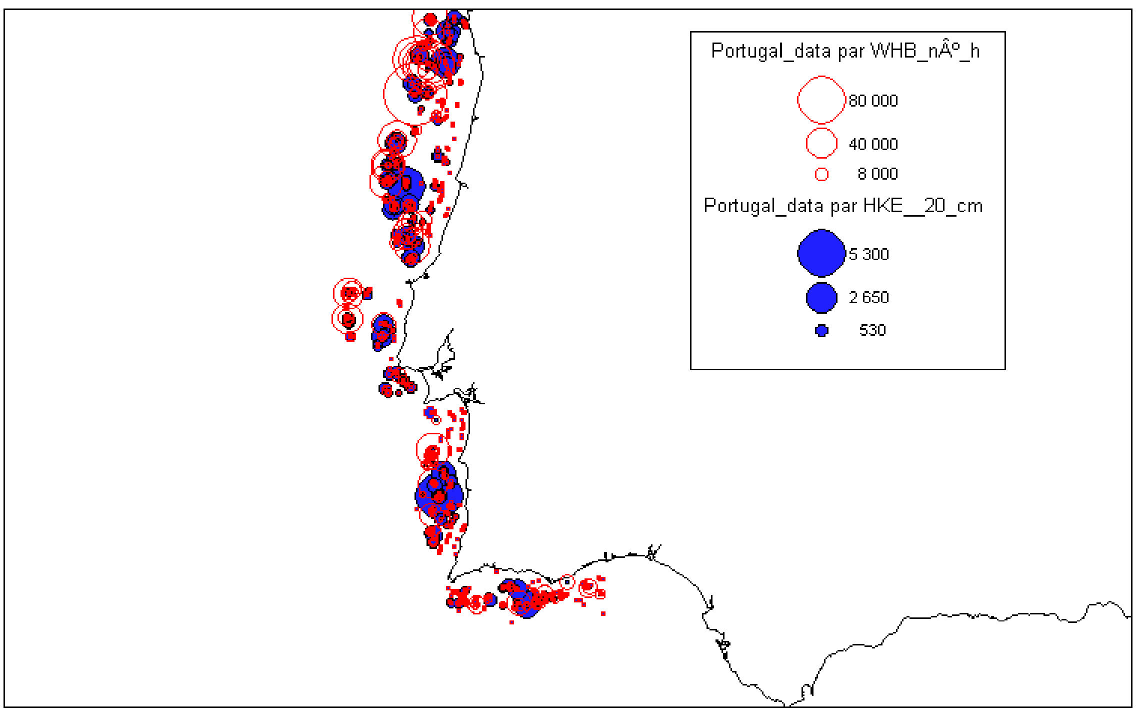


Figure 17: Distribution in number per hour of <20cm hake in blue whiting in red (P-GFS survey from 2003-2010)

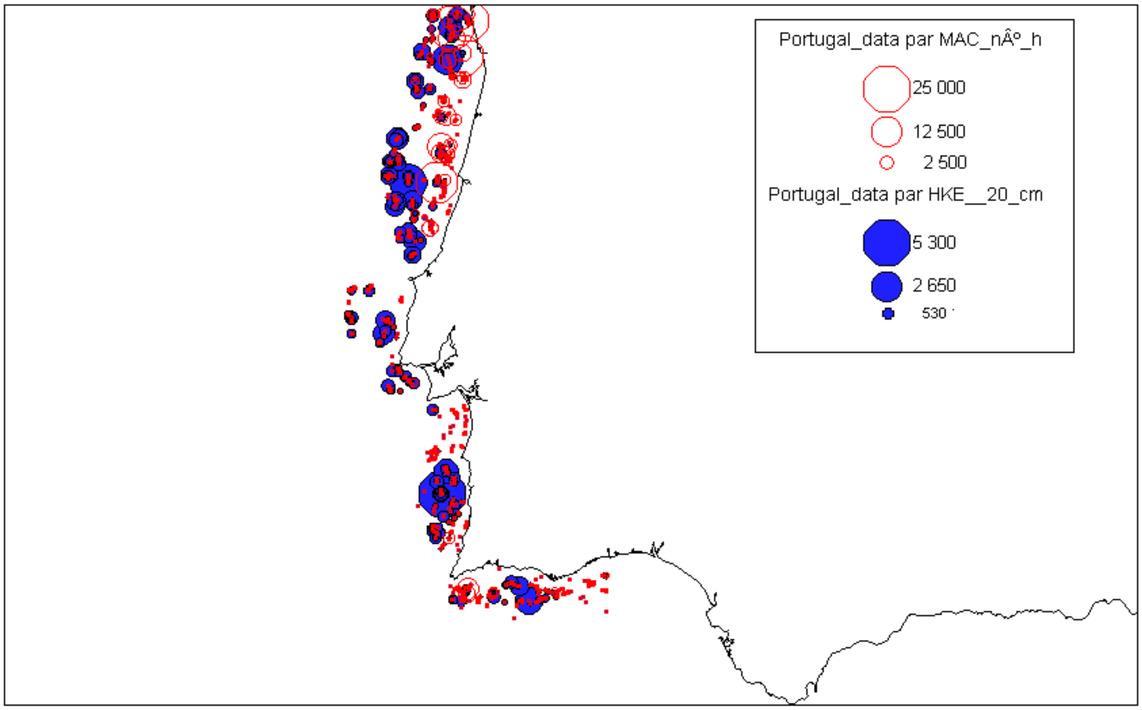


Figure 18: Distribution in number per hour of <20cm hake in blue and mackerel in red (P-GFS survey from 2003-2010)

It could be interesting to compare on the same map, the highest concentrated hauls of <20cm hake along with the highest concentrated hauls of the other specie we want to test the overlap. It could permit to have a map easier to read and interpret.
The data used in this study come from October Portuguese. The fact that the survey is conducted every year in October can be a problem to estimate the importance of hake recruitment as it is variable in time.
It would be interesting to complement this study with knowledge from the sector and geolocalised catches from professional fishing boats. It could help assessing the possibility of implementing closures for hake juveniles' protection without impacting to much trawlers that target pelagic species.

2.2. Review of closed areas and biological impacts.

Not a large review of all scientific literature regarding closed areas impacts on fisheries has been leaded but:

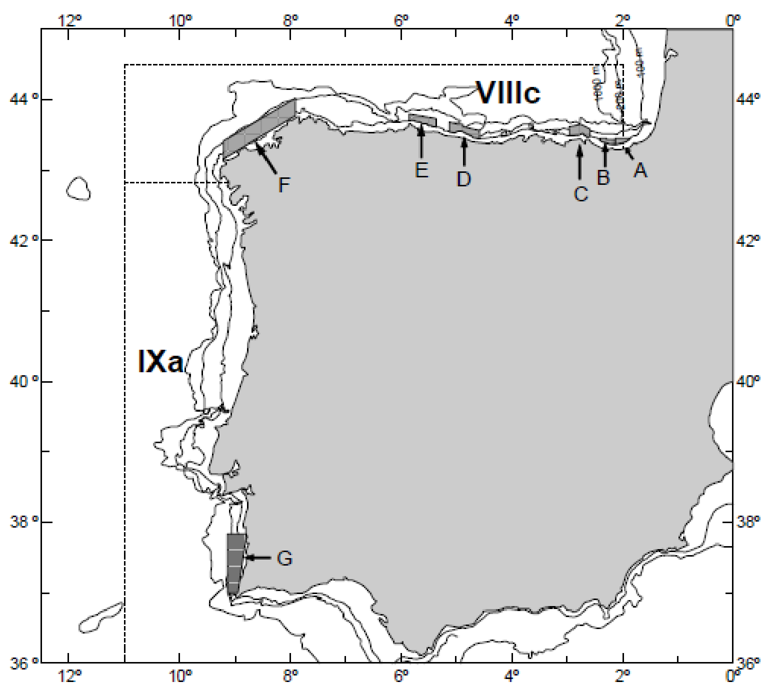
- It already exists (since 2001) several protected areas along Iberian Peninsula coast (figure 19 below) to which we can ad that trawling is forbidden in Spain in depths lower than 100m and in Portugal within 6 miles from the shore. There are no studies that evaluated the effect of any of those closed areas on hake.

- Few studies have evaluated quantitative benefits of closed areas on similar gadoid species but findings are:

Regarding Trevose box (3 Ices squares closed to trawlers and gillnetters with mesh size >55mm for the begin of the year) in the celtic sea that was created in order to protect Cod spawning aggregates and decrease the global fishing mortality on Cod.

No quantitative effect of the box has been evaluated even if a higher number of larger individuals appeared in the zone (ICES, 2007).

Regarding northern Hake boxes that were created in 2001 (reg 1162/2001) with special gear regulation: the aim of such measure was to decrease fishing mortality on juvenile hakes in order to help the recovery of the stock. Since then, the stock has recovered and its SSB is close to the target of its recovery plan (ICES 2007). Furthermore fishing mortality over age 0 and age 1 is estimated to have decreased since 2004. The only problem is that none of those improvements in stock health can be attributed to a particular measure that was taken. Here again there is no quantitative evaluation of the effect of the closure to some gears. This doesn't mean that closing certain sensible areas to certain type of gear having a big impact on juveniles has no effect, it does mean that we cannot quantify how much the measure is responsible for the recovery (STECF 2007).



Spain:

A - Fuenterrabía - Trawl prohibited all year - BOE n.183, 1st August 2001, 15024

B - Guetaria - Trawl prohibited from 1st September to 31st December - BOE n.183, 1st August 2001, 15024

C - Bermeo - Trawl prohibited all year - BOE n.183, 1st August 2001, 15024

D - Llanes - Trawl prohibited all year - BOE n.183, 1st August 2001, 15024

E - El Callejón and La Carretera - Trawl prohibited from 1st September to 31st March - BOE n.183, 1st August 2001, 15024

F - La Coruña-Cedeira - Trawl prohibited from 1st October to 1st January - BOE n.183, 1st August 2001, 15024 and Reg. CE 724/2001

Portugal:

G - Milfontes-Arrifana - Trawl prohibited from 1st December to last day of February - Reg. CE 850/98

Figure 19: Existing Spanish and Portuguese closed areas

References:

ASCGG. 2004. Rapport final du programme d'Amélioration de la Sélectivité des Chalutiers du Golf de Gascogne.

ICES, 2007. Report of the Working Group on the Assessment of Southern Shelf Demersal Stock (WGSSDS) 25 june-7 july 2007, ICES Headquarters, Copenhagen, ICES CM 2007/ACFM:28, 675p.

ICES. 2010. Report of the Working group on the assessment of Southern Shelf Stocks of Hake, Monk and Megrim. CM 2010/ACFM: 02.

Castro et al, 2007.Identification and Segmentation of mixed-species Fisheries operating in the Atlantic iberian peninsula waters (IBERMIX project). (Contract Ref.: FISH/2004/03-33).260p.

Punzón et al. 2011. Hake recruitment areas distribution and overlap with species target for the trawl fleet in the Northern Spanish shelf. Working Document ICES - STECF- EWG 11-07. Hamburg (Germany)

STECF 2007, Evaluation of closed area schemes (SGMOS-07-09) subgroup on management of stocks, of the scientific, technical and economic committee for fisheries (STECF), Ispra 2007. SEC (2007)

Annex 3 Hake recruitment areas distribution and overlap with species target for the trawl fleet in the Northern Spanish shelf

Working Document presented to the STECF
EWG "Multi annual management plans-part II"
Hamburg, 20-24 June 2011

A. Punzón[1], A. Serrano[1], F. Velasco[1], S. Cerviño[2]
(1) Instituto Español de Oceanografía, Centro Oceanográfico de Santander
P.O. Box 240, 39080 Santander, Spain
(2) Instituto Español de Oceanografía, Centro Oceanográfico de Vigo
Subida a Radio Faro, 50-52 36390 Vigo, Spain

Introduction

A recovery plan for the Southern Stock of hake was enforced by the EU in 2006, in June 2010 the STECF organized a first EWG to review the management options of several stocks under recovery plan, a new meeting is scheduled for June 2011, where the objectives are

- Clarifying the objectives of the management plan - what are the objectives of the national administrations and sector concerned?
- Defining a baseline (biological and socio-economic goals) for the assessment of options and scenarios.
- Defining the "no-change" management regime and its consequences.
- Discussing and selecting a number of options to be assessed and compared national administrations and the sector have a key role proposing options, whereas scientists advise on consequences of different options.
- Identifying the basic methodology to be used - scientists need to decide on outstanding studies required, impact assessment models to be used, define indicators and performance 'measures, check the biological reference points and define how the simulation work will be checked.

In the present working document the information on hake recruitment areas for the Northern Spanish Shelf (Galician Shelf and the Cantabrian Sea), and options for protection and conservation of hake recruitment in relation to the activity of the Trawl Fleet in the area studying the distribution of hake recruitment areas and its coincidence with other species targeted by the commercial trawlers in the area, mainly adult hake, blue whiting (*Micromesistius poutassou*), horse mackerel (*Trachurus trachurus*), both species of megrim (*Lepidorhombus whiffiagonis* and *L. boscii*) and both anglerfish species in the area (*Lophius budegassa* and *L. piscatorius*). Therefore data used will be the results of the Scientific bottom trawl surveys carried out annually in the area by the IEO, considering the catches of hake recruits, and individuals larger than market size for the commercial species: hake ≥ 27 cm, megrims, blue whiting, horse mackerel ≥ 15 cm, and anglers ≥ 30 cm.

Material and methods

The data dome from IBTS Cantabrian Demersal Surveys carried out every year between September and October (Sánchez & Serrano, 2003). The methodology used is the standard in the IBTS for the western and southern areas (ICES, 2010), 30 minutes hauls following a random stratified sampling design with five geographical sectors (Figure 20: MF. Miño-Finisterre, FE. Finisterre-Estaca de Bares, EP. Estaca de Bares - Peñas, PA. Peñas-Ajo, AB. Ajo-Bidasoa). Hauls between 30 and 70 m and deeper than 500 m are also carried out every year, although they are not considered in the calculation of stratified abundance indices (Cochran, 1971; Grosslein y Laurec, 1982), but are used to study and define depth distribution of the species studied. To study the overlap between hake recruits and target species for the trawl fleet the approach used is to compare the catches in the survey of target species (hake ≥ 27 cm, horse mackerel, blue whiting and megrims ≥ 15 cm, and anglers ≥ 30 cm) in nursery area hauls (with ≥ 100 recruits) and other hauls with hake and catches of the corresponding species by means of box-plots with notches that extend to ± 1.58 IQR[1]/sqrt(n) that provides a proxy for the 95% confidence interval for the differences between the two medians compared (Chambers et al. 1983, McGill et al. 1978), if the notches do not overlap there is a 95% confidence interval that both medians are different. In the case of both anglerfish species data have been compared in weight terms given that their importance is much evident in weight than in number.

Results:

Recruitment areas variability

According to the results presented in Figure 21-Figure 23 the main nursery areas of hake in the Northern Spanish shelf between 1990 and 2010 have been located, from Southwest to northeast in:

- Rias Bajas
- A Coruña
- Ribadeo
- Peñas
- Guetaria

These are summarized in Figure 24. Although the nursery areas can be considered more or less defined in the time series, they are highly variable in intensity and extension. Clearly A Coruña nursery area is the one that appears every year and the more conspicuous, especially in years with high recruitment. The presence and strength of the rest of the areas vary from year to year. In the last years 2005 – 2010, A Coruña and Rias Bajas have abundances larger than during good recruitments in the 1990s (i.e. 1994-1997). But it is clear that in years of good and very good recruitment, when the nurseries areas increase also the area occupied, as in 2005 o 2009 (shown in a different scale to facilitate the visualization of the rest of the maps).

It is important to bear in mind that hake is a batch spawner (Pérez and Pereiro, 1985, Murua et al., 1998) and spawn and recruitment can be very variable in time and duration, while the samplings performed in the surveys are carried out during a relatively limited period in September-October, period that not always coincide with the peak of recruitment in the different areas. For example recruitment in 2007 was apparently focused in the Rias Bajas but in this year the Survey was done from 11th Oct. to 9th Nov., one month later than usual.

[1] IQR: Inter-quartile range

This fact stress the importance of taking into account the variability of the process and the difficulties of establishing defined and fixed recruitment areas both in time and space. Driving factors for this variability according to Sanchez and Gil (2002) are related with the effect of mesoscale hydrographic structures in the area and the strength of the pole-ward current on hake larvae settlement. Regarding bathymetry, hake recruits dwell between 0 y 300 m, but they clearly tend to aggregate around 100-200 m (Figure 25).

Coincidence of hake recruits with target species for the trawl fleet

According to Castro et al. (2010) and Punzón et al. (2010) the activity of the trawl Spanish fleet in the area is:

- Otter trawl metíers: targeting mix demersal species (*Lepidorhombus spp, Lophius spp, Merluccius merluccius, Trisopterus spp,* etc.); targeting *Trachurus* trachurus; and targeting *Scomber scombrus* (spring in Cantabrian waters)
- Pair trawl metíers: targeting *Micromesistius poutassou* and *M. merluccius*; and pair trawlers targeting mackerel (winter-spring in Cantabrian waters)

The Spanish fisheries policy has established some specific measures for the trawl fleet for the conservation and management of the fisheries resources in the Cantabrian Sea. The main measures are:

- ground shallower than 100 m are closed to trawl (< 100 m);
- Some areas closed in certain seasons (total and partial) (Figure 26).

Figure 27 to Figure 33 show the spatial distribution of the main trawl target species according to the results from the scientific bottom trawl surveys that show important overlap areas with hake nurseries in the area. This overlap is more important in the case of adult (≥ 27 cm) hake, and blue whiting, species where the abundances are larger in the recruitment areas than other areas, while for horse mackerel and black anglerfish the difference in abundance although larger in recruitment areas the difference is not representative (i.e. Inter-quartiles overlap) as shown in Figure 34 and Figure 36.left. While in the case of megrims (both species) abundances are larger in non-recruitment areas, though the inter-quartiles overlap (Figure 35). Finally in the case of white anglerfish, the abundances are larger in hauls out of the recruitment areas with no overlap between inter-quartiles (Figure 36.right). These results for white-angler and megrims are related with the depth distribution, since all of them appear more in grounds deeper than hake recruits, but even if the abundance in recruitment areas is smaller than in other areas, recruits and adult megrims or anglers also coexist in these grounds.

Conclusions

According to data available from the bottom trawl surveys carried out on the northern Spanish shelf, it is difficult to set areas to protect hake recruits seasonally fixed and well defined.

1. The Spanish bottom trawl survey is not a good source to identify “spawning grounds”, since it was originally design to estimate the strength of the year recruitment, while spawning occurs in rocky grounds not covered by the survey due to bottom trawl limitations. On the other hand the survey provides good information to identify nursery areas for hake, though limitations

regarding seasonal coverage limit comparisons between years given the extended season of hake spawning/recruitment, and its inter-annual variability.

2. Main recruitment areas in autumn are identified. The main nursery area in Spain is in "Coruña-Celeiro" area, constant over the years but its extension varies with the strength of the new year-class; mainly at depths ranging from 100-200 m. This area is closed to trawling activity since 2001, from October to January. Other recruitment areas vary in extension and importance depending on the strength of the year-class.

3. The areas where small hake (≤ 20 cm) is abundant the overlapping with hake (>27cm), blue whiting, horse mackerel and black anglerfish in important. Overlapping with megrims and white anglerfish are less relevant. Areas where only hake recruitment occurs could not be identified.

4. More information on the variability of the seasonality of hake recruitment is still an important gap in the knowledge needed to approach the conservation issues of hake recruitment, which could help management and more flexible and agile measures.

Reference

Cochran, G. 1971. Técnicas de muestreo. Compañía Editorial Continental, S.A. Méjico, 127 – 204.

Grosslein, M.D. and Laurec, A. 1982. Bottom trawl survey design, operation and analysis. CECAF/ECAF Series 81/22: 22 pp.

Murua, H., Motos, L., and Lucio, P. (1998). Reproductive modality and batch fecundity of the European hake (Merluccius merluccius L.) in the Bay of Biscay. Calif. Cooper. Ocean. Fish. Invest. Rep. 39, 196–203.

Castro, J., Punzón, A., Pierce, G., Marín, M. & Abad, E., 2010. Identification of métiers of the Northern Spanish coastal bottom pair trawl fleet by using the partitioning method CLARA. Fisheries Research, 2010, 102, 184-190

Chambers, J. M., Cleveland, W. S., Kleiner, B. and Tukey, P. A. (1983) *Graphical Methods for Data Analysis.* Wadsworth & Brooks/Cole.

ICES, 2010. Manual for the International Bottom Trawl Surveys in the Western and Southern Areas. Addendum 2 to the Report of the International Bottom Trawl Surveys Working Group. Lisbon, Portugal, 22-26 March 2010. ICES CM 2010/SSGESST:06. 58 pp.McGill, R., Tukey, J. W. and Larsen, W. A. (1978) Variations of box plots. *The American Statistician* **32**, 12–16.

Pérez, N., and Pereiro, F. J. (1985). Aspectos de la reproducción de la merluza, *M. merluccius*, de la plataforma gallega y cantábrica. Bol. Ins. Esp. Ocean 3, 39–47.

Punzón, A., Hernández, C., Abad, E., Carmen Hernández, Esther Abad, Castro, J., Pérez, N. & Trujillo, V., 2010. Spanish otter trawl fisheries in the Cantabrian Sea. ICES Journal of Marine Science, 67, 1-13.

Sánchez, F. & Gil, J., 2000 Hydrographic mesoscale structures and Poleward Current as a determinant of hake (Merluccius merluccius) recruitment in southern Bay of Biscay. *ICES Journal of Marine Science*, 57, 152-170.

Sánchez, F., de la Gándara, F., & Gancedo, R. 1995. Atlas de los peces demersales de Galicia y el Cantábrico. Otoño 1991–1993. *Publ. Esp. Inst. Esp. de Oceanogr.*, 20, 99 pp.

Sánchez, F. & Serrano, 2003. A. Variability of groundfish communities of the Cantabrian Sea during the 1990s. *ICES Marine Science Symposia*, 219, 249-260

Figures

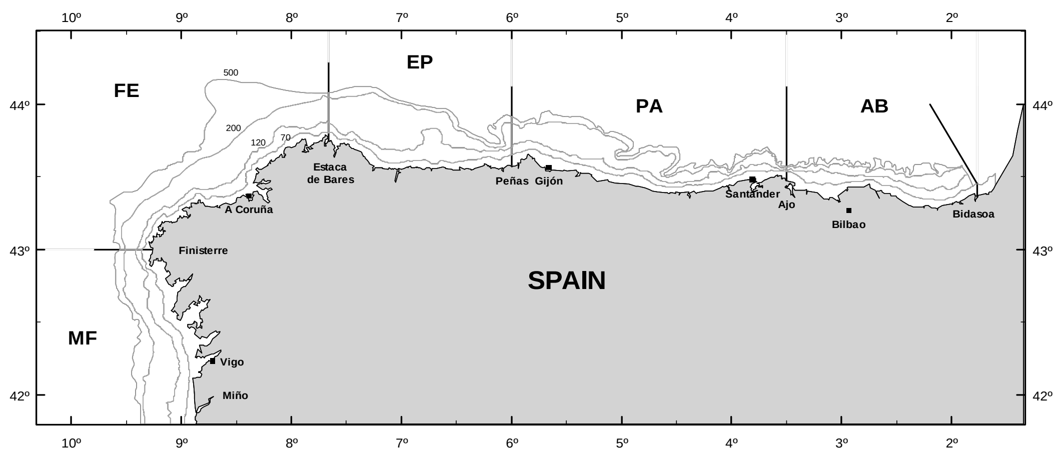


Figure 20. Stratification design used on the Northern Spanish Shelf Ground-fish survey; depth strata used since 1997 are: A) 70-120 m, B) 121 – 200 m and C) 200 – 500 m. Geographic surveys are MF: Miño-Finisterre, FE: Finisterre-Estaca, EP: Estaca-cabo Peñas, PA: Peñas-cabo Ajo, and AB: Ajo-Bidasoa.

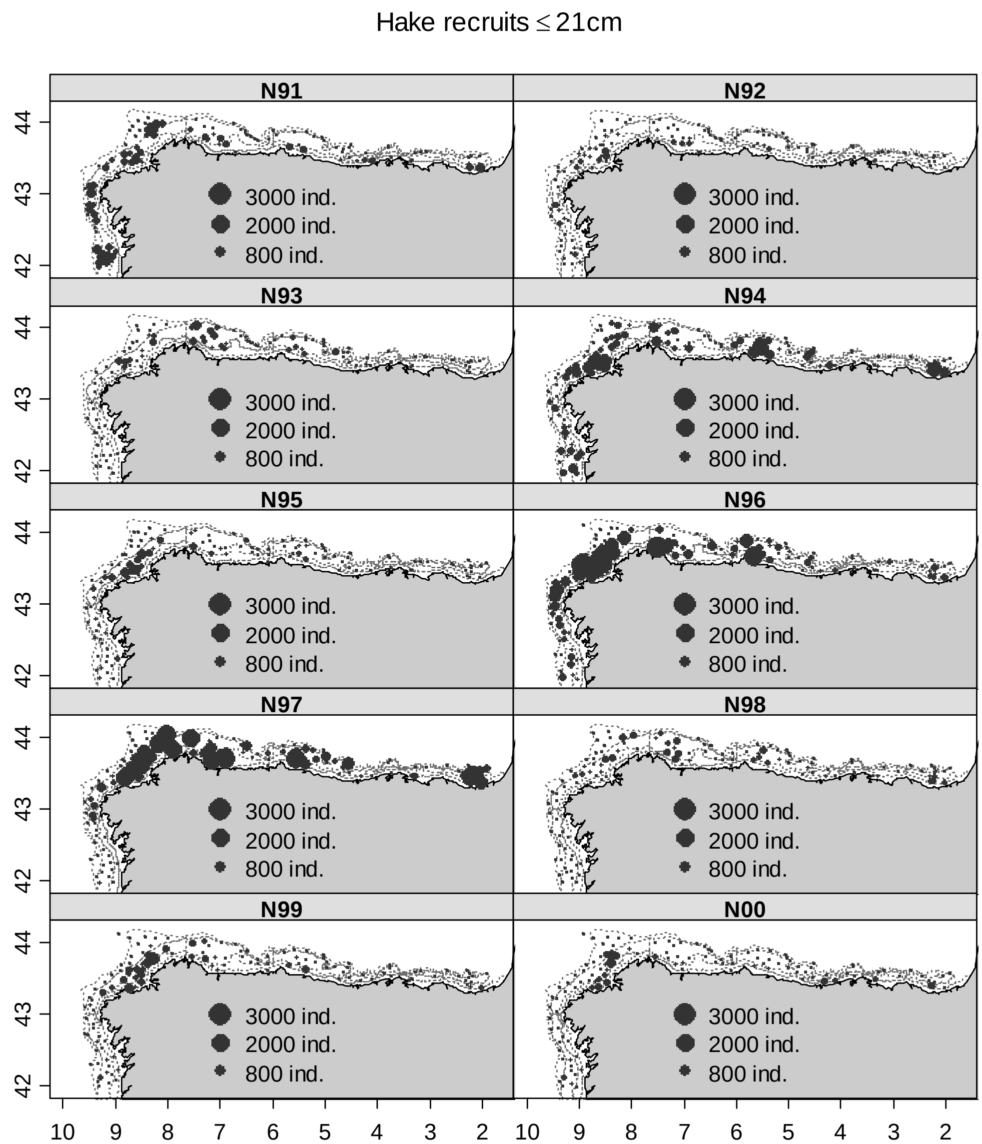


Figure 21. Distribution of hake recruits (≤21 cm) in Northern Spanish Shelf Ground-fish between 1991 and 2000

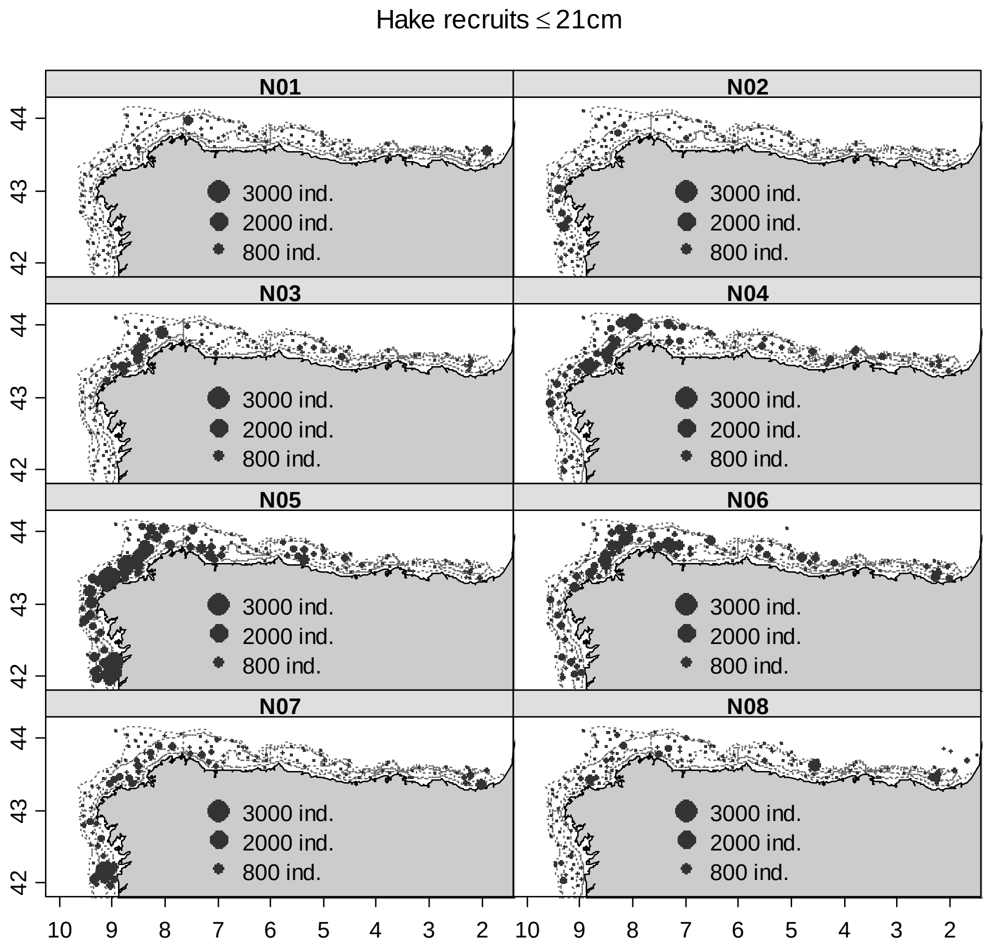


Figure 22. Distribution of hake recruits (≤21 cm) in Northern Spanish Shelf Ground-fish between 2001 and 2008. 2009 and 2010 shown below

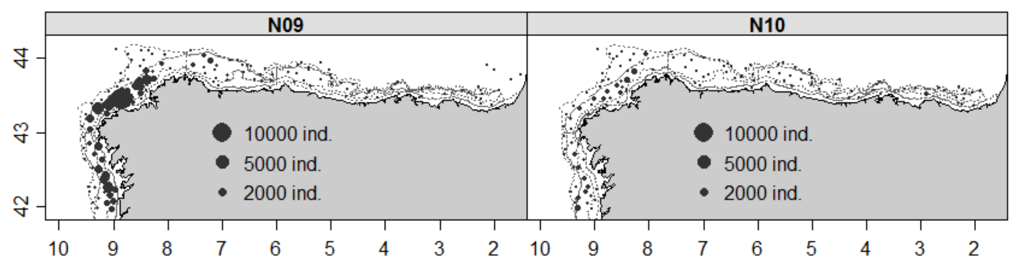


Figure 23. Distribution of hake recruits (≤21 cm) in Northern Spanish Shelf Ground-fish in 2009 and 2010, shown separately to enhance visualization

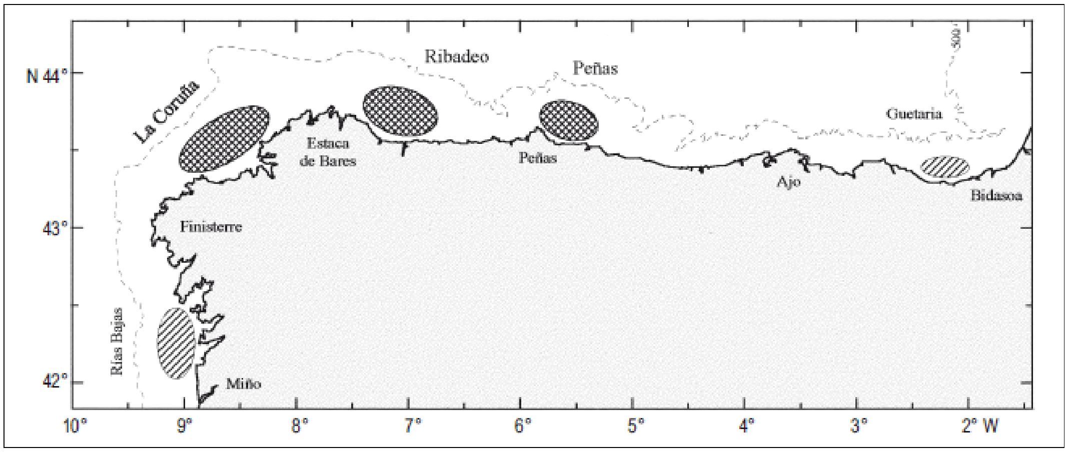


Figure 24. Main nursery areas of hake in the last decade (based in Sánchez, 1995). Shaded in a diagonal cross for the main areas appearing all years and shaded in a forward slash for the concentrations which only appear in some years (Sánchez & Gil, 2000)

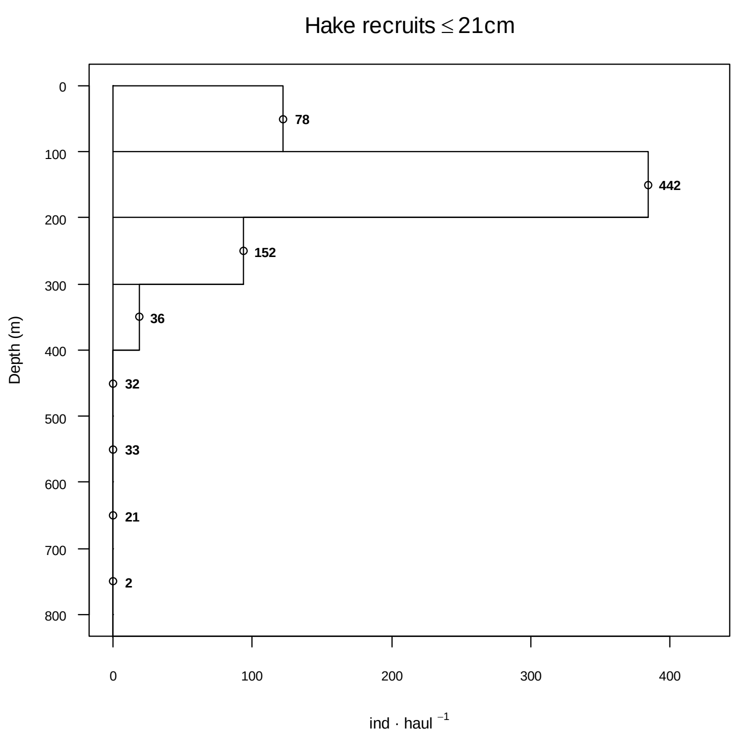


Figure 25. Depth distribution of hake recruits (≤21 cm) in number of individuals, during the surveys carried out on the Spanish Northern shelf between 2006 and 2010

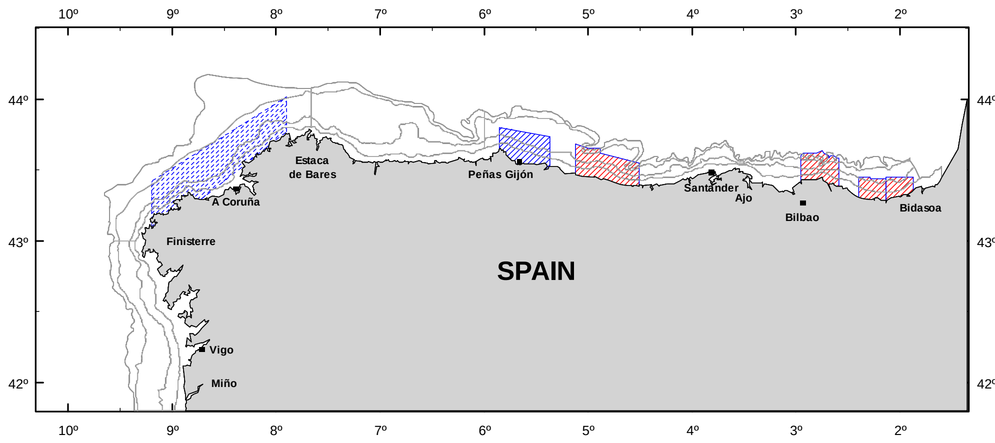


Figure 26. Areas closed to trawling activity in the northern Spanish shelf. Areas shadowed in red are permanent closures while those shadowed in blue are seasonal, dot lines "La Coruña-Cedeira" from Oct to Jan, both included, and continuous line: "El Callejón-La Carretera": from Sept to Mar, both included.

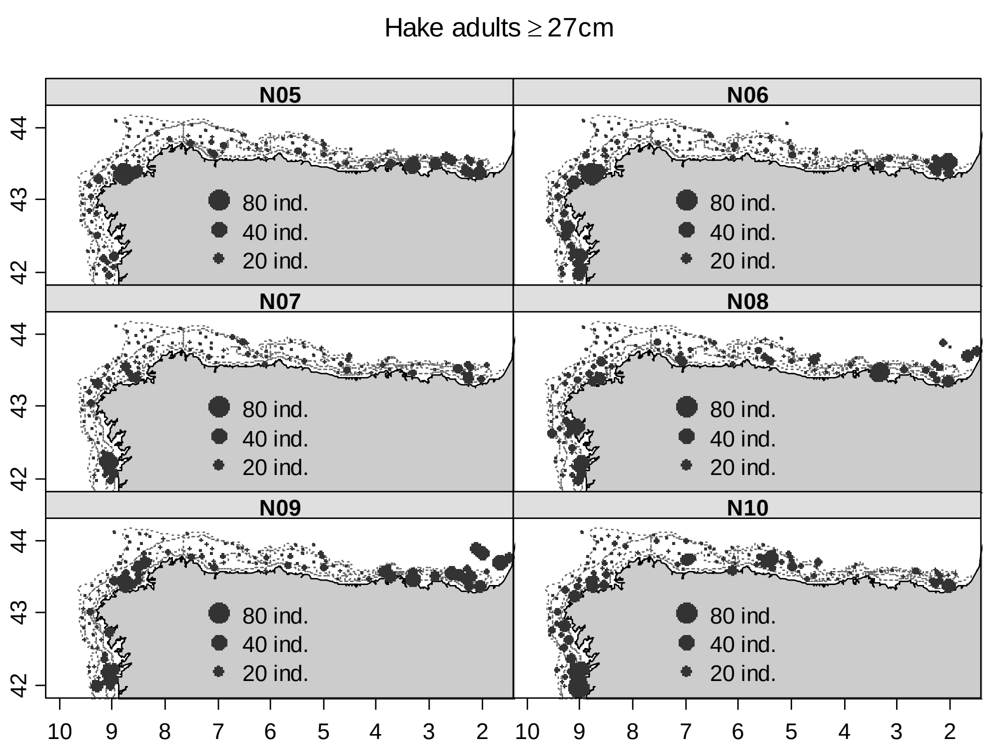


Figure 27. Distribution of hake larger than minimum landing size (MLS≥27 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

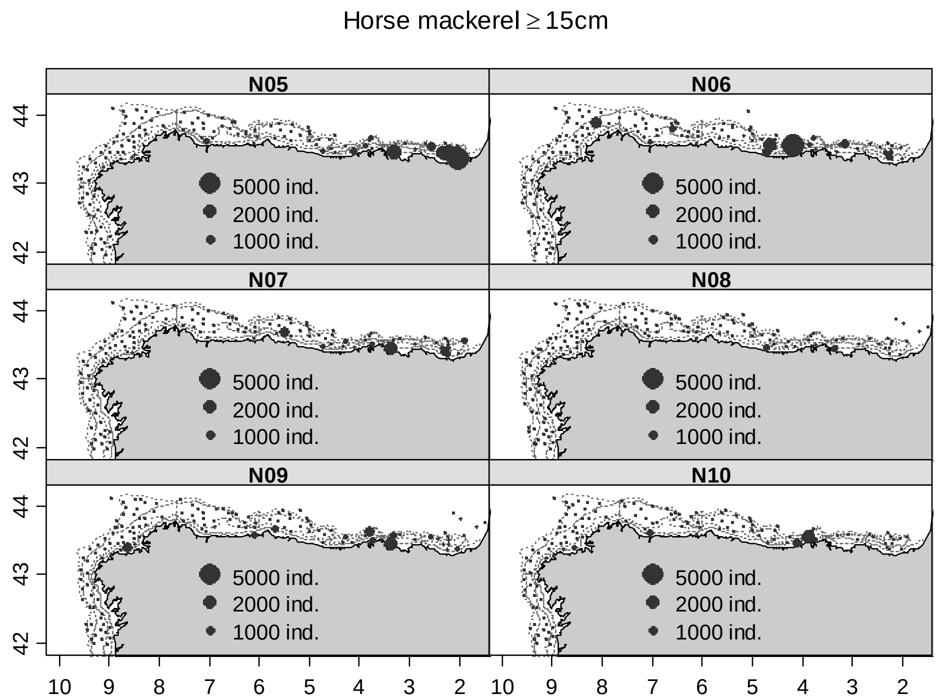


Figure 28. Distribution of horse mackerel larger than MLS (≥15 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

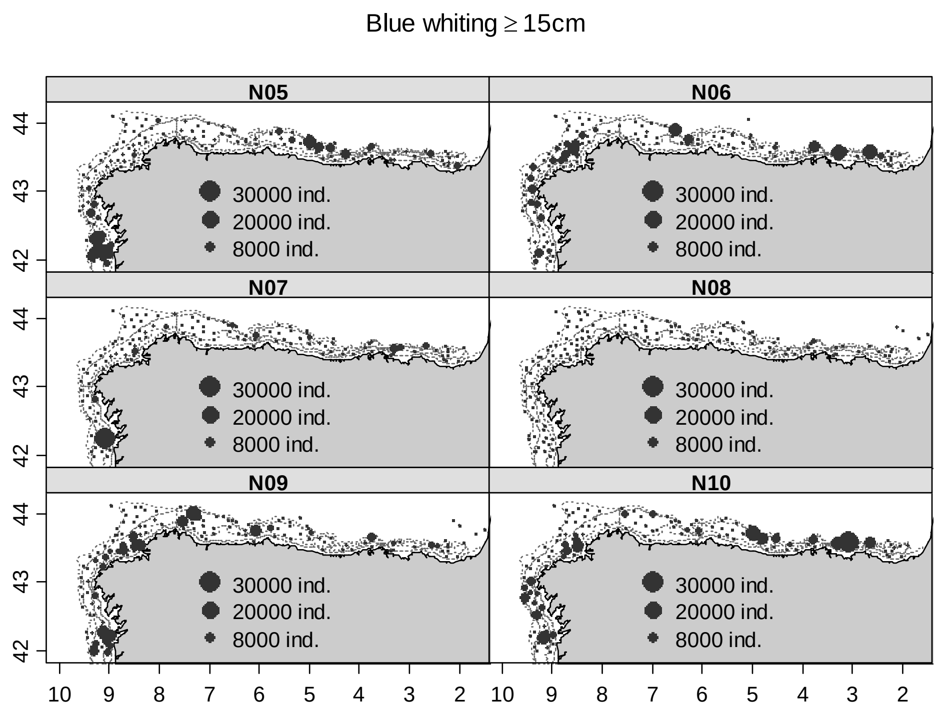


Figure 29. Distribution of blue whiting larger than MLS (≥15 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

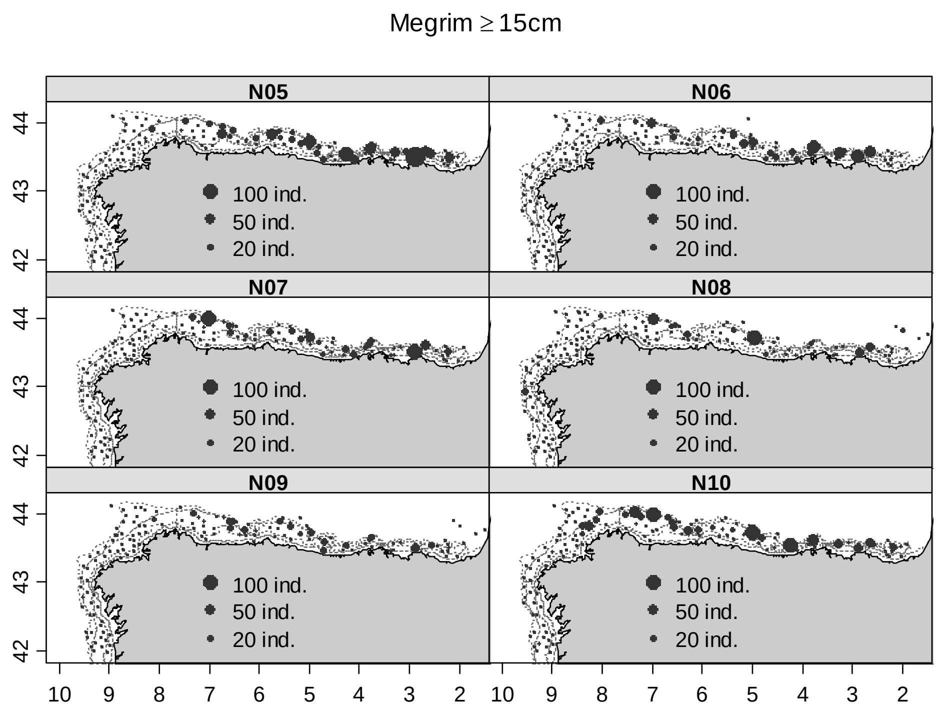


Figure 30. Distribution in number of individuals of megrim larger than MLS (≥15 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

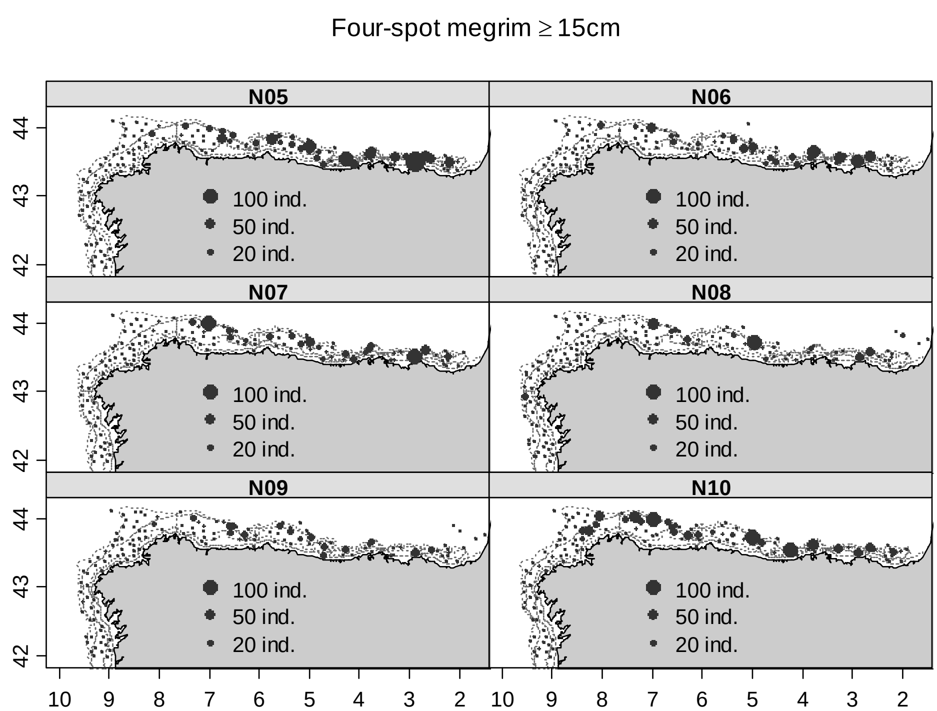


Figure 31. Distribution in number of individuals of four-spot megrim larger than MLS (≥15 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

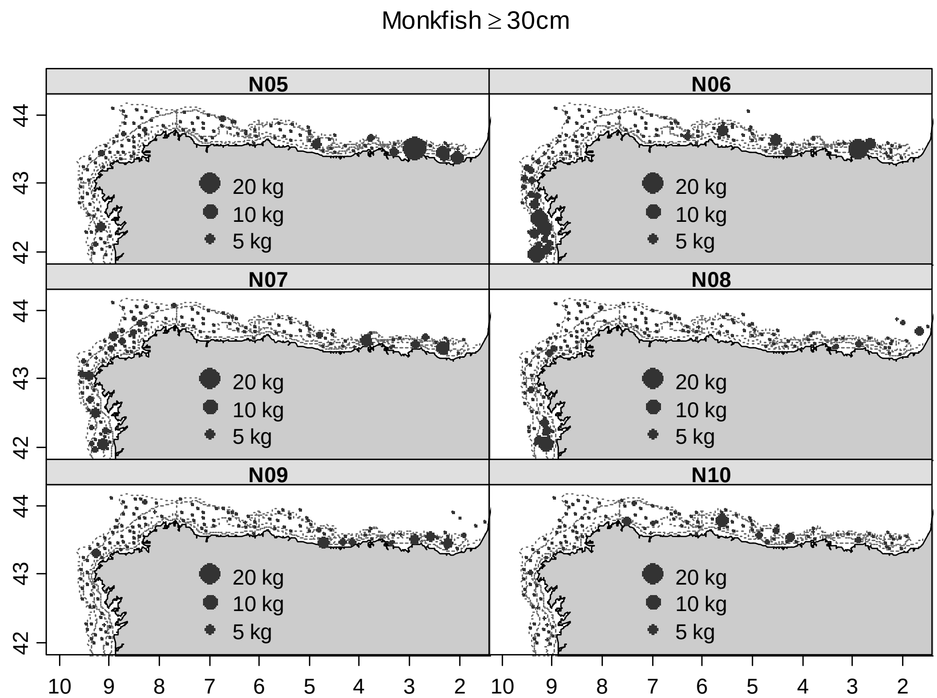


Figure 32. Distribution in biomass of monkfish larger than MLS (≥30 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

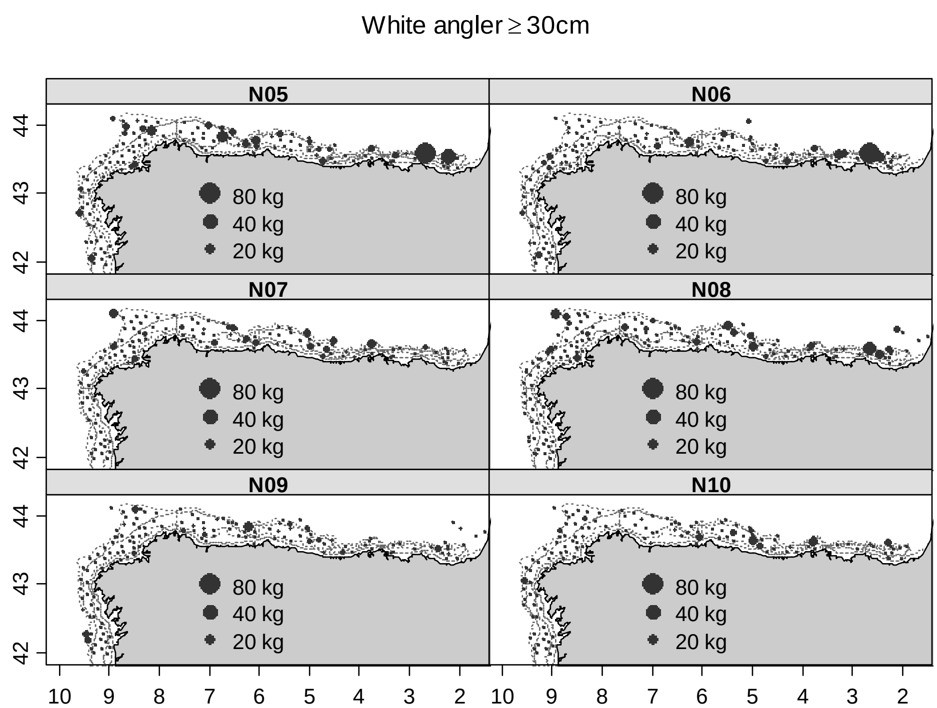


Figure 33. Distribution in biomass of white angler larger than MLS (≥30 cm) in Northern Spanish Shelf Ground-fish between 2005 and 2010

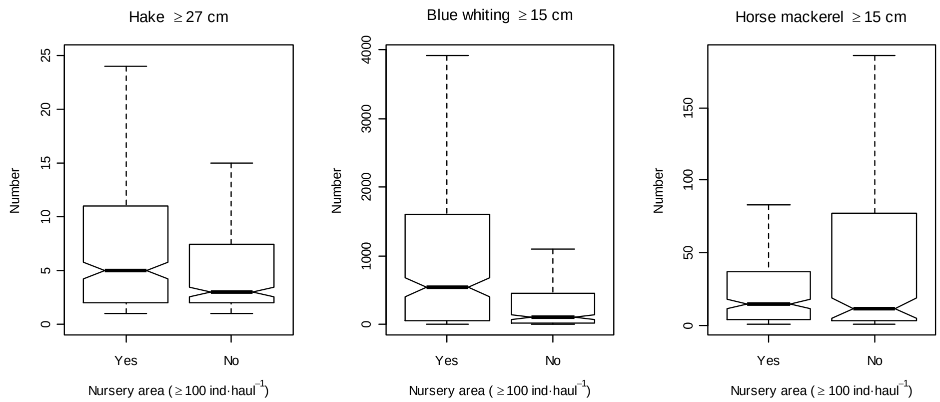


Figure 34. Comparison of abundances in number of hake adults, horse mackerel and blue whiting in hauls in nursery areas (with more than 100 recruits per haul) and other hauls (only hauls with catches of the species considered). Notches represent the inter-quartiles of abundances. Data from surveys in 2006-2010.

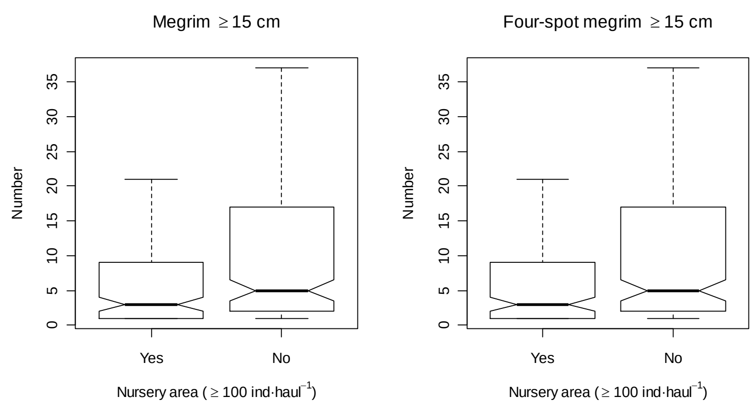


Figure 35. Comparison of abundances in number of megrim and four-spot megrim in hauls in nursery areas (with more than 100 recruits per haul) and other hauls(only hauls with catches of the species considered) . Notches represent the inter-quartiles of abundances. Data from surveys in 2006-2010.

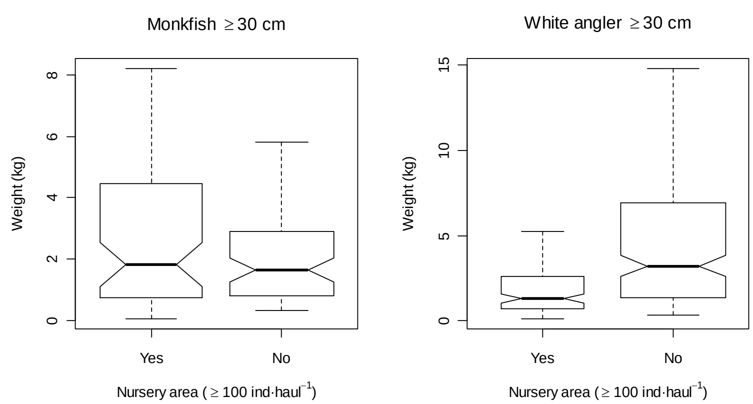


Figure 36. Comparison of abundances in biomass of monkfish and white angler in hauls in nursery areas (with more than 100 recruits per haul) and other hauls (only hauls with catches of the species considered) . Notches represent the inter-quartiles of abundances. Data from surveys in 2006-2010.

Vessel dynamics, ITQ's and endogenous vessels distributions[1]

José M. Da-Rocha

Universidade de Vigo

Pau S. Pujolàs

IDEA, Universitat Autònoma de Barcelona

June 16, 2011

Abstract

This paper uses option theory for estimating the economic benefits of adopting a property right-based management in the European Southern Hake multi species fishery. For seizing the heterogeneity in the observed value per kilo of hake at vessel level, we assume idiosyncratic uncertainty. By using Kolmogorov forward equation we analytically characterize vessels stationary distribution as functions of fishery regulations and fleet subsidies.

JEL classification: O1.

Keywords: ITQ's, firm dynamics, investment under uncertainty, Kolmogorov forward equation, endogenous fisheries models.

[1]Financial aid from the Spanish Ministry of Education and Science (ECO2009-14697-C02-02) is gratefully acknowledged.

Non technical report

1. Increasing days per vessel in 70% (from 156 to 264) impacts strongly on fleet profits: on the one hand, fleet expected value increases in a 65.67%, and on the other hand, the fraction of fleet vessels having short-run losses diminishes in a 22%.

2. A fishery rationalization policy that increases the number of days per vessel (from 156 to 264) and reduces fishing mortality from $F_{sq} = 0.80$ to $F_{max} = 0.26$ brings a 89% increase in profits while reducing current fleet in only 25%. Therefore, the desired levels of fishing mortality F_{max} can be achieved reducing fleet less than proportionally to the reduction in fishing mortality.

3. Introducing ITQs that can be sold and leased allows sharing among all vessels the surplus generated by the rationalization fishery policy. This is due to the fact that ITQs increase the overall fleet revenue without having all vessels fishing. Moreover, introducing ITQs would allow maintaining the current fleet size in terms of permit output holders. This result is possible because the ITQs allocation, in terms of days per vessel, is smaller than the current number of days per vessel.

4. The introduction of ITQs in this fishery implies allocating to each vessel a quota equivalent to 147 times its average landings per day. Under these conditions, vessels obtaining total landings in value of 4.44 euros per kilo of hake or more will remain in the fishery. On the contrary, a 4.32% of the fleet will not attain the minimum necessary total landings and will sell fishing rights (at 99.15 euros per kilo).

5. Introducing leasing markets allows concentrating the total amount of fishing days in a 55.72% of the fleet. Leasing price will be equal to 4.96 euros per kilo and day. Given this price, the total value of landings per kilo of hake will be 12.30 euros in average (37% greater than the current average value)

6. Subsidies have shown to have little impact on fleet size and productivity and, therefore, on the fishery overall size. Subsidies do affect fleet profitability. Eliminating subsidies reduces ITQs leasing and selling prices and induces property concentration. When variable costs increase, ITQs prices diminish as a consequence of the erosion on operating profits. Increasing fixed cost brings a greater concentration on property as many fishers will rather sell their rights and abandon the fishery.

Resumen ejecutivo

1. Incrementar un 70 por ciento el numero de días por barco (de 156 a 264) tiene un fuerte impacto sobre los beneficios de la flota: en primer lugar, incrementa un 65.67 por ciento el valor medio esperado de la flota; en segundo lugar reduce un 22 por ciento la fracción de la flota que puede estar operando con perdidas a corto plazo.

2. Una política de racionalización de la pesquería basada en aumentar el numero de días por barco, de 156 a 264, y reducir la mortalidad por pesca del nivel atual, $F_{sq} = 0.80$, a $F_{max} = 0.26$, permitiría obtener un 89 por ciento más de beneficios reduciendo solo un 25 por ciento la flota actual. Por tanto, las reducciones de flota asociadas a una política de racionalización de la pesquería no son proporcionales a las reducciones de F que se precisan para alcanzar F_{max}.

3. La introducción de ITQ's permite repartir los beneficios de la política de racionalización de la pesquería entre todos los barcos. Ello se debe a que los ITQ's aumnatn los ingresos de todos los barcos de la flota sin necesidad de que todos los barcos esten pescando. Además la introducción de ITQ's permitiría sostener el tamaño actual de flota, ya que el numero de días por barco que se reparte entre la flota es siempre menor que los 156 actuales.

4. Introducir ITQ's en esta pesquería supondría asignar a cada barco derechos equivalentes a 147 veces el promedio de sus desembarcos por día. Bajo estas condiciones, los barcos con un valor por unidad de merluza superior o igual a 4.44 euros por kilo se mantendrían en la pesquería. El 4,32% restante (los menores a 4.44 euros per kilo) venderían los derechos (a razón de 99.15 euros por kilo) y abandonarían la pesquería.

5. La existencia de mercados de alquiler permitiría concentrar los días de pesca en el 55.72 por ciento de la flota. El precio de alquiler es de 4.96 euros por kilo día. A estos precios, el valor medio de los desembarcos sería de 12.30 euros por kilo de merluza (un 37 por ciento más alto que en la actualidad).

6. Los subsidios tienen escaso impacto sobre la fracción de la flota que se mantiene activa, sobre su productividad, y por tanto, sobre el tamaño de la pesquería. Son transferencias en rentas que afectan notablemente a la rentabilidad de la flota. La eliminación de los subsidios reduce los precios de alquiler y compra de ITQ's y concentra la propiedad. Aumentar los costes variables reduce los precios de los derechos al erosionar los resultados de explotación. Aumentar los costes fijos concentra la propiedad de los derechos, ya que un mayor numero de los actuales pescadores preferirán vender los derechos y abandonar la pesquería.

1 Introduction

According to evidence property rights regimes improve fisheries profitability and sustainability (Grafton *et al* 2006). Literature identifies two mechanisms for inducing these improvements: cost efficiency (see Kompas and Che, 2005; Kulmala *et al* 2005; Weninger 2008) and price rises (Grafton *et al* 2000).

In this paper we use option theory for estimating the economic benefits of adopting a property right-based management in the European Southern Hake multi species fishery. For seizing the heterogeneity observed in the per kilo of hake value at vessel level, we assume idiosyncratic uncertainty (see Hopenhayn, 1992; and Hopenhayn and Rogerson, 1993). We extend Weninger and Just (2002) work characterizing analytically fleet dynamics with and without ITQ's. The model presented considers a restricted access fishery and imposes limits on total catches, TAC's, and on the amount of days a vessel is allowed to fish along the season.

Upon Luttmer (2007), we build up an analytically tractable fleet distribution model in which vessels value per unit evolves according to a standard Brownian motion. An analytical solution for the vessels stationary distribution is obtained by using the Kolmogorov forward equation subject to boundary conditions determined by the optimal exit/entry decision. Constraints on the maximum number of days affect operating profits and vessel entry and delay-exit decisions. Therefore, the distribution of vessels is a function of fishery regulations.

For calibrating the Brownian motion, we perform a two stage data analysis. In the first stage, a joint-production technology is used for explicitly modeling multi-species vessels in the empirical model. Given that common inputs are not observable we apply duality theory: input allocation is related to product prices. Provided that an estimation method cannot have more than one dependent variable (output vector), we estimate the vessel technology by using a global stochastic optimization algorithm (Egea *et al.*, 2009). We estimate a joint function for a sample of 164 vessels which landed hake during 22 months in Galicia.

The calibration includes a second stage which links the individual vessel performance to the Brownian process. This second stage analysis shows that there is no correlation between daily hake landings and the value per kilo of hake. Therefore, the introduction of ITQs increases fleet profitability, improves cost efficiency and rises revenues by reallocating hake quotas form vessels with low value per kilo of hake to those vessels with greater value per kilo of hake, but does not imply changes in vessel size distribution.

We use the the calibrated model for analyzing the impact on long term fleet size and profitability of a fishery rationalization policy that increases the number of days per vessel (from 156 to 264) and reduces fishing mortality from $F_{sq} = 0.80$ to $F_{max} = 0.26$; and a fishery rationalization policy that introduce ITQ's and reduces fishing mortality from $F_{sq} = 0.80$ to $F_{max} = 0.26$. We find that introducing ITQs that can be sold and leased allows sharing among all vessels the surplus generated by the rationalization fishery policy. This is due to the fact that ITQs increase the overall fleet revenue without having all vessels fishing. Moreover, introducing ITQs would allow maintaining the current fleet size in terms of permit output holders. This result is possible because the ITQs allocation in terms of days per vessel is smaller than the current number of days per vessel.

The paper is organized in the following manner. We start out describing vessel and stock dynamics in section 2. In section 3 we characterize the steady state fleet distribution under the current controlled access management program. Section 4 shows how ITQs change the steady state fleet distribution. Section 5 calibrates the model and section 6 quantifies the fishery rationalization process.

2 A Long run model of fleet capacity

We introduce vessel dynamics in a multi species fishery management model with restricted access. We introduce idiosyncratic uncertainty for seizing the observed heterogeneity in the share of hake over total landings and in the price per kilo of hake at vessel level. Optimal entry and exit delay decisions are obtained by using option theory. Finally, we use a standard age-structured model to model stock dynamics

2.1 Vessel dynamics

Consider a fleet segment where there is a continuum of heterogeneous vessels with measure M. Hake is not their main target for any, but it is a percentage of their total of landings. Let φ be the value per kilo of hake

$$\varphi = p + v_h \tag{1}$$

that depends on the price of hake, p, and the ratio of other species value over hake harvest, v_h. We assume that vessels face idiosyncratic (specific) value per kilo of hake uncertainty. Therefore, we allow φ to vary across vessels and over time. To approximate the above assumption, we determine that φ of a given vessel evolves according to the following a geometric Brownian motion stochastic process

$$\frac{d\varphi}{\varphi} = \alpha dt + \sigma dz, \tag{2}$$

where $\alpha < 0$ is the expected growth rate, σ is the standard deviation (per unit volatility), and dz is the random increment to a Wiener process. Associated with the Brownian process, the measure of value per kilo of hake follows the following Kolmogorov forward equation

$$\frac{\partial f(\varphi,t)}{\partial t} = -\alpha\frac{\partial f(\varphi,t)}{\partial\varphi} + \frac{\sigma^2}{2}\frac{\partial^2 f(\varphi,t)}{\partial\varphi^2} \tag{3}$$

with boundary condition $f(\underline{\varphi},t) = 0\ \forall t$.

A vessel with value per kilo of hake φ has an income equal to φh per day, where h is the average daily hake landings. We assume it has a constant cost per day of fishing equal to c_d, and a fixed cost of keeping the vessel of c_f, and both are linear to hake. Therefore an active vessel with value per kilo of hake φ solves

$$\max_d\,(\varphi h - c_d h)\,d - c_f h \qquad s.t \qquad d\ \leq\ n \leq \bar{d}, \tag{4}$$

d is the number of days and $\bar{d}$, is the maximum number of days per season and n is a constraint chosen by the authority. It is trivial that as long as $\varphi - c_d$ is positive, the vessel chooses to fish the maximum number of days, $n \leq \bar{d}$. Thus, vessels's profits per kilo of hake can be written as

$$\pi(\varphi) = \begin{cases} (\varphi - c_d)\,n - c_f & \text{if} \quad \varphi \geq c_d \\ \\ -c_f & \text{if} \quad \varphi < c_d \end{cases} \tag{5}$$

We define the threshold level $\hat{\varphi}_{sq} = c_d$ as the productivity level at which vessels choose to stop fishing, and the cutoff level φ^*_{sq} as the productivity at which vessels choose to exit the economy. In general, $\hat{\varphi}_{sq} \neq \varphi^*_{sq}$. The mechanism that triggers exit from the industry is the fixed operating cost (the economic capital cost). The fixed operating cost implies a minimum vessel value per kilo of hake, a threshold φ^*, that separates the continuation and abandonment region of the state space. Therefore, a vessel chooses remaining or not in the fishery by solving

$$\begin{aligned} W_{sq}(\varphi) \quad &= \max_{exit}\left\{0, \pi(\varphi) + (1+\rho dt)^{-1} E W_{sq}(\varphi + d\varphi)\right\}, \\ s.t.\ &\begin{cases} \pi(\varphi) = \begin{cases} (\varphi - c_d)\,n - c_f & \text{if} \quad \varphi \geq c_d \\ -c_f & \text{if} \quad \varphi < c_d \end{cases} \\ \\ \dfrac{d\varphi}{\varphi} = -\alpha dt + \sigma dz \end{cases} \end{aligned} \tag{6}$$

The following proposition characterizes the value per kilo of hake level at a stationary equilibrium.

Proposition 1. *The minimum value per kilo of hake, φ^*_{sq}, and the value function W_{sq} are given by*

$$\varphi^*_{sq} = \hat{\varphi}_{sq} \left(\frac{c_f}{\hat{\varphi}_{sq} n} \frac{(-\beta_2)(\rho - \alpha)}{(\rho - \alpha\beta_2)} \right)^{\frac{1}{\beta_1}} \tag{7}$$

$$W_{sq}(\varphi) = \begin{cases} C_1 \varphi^{\beta_1} + C_2 \varphi^{\beta_2} - \frac{c_f}{\rho} \quad if \quad \varphi \leq \hat{\varphi}_{sq} \\ \\ B_2 \varphi^{\beta_2} + \frac{n}{(\rho-\alpha)} \varphi - \frac{c_f + \hat{\varphi}_{sq} n}{\rho} \quad if \quad \varphi > \hat{\varphi}_{sq} \end{cases} \tag{8}$$

where

$$\begin{aligned} \hat{\varphi}_{sq} &= c_d \\ C_1 &= \frac{c_f}{\left(\varphi^*_{sq}\right)^{\beta_1} \rho} \left(\frac{\beta_2}{\beta_2 - \beta_1} \right) \\ C_2 &= -\frac{\beta_1}{\beta_2} C_1^{\beta_1 - \beta_2} \varphi^*_{sq} \\ B_2 &= C_2 + C_1 \hat{\varphi}_{sq}^{\beta_1 - \beta_2} - \frac{\alpha}{\rho} \frac{n}{(\rho - \alpha)} \hat{\varphi}_{sq}^{1-\beta_2} \end{aligned}$$

and $\beta_1 > 0$ and $\beta_2 < 0$ are given by

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{\alpha}{\sigma^2} \right)^2 + \frac{2\rho}{\sigma^2}} > 1 \tag{9}$$

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt{\left(\frac{1}{2} - \frac{\alpha}{\sigma^2} \right)^2 + \frac{2\rho}{\sigma^2}} < 0 \tag{10}$$

Proof See appendix A.1.

Finally, we assume that potential entering vessels make their entry decision taking the productivity distribution, $G(\varphi)$, as given. That is to say, we assume that the potential entering optimally decides whether to engage in production or not by solving a competitive entry condition

$$\frac{\int_{\varphi^*_{sq}}^{\infty} W_{sq}(\varphi) dG(\varphi) d\varphi}{\int_{\varphi^*_{sq}}^{\infty} dG(\varphi) d\varphi} \geq c_{entry}, \tag{11}$$

where $W_{sq}(\varphi)$ is the value function that solves problem (6), and the mass of entering firms is normalized equal to one.

2.2 Stock dynamics

We use a standard age-structured model. Let us assume that the fish stock is broken into A cohorts. The stock dynamics is given by

$$N_{t+1}^{a+1} = e^{-z_t^a} N_t^a, \tag{12}$$

where z_t^a is the total mortality rate affecting the fish population in the a^{th} age during the t^{th} period, N_t^a. This mortality rate can be decomposed into fishing mortality and natural mortality. Moreover fishing mortality can be decomposed into landings and discards. Formally,

$$z_t^a = (p^a + d^a)F_t + M, \tag{13}$$

where, M is the natural mortality which is assumed constant across ages, and p^a and d^a are the selectivity parameters of landings and discards at age a, which can be estimated empirically. The size of a new cohort (recruitment),N_{t+1}^1 is assumed constant. The Spawning Stock Biomass, $SSB_t = \sum_{a=1}^{A} \mu^a \omega^a N_t^a$ is a function of abundance N_t^a, weight ω^a and maturity fraction δ^a at age a. Finally, yield is given by Baranov's equation

$$Y_t^a = \omega^a \frac{p^a F_t}{z_t^a}(1 - e^{-z_t^a})N_t^a. \tag{14}$$

We restrict the analysis to long run equilibria dynamics. Therefore, by backward substitution in the first restriction, the size of cohort age $a > 1$ (in any period) N^a, can be expressed as a function of the past mortality rates and initial recruitment,

$$N^a = e^{-z^{a-1}(F)} N^{a-1} = e^{-z^{a-1}(F)} e^{-z^{a-2}(F)} N^{a-2} = ... = \Pi_{i=1}^{a-1} e^{-z^{a-i}(F)} N^1. \tag{15}$$

Therefore we can express N^a as

$$N^a = \phi^a N^1, \qquad \text{for } a = 1, ...A, \tag{16}$$

where

$$\phi^a = \phi(F) = \begin{cases} 1 & \text{for } a = 1, \\ \Pi_{i=1}^{a-1} e^{-z^{a-i}(F)} & \text{for } a = 2, ...A, \end{cases} \tag{17}$$

can be understood as the survival function that shows the probability of a recruit born in period $t - (a - 1)$ to reach age $a > 1$ for a given fishing mortality path $\{F_\tau\}_{\tau=t-1}^{t-(a-1)} = F$.

3 Steady state

Constraints on the number of days per vessel affect firm operating profits and entry and delay-exit decisions. Therefore the stationary distribution of value per kilo of hake, obtained by using forward Kolmogorov equations subject to boundary conditions determined by the optimal delay-exit decisions, is endogenous and may depend on both costs and fishery regulations. That is,

$$\alpha \frac{\partial f(\varphi|\varphi^*_{sq})}{\partial \varphi} + \frac{\sigma^2}{2} \frac{\partial^2 f(\varphi|\varphi^*_{sq})}{\partial \varphi^2} + \epsilon f(\varphi|\varphi^*_{sq}) = 0. \tag{18}$$

As Luttmer [10] we assume that the potential entering vessel imitates existing firm $dG(\varphi) = \epsilon f(\varphi|\varphi^*_{sq})$. Therefore,

$$dG(\varphi) = \frac{1}{2} \frac{\alpha^2}{\sigma^2} f(\varphi|\varphi^*_{sq}), \tag{19}$$

determines the distribution of new vessels, where

$$f(\varphi|\varphi^*_{sq}) = \left(\alpha/\sigma^2\right)^2 (\varphi - \varphi^*_{sq}) e^{-\alpha/\sigma^2(\varphi - \varphi^*_{sq})}. \tag{20}$$

Finally, we assume that hake per day h is a random variable which is independent of φ and follows a log normal distribution, $\mu(h)$ with mean $\bar{h}$ and standard deviation σ_h. Therefore, in equilibrium total harvest by the active fleet

$$h^T = M \int \left(nh \int_{\hat{\varphi}_{sq}(h)}^{\infty} f(\varphi|\varphi^*_{sq}) d\varphi \right) \mu(h) dh \tag{21}$$

must be equal to the T.A.C. associated with a given fishing mortality F

$$Y^T(F) = \sum_{a=1}^{A} \omega^a \frac{p^a F}{z^a} (1 - e^{-z^a}) \phi^a_t N^1. \tag{22}$$

It is now possible to define a steady state equilibrium in this fishery.

Definition. Given $h \sim \mu(\bar{h}, \sigma_h)$, N^1, n, c_d, c_f and c_{entry} a steady state equilibrium is a fishing mortality, F, cut-offs $\underline{\varphi}$ and $\hat{\varphi}$, and a number of vessels, M, such that:

a) The individual delay-exit decision is optimal (equation 7).

b) The individual entry is optimal (equation 11).

c) Total fleet landings (equation 21) fulfill the T.A.C. (equation 22).

4 Permit output markets: ITQ's

Now assume that, instead of restrictions on the maximum number of days, a permit lease market develops. Let us assume that active vessels with average landings per day equal to h are endowed with $q(h) = qh$ permits. Therefore, vessels with value per kilo of hake φ solve

$$\max_d \left[(\varphi - r_q) - c_d\right] dh - c_f h + r_q q h \qquad s.t \qquad d \le \bar{d}, \tag{23}$$

where is the lease rate per kilo of permit, r_q. Vessels profits per kilo of hake can be written as

$$\pi(\varphi) = \begin{cases} \left[(\varphi - r_q) - c_d\right]\bar{d} - c_f + r_q q & \text{if} \quad \varphi \geq c_d + r_q \\ \\ -c_f + r_q q & \text{if} \quad \varphi < c_d + r_q \end{cases} \tag{24}$$

We also assume that if a vessel exits the fishery, it sells the output permit at price p_q. The vessel chooses remaining in the fishery or not by solving

$$W_{itq}(\varphi) \quad = \max_{exit} \left\{ hp_q q, \pi(\varphi) + (1+\rho dt)^{-1} EW_{itq}(\varphi + d\varphi) \right\},$$

$$s.t. \begin{cases} \pi(\varphi) = \begin{cases} \left[(\varphi - r_q) - c_d\right]\bar{d} - c_f + r_q q & \text{if} \quad \varphi \geq c_d + r_q \\ \\ -c_f + r_q q & \text{if} \quad \varphi < c_d + r_q \end{cases} \\ \\ \dfrac{d\varphi}{\varphi} = -\alpha dt + \sigma dz \end{cases} \tag{25}$$

Now, as in Weninger and Just [11], there exits a second mechanism that triggers exit from the industry: the permit holding cost, $p_q q$. The following proposition characterizes the value per kilo of hake level in a stationary equilibrium where $q = q'$.

Proposition 2. *The minimum value per kilo of hake level, φ^*, is given by*

$$\varphi^*_{itq} = \hat{\varphi}_{itq} \left[\frac{c_f - r_q q + p_q q \rho}{\rho \hat{\varphi}_{itq} d} \left(\frac{\beta_2}{\frac{(-\beta_2)}{\rho} - \frac{(1-\beta_2)}{(\rho - \alpha)}} \right) \right]^{\frac{1}{\beta_1}} \tag{26}$$

$$W_{itq}(\varphi) = \begin{cases} C_1 \varphi^{\beta_1} + C_2 \varphi^{\beta_2} - \dfrac{c_f - r_q q}{\rho} & if \quad \varphi \leq \hat{\varphi}_{itq} \\ \\ B_2 \varphi^{\beta_2} + \dfrac{d}{(\rho - \alpha)} \varphi - \dfrac{\hat{\varphi}_{itq} d + c_f - r_q q}{\rho} & if \quad \varphi > \hat{\varphi}_{itq} \end{cases} \tag{27}$$

where

$$\begin{aligned} \hat{\varphi}_{itq} &= c_d + r_q \\ C_1 &= \frac{c_f - r_q q + p_q q \rho}{(\varphi^*_{itq})^{\beta_1} \rho} \left(\frac{\beta_2}{\beta_2 - \beta_1} \right) \\ C_2 &= -\frac{\beta_1}{\beta_2} C_1^{\beta_1 - \beta_2} \varphi^*_{itq} \\ B_2 &= C_2 + C_1 \hat{\varphi}_{itq}^{\beta_1 - \beta_2} - \frac{\alpha}{\rho} \frac{d}{(\rho - \alpha)} \hat{\varphi}_{itq}^{1-\beta_2} \end{aligned} \tag{28}$$

and $\beta_1 > 0$ and $\beta_2 < 0$ are given by equations (9) and (10)

Proof See appendix A.1.

It is now possible to define a steady state equilibrium in this fishery. In the steady state equilibrium prices r_q and p_q will be constant. Therefore, we can define the steady state equilibrium as follows.

Definition. Given $h \sim \mu(\bar{h}, \sigma_h)$, N^1, c_d, c_f and c_{entry} a steady state equilibrium is a fishing mortality F, cut-offs φ^*_{itq}, $\hat{\varphi}_{itq}$ a lease rate, r_q, an output permit price, p_q and a quantity of quota per vessel q such that:

a) The individual delay-exit decision is optimal

b) The lease rate per kilo of quota clears the market

$$q = \bar{d} \int_{\hat{\varphi}_{itq}}^{\infty} f(\varphi|\varphi^*_{itq}) d\varphi. \tag{29}$$

c) The individual demand for quota is optimal

$$\frac{\partial \int_{\varphi^*_{itq}}^{\infty} W(\varphi) f(\varphi|\varphi^*_{itq}) d\varphi}{\partial q} = p_q. \tag{30}$$

d) Entry is given by

$$\int_{\varphi^*_{itq}}^{\infty} \left[W(\varphi) - p_q q(h)\right] \epsilon f(\varphi|\varphi^*_{itq}) d\varphi = c_{entry}. \tag{31}$$

e) Total harvest is equal to the T.A.C.

$$M_{itq} = \frac{Y^T(F)}{\bar{h}\bar{d} \displaystyle\int_{\hat{\varphi}_{itq}}^{\infty} f(\varphi|\varphi^*_{itq}) d\varphi} \tag{32}$$

In this equilibrium we have two prices, r_q, p_q, two cutoffs, φ^*_{itq}, $\hat{\varphi}_{itq}$,the mass of vessels, M_{itq} and the volume of quota, q. However, by using equation (30), price of quota is given by the usual non-arbitrage condition

$$p_q = \frac{r_q}{\rho}. \tag{33}$$

and by using equation (28), cutoffs are given by

$$\hat{\varphi}_{itq} = c_d + r_q, \tag{34}$$

$$\varphi^*_{itq} = \hat{\varphi}_{itq}\left[\frac{c_f}{\rho d\hat{\varphi}_{itq}}\left(\frac{\beta_2}{\frac{(-\beta_2)}{\rho}-\frac{(1-\beta_2)}{(\rho-\alpha)}}\right)\right]^{\frac{1}{\beta_1}}. \tag{35}$$

Therefore, we find the equilibrium by guessing r_q and solving equations (29) and (31). Once r_q is obtained we compute the mass of vessels operating the fishery, M_{itq} by using equation (32).

5 Calibration

1. **Vessel sample**. Using vessel-level dataset from Pesca Galicia[2], we construct a panel from daily data starting January 1st, 2007 and up to October 31st, 2008. Our panel selects 164 vessels, that are more that 10 meters long and harvest at least 5 Tn. per season.[3] Table 2 shows the partition of the data set. We exclude the Northern Stock fleet, and vessels with length < 10 m and /or landings per season < 5 Tn. We also exclude those vessels that were in the data set only for one season and those that are not in the Galician Census. We consider we are observing only partial information from those vessels.

2. **Multi species production function**. Hake is not the main target of the fleet. Therefore we explicitly model multi-species vessels in the empirical model. That is, we consider that we can relate hake landings $h_{i,d}$ of vessel i on day d, to its total landings of the other species, $H_{i,d}$, the observed relative price of hake and $p^h_{i,d}$ and the relative abundance of hake $x_{i,d}$ and other species $X_{i,d}$. Formally we assume that each each vessel daily solves

$$\max_{e_1,e_2} \quad p^h_{i,d}h_{i,d} + H_{i,d}$$
$$s.t. \begin{cases} h_{i,d} = x^{\beta_1}_{i,d}A_h(\lambda_1 e_1)^{\alpha_{11}}(\lambda_2 e_2)^{\alpha_{12}} \\ H_{i,d} = X^{\beta_2}_{i,d}A_H[(1-\lambda_1)e_1]^{\alpha_{21}}[(1-\lambda_2)e_2]^{\alpha_{22}} \\ e_1+e_2 \leq 3, \quad e_i \in [1,2] \quad i=1,2 \end{cases}$$

Note that unlike standard fishing production functions, we assume that daily landings per vessel are a multiple or joint output with some common inputs. Given that those common inputs are not observable we apply duality theory. If vessels maximise profits, the input allocation is related to product prices. Given that a method of estimation

[2] http://www.pescagalicia.com/

[3] 5 Tn. per season is limit to be subject to the Hake Recovery Plan effort regulation.

Table 1: Hake Landings by Fleet in Galicia, 2007

	Tn Hake	n of vessels
Total	21.977.50	1.158
Northern Stock fleet	7.029.00	126
Vessels with length < 10 m	270.80	331
Vessels with landings per season < 5 Tn	380.30	427
Present in the sample only one season	695.01	23
Out from Galician Census	4.610.49	76
ESP	1.268.48	32
FRA	3.077.48	38
IRL	230.21	3
PRT	34.33	3
Without vessel	1.169.05	1
Demersal Long-liners in VI ICES	427.76	10
Sample	**7.395.08**	**164**
Demersal Trawls	5.601.82	89
Gillnet	1.163.93	30
Demersal Trawls in Portuguese waters	201.91	4
Demersal Long-liners	149.44	10
Artisanal fleet	277.97	31

Table 2: Production function's parameters, 164 vessels

	α^i_{11}	α^i_{21}	δ^i_1	β^i_1	A^i_1
mean	0.5086	0.8938	0.7323	0.3577	7.54e+5
c.v.	1.4404	1.0546	0.3123	0.1611	0.3211
	α^i_{12}	α^i_{22}	δ^i_2	β^i_2	A^i_2
mean	0.3443	0.8071	0.7108	0.6916	2.65e+5
c.v.	1.7091	1.1194	0.3623	0.1237	1.0015

cannot have more than one dependent variable (output vector), we estimate the vessel technology by using a global stochastic optimization algorithm (enhanced scatter search).[4] Therefore, a production function can be estimated for each vessel. That is

$$\{\alpha_{11}^i, \alpha_{12}^i, \alpha_{21}^i, \alpha_{22}^i, \delta_1^i, \delta_2^i, \beta_1^i, \beta_2^i, A_1^i, A_2^i\}_{i=1}^{164} \tag{36}$$

Figure 1 shows the histogram of these ten parameters for the 164 productions functions estimated. Note that β_i parameters are quite constant. That means that distributional effects of changes on hake abundance are close to zero.

3. **Value per kilo of hake and hake per day distributions** Using each vessel's production function we simulate its value per kilo of hake. After that we compute ξ by minimising the distance between the stationary distribution

$$f(\varphi|\varphi^*) = \xi^2(\varphi - \varphi^*)e^{-\xi(\varphi-\varphi^*)}. \tag{37}$$

and the value per kilo of hake generated by the production functions. Figure 2 shows the histogram for the 164 value per kilo of hake and the distribution associated with the parameter $\xi = 0.369019$. Figure 3 also shows the correlation between the value per kilo of hake and landings per day for the 164 vessel sample. Data supports the assumption of independence between the value per kilo of hake and hake per day distribution. Therefore, the daily landings distribution was fitted using a log normal distribution with mean equal to 5.5235 (that is, 250 kilos per day) and standard deviation equal to 0.9779 (see right side panel of figure 3). Finally we verify that daily landings and gross register tonnage (GRT) have a low correlation (0.2047) .

4. **Parameters calibrated from the model** For ending the calibration, we consider a discount factor $\rho = 0.05$. Brownian motion parameters are calculated to mimic the landings per kilo of hake distribution and the life span of vessels (25 years). That is

$$-\frac{\alpha}{\sigma^2} = \xi \tag{38}$$

$$\frac{1}{2}\frac{\alpha^2}{\sigma^2} = \frac{1}{25} \tag{39}$$

The daily cost, c_d, is given by the minimum landings and the value per kilo of hake, 3.5495. For calculating the fix cost per season, c_f, we assume that there are not active vessels without landings, $\varphi_{sq}^{ast} = \hat{\varphi}_{sq}$. Finally the (normalized) entry cost $\epsilon \times c_{entry}$ is obtained by solving equation (11) using the average number of days per vessel observed in the sample, $n = 192$. Table 3 summarizes the parameter values used for the benchmark model.

[4]The Enhanced Scatter Search is a method based on the use and combination of a reference set of good solutions, maintaining an appropriate level of diversity (Egea *et al.*, 2009).

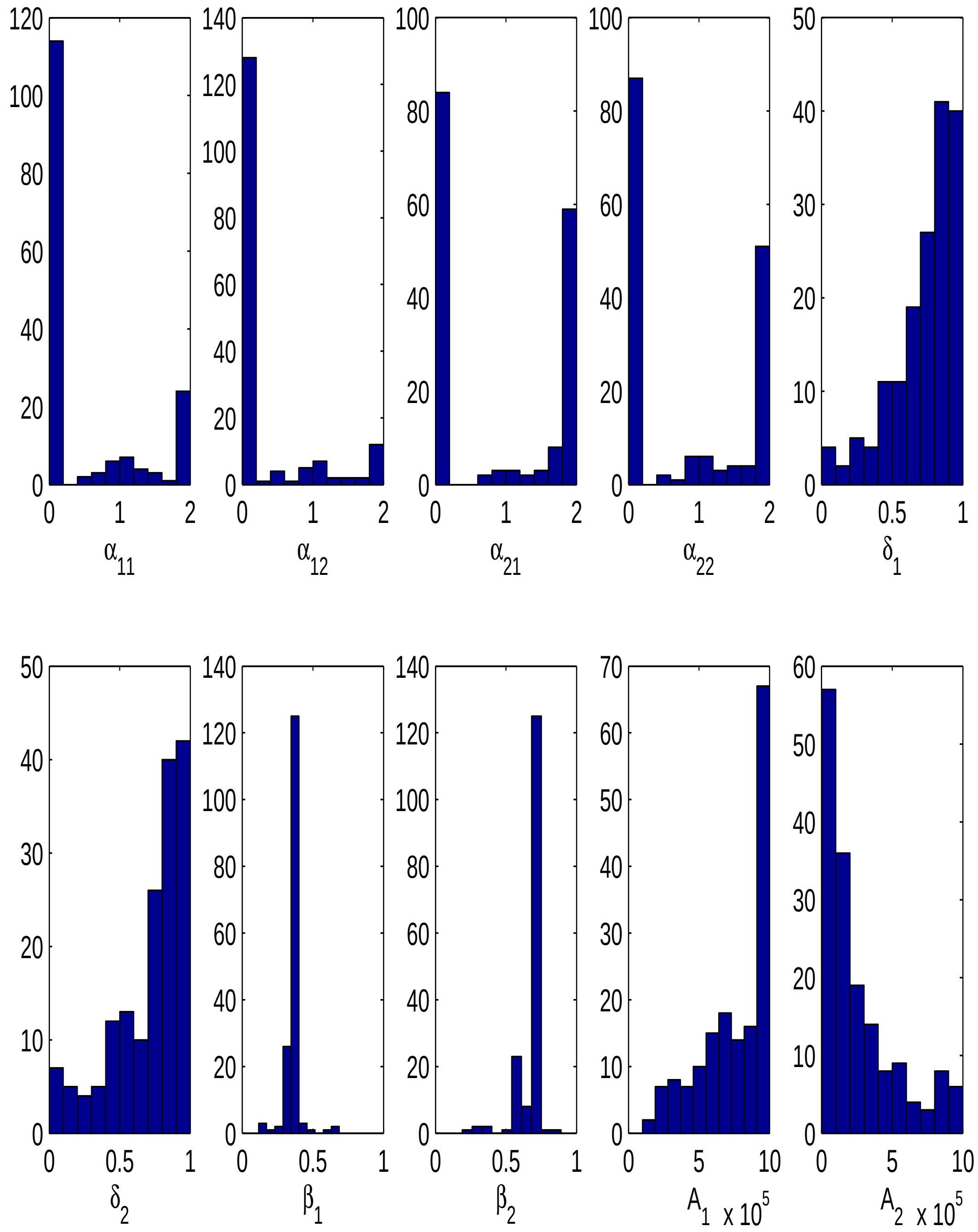


Figure 1: Production function parameters

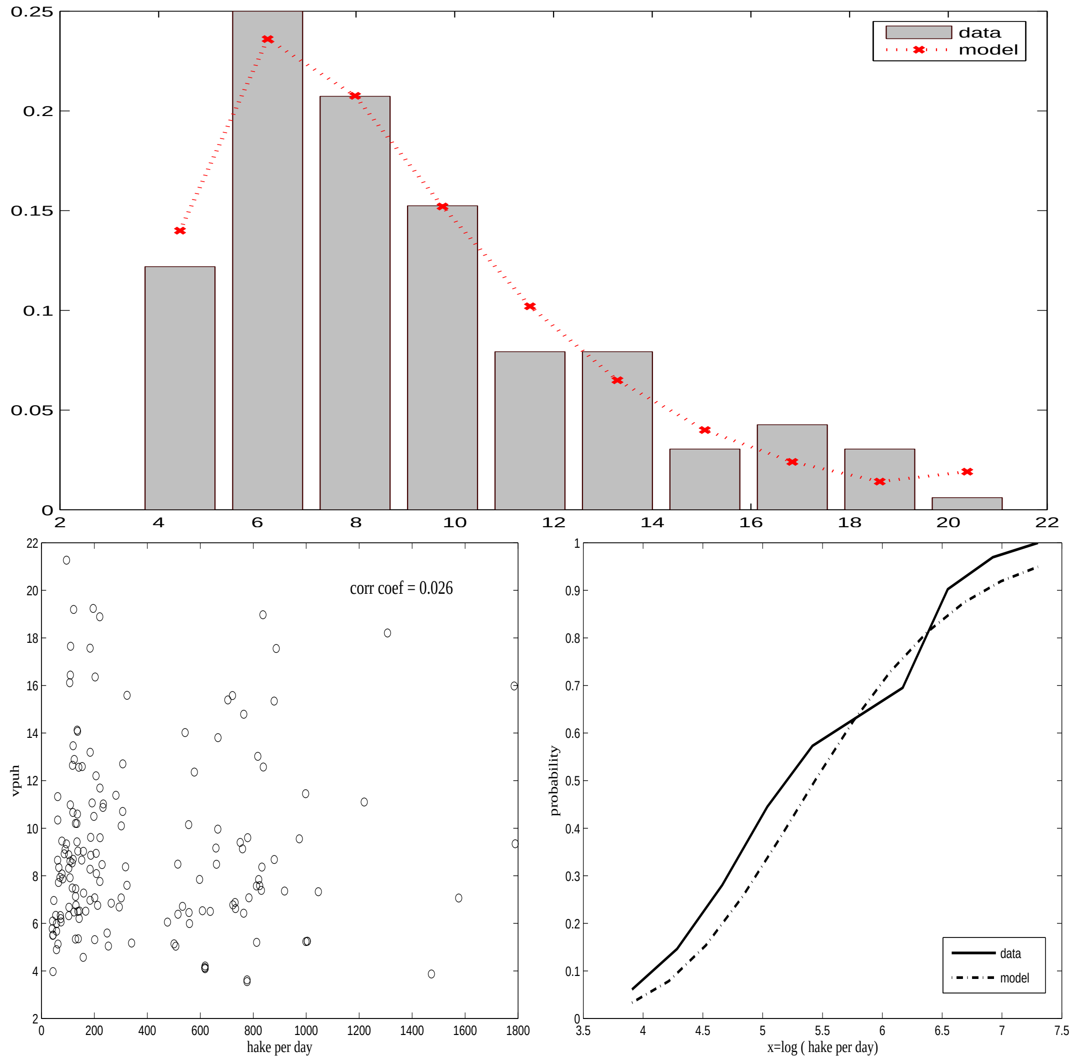


Figure 2: Upper panel: value per kilo of hake partition; lower panel, correlation between hake per day and value per kilo of hake (left) and hake per day lognormal cdf (right).

Table 3: Baseline Fishery

Brownian motion		
ρ	discount rate	0.0500
α	growth rate	-0.2168
σ	diffusion	0.7665
Vessel costs		
c_d	daily cost	3.5495
c_f	fixed cot per season	820.0983
$c_{entry} \times \epsilon^{-1}$	entry cost normalized by entry mass	0.2933
Harvest per day (lognormal)		
$\bar{h}$	log (kilos)	5.5235
σ_h	std. of log (kilos)	0.9779
Mass (vessels)		
M	fleet size	304

Table 4: Age Structured model

	Npop	M	Sland	Sdisc	Wland	Wdisc	Mat	Wpop
0	116740	0.4	0.00	0.03	0.12	0.02	0.02	0.00
1	88764	0.4	0.28	0.41	0.22	0.08	0.28	0.05
2	20607	0.4	0.97	0.20	0.45	0.29	0.69	0.29
3	4241	0.4	1.07	0.07	1.06	0.76	0.84	0.85
4	1294	0.4	1.07	0.03	1.96	1.49	0.90	1.70
5	371	0.4	1.07	0.01	3.04	2.43	0.92	2.74
6	203	0.4	1.07	0.01	4.21	3.50	0.93	3.90
7	83	0.4	1.07	0.00	5.40	4.63	0.94	5.09
8	50	0.4	1.07	0.00	7.21	6.20	0.94	6.93

Table 5: Calibration, 2007 data

	Baseline		DCF data
Average value per kilo of hake ($E\varphi$)	8.97		11.61
Annual income per kilo of hake (φd)	1722.10	100	100
Annual cost per kilo of hake ($c_d d$)	681.50	39.57	42.90
Annual fix cost per kilo of hake c_f	820.10	47.62	30.90
Profits per kilo of hake ($\pi(\varphi)$)	220.50	12.80	27.20

5. **Stock dynamics** Information used for stock dynamics comes from the ICES Working Group on Hake , Megrims and Monkfish (ICES, 2010) assessment results performed with GADGET. These age data include abundance, stock weight, landings weight, discards weight and maturity as well as exploitation pattern for landings and discards (see Table 4). Figure 4) shows that F_{max} is equal to .2650, and the Maximum Sustainable Yield is equal to 17,253 Tn. The mass of vessels match the yield associated with $F_{sq} = 0.83$.

6 Numerical findings

Table 6 shows average costs and profits per vessel using the DCF economic data for calibrating the model (see Cerviño *et al*, 2010). Calibrated model assumes that the value per kilo of hake is 8.97 euros. This value is lower than the 11.61 euros per hake found at the *The 2009 Annual Economic Report on the European Fishing Fleet*, (DCF). This difference is due to the fact that in 2007, sample vessels obtained in average 2.845 euros per kilo, price which is significantly smaller than the 4.30 euros per kilo reported to DCF. In terms of cost structure, the calibrated parameters show that variable costs represent 40% of revenues. This data is similar to the one obtained by Cerviño *et al.*

6.1 The role of number of days per vessel

Increasing days per vessel in 70% (from 156 to 264) impacts strongly on fleet profits. Table 6.1 shows that when there is a 70% increase in the number of days per vessel, the fleet expected value increases in a 65.67%. Increasing the number of days per vessel also implies reducing in 22% the fraction of fleet vessels that can have losses in the short run. When we introduce 156 days per vessel, model predicts that 47% of the fleet will have negative profits. If the number of days is increased up to 264, the probability of having negative profits falls down to 36 percent (see Figure 3).

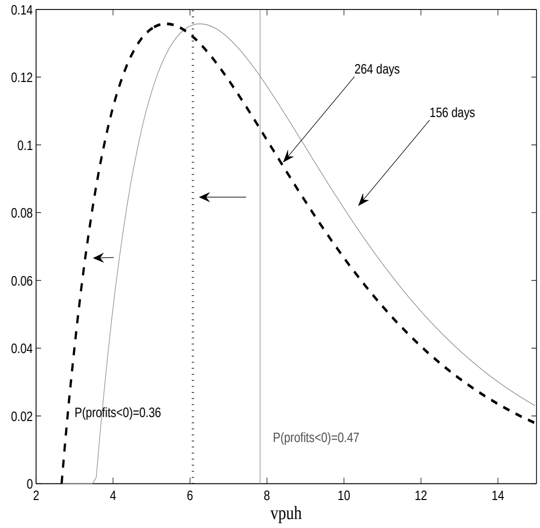


Figure 3: Effects of changes in the number of days per vessel, n.

Table 6: Changes in days per vessel, d

	2011		Δ
days (d)	156	264	69.23
Average value per kilo of hake ($E\varphi$)	9.40	8.40	-10.57
Annual income per kilo of hake (φd)	1465.70	2218.30	51.35
Annual cost per kilo of hake ($c_d d$)	553.72	937.07	69.23
Annual fixed cost per kilo of hake c_f	820.10	820.10	0.00
Expected vessel value per kilo of hake ($W(\varphi)$)	2416.01	4002.59	65.67
Inactive vessels ($\int_{\varphi^*}^{\hat{\varphi}}$)	0.00	0.02	

6.2 Fleet size and Fishing mortality

Changes in fishing mortality have an impact on fleet size. For calculating this impact, we can assume that each vessel's average daily hake landings evolve according to:

$$h(F) = \left(\frac{Y(F)}{Y_0}\right)^{\bar{\beta 1}} \times h \tag{40}$$

where $\bar{\beta}_1 = .3577$ is the average value of the parameter distribution.[5] Figure 6.2 shows the impact changes in fishing mortality hake : on Yield (upper left panel); on the change in vessel average daily hake landings, $\left(\frac{Y(F)}{Y_0}\right)^{\bar{\beta 1}}$, (upper right panel); on the mass (number) of vessels (lower left panel); and on fishery stock value (lower right panel). Both the mass of vessels and the fishery stock value are a function of the number of days per vessels.

The first result worth noticing is that for achieving F_{max} requires a reduction in the fleet mass less than proportional to the reduction in F. Achieving F_{max} increases total yield in 44%, while daily yields increase only in 14.32%. Therefore it is possible to maintain the current fleet mass while keeping the number of days per vessel constant. The fishery

Table 7: Changes in fishing mortality, F

Scenario	F	Yield	h	days	Mass of vessels	Value
F_{max}	0.2600	1.7251e+004	114.32	264	232.6155	1.1462e+006
F_{sq}	0.8000	1.1933 e+004	100.00	156	304.7641	6.0642e+005

stock value will be increased if the reduction in fishing mortality is obtained by a fleet mass reduction rather than by a reduction in the number of days per vessel. If the fleet mass is reduced in 25%, the number of days per vessel can be increased to 264. This fleet mass reduction also increases the fishery stock value, as the increase in the per vessel profitability compensates the fleet mass reduction.Table 7 summarizes these findings. A fishery rationalization policy that increases the number of days per vessel (from 156 to 264) and reduces fishing mortality from $F_{sq} = 0.80$ to $F_{max} = 0.26$ brings a 89% increase in profits while reducing current fleet in only 25%.

6.3 The role of $ITQ's$

Introducing ITQs that can be sold and leased allows sharing among all vessels the rationalization fishery policy surplus. This is due to the fact that ITQs increase the overall fleet rev-

[5] Remember that the β_1^i distribution exhibits a low dispersion.

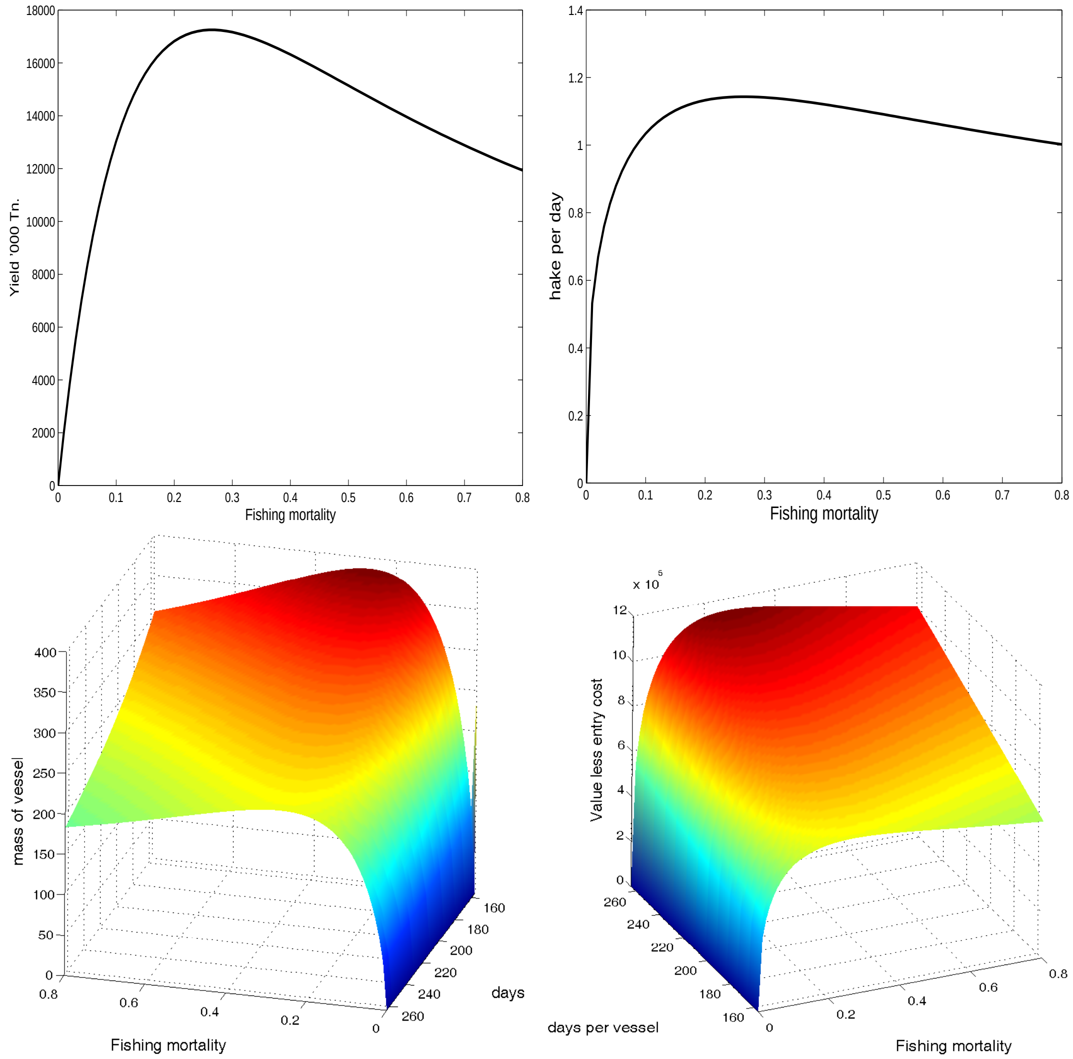


Figure 4: Vessel and Stock dynamics: Fmax, hake per day, fleet size and Total expected value.

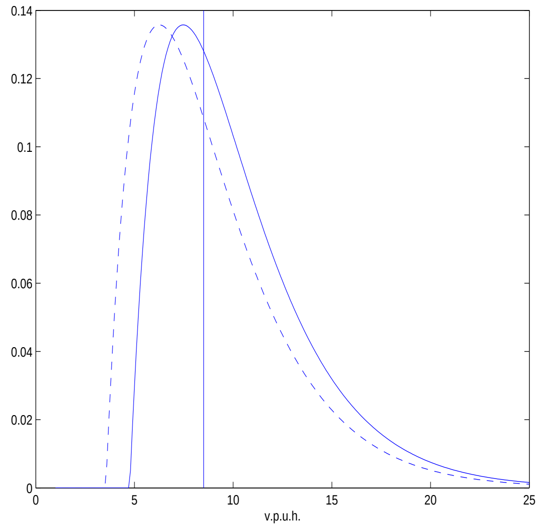


Figure 5: ITQ's

enue without having all vessels fishing. Formally, note that with ITQs $\int_{\hat{\varphi}_{itq}}^{\infty} f(\varphi|\varphi^*_{itq})d\varphi < 1$, therefore

$$M_{itq} = \frac{Y^T(F)}{\bar{h}\bar{d}\int_{\hat{\varphi}_{itq}}^{\infty} f(\varphi|\varphi^*_{itq})d\varphi} > \frac{Y^T(F)}{\bar{h}\bar{d}} = M_{without\ itq} \qquad \forall F \tag{41}$$

Introducing ITQs changes the incentives for remaining in the fishery. Vessels with $\varphi < \varphi^*_{itq}$ will sell ITQs and exit the fishery. On the contrary vessels with $\varphi \geq \varphi^*_{itq}$, will remain in the fishery. Figure 5 shows the impact of introducing ITQs. Note that the new fleet distribution shifts to the right. That is to say, the new distribution of vessels is in average more productive. Moreover, the existence of a lease market concentrates the total amount of fishing days in the most productive vessels $\varphi \geq \hat{*}_{itq}$.

Table 7 shows these results for seven different scenarios. The first column represents the reference fishery. Columns 2 through 7 show the impact of introducing ITQs while removing subsidies on variables and fixed costs. We have estimated that subsidies to variable costs (discounts in oil price, landing taxes, ...) may represent between a 75 and a 125% of current costs. Regarding fixed costs, vessels are required to cease their activity for a period of time along the year (1 month in 2010, and 1.5 month in 2009 and 2008). This closure of activity is subsidized with 20,000 euros per vessel and month. Each of these months of closure of activity is an indirect subsidy equivalent to a 10% of the fixed costs the model estimates.

We can point out that the introduction of ITQs in this fishery implies allocating to each vessel a quota equivalent to 147 times its average landings per day. Under these conditions, vessels obtaining total landings in value of 4.44 euros per kilo of hake or more will remain in the fishery. On the contrary, a 4.32% of the fleet will not attain the minimum necessary total landings and will sell fishing rights (at 99.15 euros per kilo).

Introducing leasing markets allows concentrating the total amount of fishing days in a 55.72% of the fleet. Leasing price will be equal to 4.96 euros per kilo and day. Given this price, the total value of landings per kilo of hake will be 12.30 euros in average (37% greater than the current average value)

Subsidies have shown to have little impact on fleet size and productivity and, therefore, on the fishery overall size. Subsidies do affect fleet profitability. Eliminating subsidies reduces ITQs leasing and selling prices and induces property concentration. When variable costs increase, ITQs prices diminish as a consequence of operating profits erosion. Increasing fixed cost brings a greater property concentration as many fishers will rather sell their rights and abandon the fishery.

Finally, introducing ITQs allows maintaining the current fleet size in terms of permit output holders. This result is possible because the ITQs allocation in terms of days per vessel is smaller than the current number of days per vessel.

7 Conclusions

to be done.

Table 8: Introducing ITQ's

	baseline		subsidies reduction					
	no ITQs	ITQs	low		medium		high	
$c_d/c_d^{baseline}$	1.00	1.00	1.75	1.75	2.00	2.00	2.25	2.25
$c_f/c_f^{baseline}$	1.00	1.00	1.10	1.20	1.10	1.20	1.10	1.20
Itq price per kilo of hake lease market(r_q)		4.96	2.65	3.00	1.77	2.11	0.88	1.22
Itq price per kilo of hake stock market(p_q)		99.15	53.06	59.92	35.31	42.17	17.57	24.42
Permit outputs per kilo of hake (q)		147.10	146.05	145.26	146.05	145.26	146.05	145.26
Minimum vpuh (φ^*)	2.98	4.44	4.76	5.08	4.76	5.08	4.76	5.08
Minimum active vpuh ($\hat{\varphi}$)	6.53	8.51	8.86	9.21	8.86	9.21	8.86	9.21
Survivors ($\int_{\varphi^*_{itq}}^{\infty} f_{2011}$)		95.68	92.53	88.95	92.53	88.95	92.53	88.95
Active fleet ($\int_{\hat{\varphi}_{itq}}^{\infty} f(\varphi\|\varphi^*_{itq})$)	100.00	55.72	55.32	55.02	55.32	55.02	55.32	55.02
Expected value per kilo of hake ($E\varphi$))	8.40	12.30	12.35	12.41	12.35	12.41	12.35	12.41
Expected vessel value ($W(\varphi)$)	4927.6	14585.6	7749.9	8703.9	5157.9	6125.9	2566.0	3547.9

A Appendix

A.1 Vessel dynamics

We follow Dixit and Pindyck [2] for solving this exit-delay problem. We know that the firm chooses to stay in the market as long as the firm has a positive option value. Let profits be

$$\pi = \begin{cases} A\varphi - b & \text{if} \quad A \geq 0 \\ -c & \text{if} \quad A < 0 \end{cases} \tag{42}$$

where

	without ITQs	with ITQ
A	n	$\bar{d}$
b	$c_d n + c_f$	$(r_q + c_d)\bar{d} + c_f - r_q q$
c	c_f	$c_f - r_q q$

The vessel chooses whether to remain in the fishery or not by solving

$$\begin{aligned} V(\varphi) &= \max_{exit} \left\{ p_q q, \pi(\varphi) + (1+\rho dt)^{-1} EV(\varphi + d\varphi) \right\} \\ st &: \begin{cases} d\varphi = \alpha\varphi dt + \sigma\varphi dz \\ \pi = \begin{cases} A\varphi - b & \text{if} \quad \varphi \geq \frac{b-c}{A} \\ -c & \text{if} \quad \varphi < \frac{b-c}{A} \end{cases} \end{cases} \end{aligned}$$

where the cutoff for not producing $\hat{\varphi} = \frac{b-c}{A}$ determines those vessels that are indifferent between producing or not. The following Lemma characterizes the value function and the cutoff for this economy.

Lemma 1. The minimum firm size exit, x, and the value of a firm are given by

$$x = \left(\frac{c + \rho p_q q}{(b-c)^{1-\beta_1} A^{\beta_1}} \frac{-\beta_2(\rho - \alpha)}{(\rho - \alpha\beta_2)} \right)^{\frac{1}{\beta_1}} \tag{43}$$

and

$$V(\varphi) = \begin{cases} C_1\varphi^{\beta_1} + C_2\varphi^{\beta_2} - \frac{c}{\rho} \quad if \quad \varphi \leq \frac{b-c}{A} \\ \\ B_2\varphi^{\beta_2} + \frac{A\varphi}{(\rho-\alpha)} - \frac{b}{\rho} \quad if \quad \varphi > \frac{b-c}{A} \end{cases} \tag{44}$$

Proof. The problem of a firm is given by

$$\begin{aligned} V(\varphi) &= \max_{exit} \left\{ p_q q, \pi(\varphi) + (1+\rho dt)^{-1} EV(\varphi + d\varphi) \right\} \\ st &: \begin{cases} d\varphi = \alpha\varphi dt + \sigma\varphi dz \\ \pi = \begin{cases} A\varphi - b & \text{if} \quad \varphi \geq \frac{b-c}{A} \\ -c & \text{if} \quad \varphi < \frac{b-c}{A} \end{cases} \end{cases} \end{aligned}$$

The solution to this equation satisfies

$$\frac{1}{2}\varphi^2\sigma^2 V''(\varphi,q) + \alpha\varphi V'(\varphi,q) - \rho V(\varphi,q) + \pi(\varphi,q) = 0 \tag{45}$$

Therefore, consider

$$V(\varphi) = \begin{cases} C_1\varphi^{\beta_1} + C_2\varphi^{\beta_2} + d_1 \quad if \quad \varphi \leq \frac{b-c}{A} \\ \\ B_1\varphi^{\beta_1} + B_2\varphi^{\beta_2} + c_2\varphi + d_2 \quad if \quad \varphi > \frac{b-c}{A} \end{cases} \tag{46}$$

Then the solution is equal to

$$V(\varphi) = \begin{cases} C_1\varphi^{\beta_1} + C_2\varphi^{\beta_2} - \frac{c}{\rho} \quad if \quad \varphi \leq \frac{b-c}{A} \\ \\ B_1\varphi^{\beta_1} + B_2\varphi^{\beta_2} + \frac{A\varphi}{(\rho-\alpha)} - \frac{b}{\rho} \quad if \quad \varphi > \frac{b-c}{A} \end{cases} \tag{47}$$

where $\beta_1 > 0$ and $\beta_2 < 0$ are given by

$$\begin{aligned} \beta_1 &= \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{\alpha}{\sigma^2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1 \\ \beta_2 &= \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt{\left(\frac{1}{2} - \frac{\alpha}{\sigma^2}\right)^2 + \frac{2\rho}{\sigma^2}} < 0 \end{aligned}$$

Then we have that B_1 is 0 because the value would be unbounded as $\varphi \to \infty$. We have four conditions[6] that determine the values of A_1, A_2, B_2 and x. Namely, these conditions are:

$$\begin{aligned} C_1\varphi^{\beta_1} + C_2\varphi^{\beta_2} - \frac{c}{\rho}\bigg|_{\varphi=x} &= p_q q \\ (B_2 - C_2)\varphi^{\beta_2} - C_1\varphi^{\beta_1} + \frac{A\varphi}{(\rho-\alpha)} - \frac{b-c}{\rho}\bigg|_{\varphi=\frac{b-c}{A}} &= 0 \\ \beta_1 C_1\varphi^{\beta_1} + \beta_2 C_2\varphi^{\beta_2}\bigg|_{\varphi=x} &= 0 \\ \beta_2(B_2 - C_2)\varphi^{\beta_2} - \beta_1 C_1\varphi^{\beta_1} + \frac{A\varphi}{(\rho-\alpha)}\bigg|_{\varphi=\frac{b-c}{A}} &= 0 \end{aligned}$$

Putting the fourth equation into the second to get rid of $C_2 - B_2$,

$$\begin{aligned} B_2 - C_2 &= C_1\left(\frac{b-c}{A}\right)^{\beta_1-\beta_2} - \frac{(b-c)^{1-\beta_2}A^{\beta_2}}{(\rho-\alpha)} + \frac{(b-c)^{1-\beta_2}A^{\beta_2}}{\rho} \\ C_1 &= \frac{-\beta_2\frac{b-c}{\rho} - (1-\beta_2)\frac{b-c}{(\rho-\alpha)}}{(\beta_2-\beta_1)\left(\frac{b-c}{A}\right)^{\beta_1}} \end{aligned}$$

[6]Two equations from the smooth pasting conditions and two more for the value matching ones.

and using the same strategy between the third and the first for C_2,

$$\begin{aligned} C_2 &= -\frac{\beta_1}{\beta_2} C_1 x^{\beta_1-\beta_2} \\ C_1 &= \frac{c+p_q q\rho}{x^{\beta_1}\rho}\left(\frac{\beta_2}{\beta_2-\beta_1}\right) \end{aligned}$$

and finally combining the resulting two expressions for getting rid of C_1, we get the equation on x :

$$\frac{c+p_q q\rho}{\rho}\left(\frac{\beta_2}{-\beta_2\frac{b-c}{\rho}-(1-\beta_2)\frac{b-c}{(\rho-\alpha)}}\right)\left(\frac{b-c}{A}\right)^{\beta_1} = x^{\beta_1} \tag{48}$$

Substituting the previous equations gives the desired results. ■.

The previous Lemma found the general solution for the economy we are describing. Therefore the expected value of entering $\int_x^\infty V(\varphi) f(\varphi)\, d\varphi = c_E + p_q q$, is given by

$$\begin{aligned} &\int_x^{\frac{b-c}{A}} \left(\frac{(\rho-\alpha\beta_2)}{(\beta_1-\beta_2)\rho(\rho-\alpha)}(b-c)^{1-\beta_1} A^{\beta_1}\left(\varphi^{\beta_1}-\frac{\beta_1}{\beta_2}x^{\beta_1-\beta_2}\varphi^{\beta_2}\right)-\frac{c}{\rho}\right) f(\varphi)\, d\varphi \\ &+\int_{\frac{b-c}{A}}^{\infty}\left(\begin{array}{c} \frac{(\rho-\alpha\beta_2)}{(\beta_1-\beta_2)\rho(\rho-\alpha)}\left(-\frac{\beta_1}{\beta_2}(b-c)^{1-\beta_1}A^{\beta_1}x^{\beta_1-\beta_2}+(b-c)^{1-\beta_2}A^{\beta_2}\right)\varphi^{\beta_2} \\ +\frac{A\varphi}{(\rho-\alpha)}-\frac{b}{\rho} \end{array}\right) f(\varphi)\, d\varphi \\ = \;& c_E + p_q q \end{aligned}$$

Note that

$$\frac{\partial \int_{\varphi^*}^{\infty} V(\varphi) f(\varphi)\, d\varphi}{\partial q} = p_q \Rightarrow p_q = \frac{r}{\rho} \tag{49}$$

References

[1] Cerviño, S., E. Jardim and J.M. da Rocha. 2010. The value of Southern hake recovery plan: What should have happened if it had been perfectly implemented and what will happen if is not implemented? Working Document for STECF- SGMOS 10-06b. Vigo, October 2010.

[2] R.K. Dixit and R.S. Pindyck, 1994. Investment under Uncertainty. Princeton, NJ: Princeton University Press.

[3] Egea, J.A., Balsa-Canto, E., García, M.S.G. and J.R. Banga, 2009. Dynamic Optimization of Nonlinear Processes with an Enhanced Scatter Search Method. Industrial & Engineering Chemistry Research, 48(9), 4388-4401.

[4] H. Hopenhayn, 1992. Entry, Exit, and firm Dynamics in Long Run Equilibrium. Econometrica, 60, 1127-1150.

[5] H. Hopenhayn and R. Rogerson. 1993. Policy Distortions and Aggregate Productivity with Heterogeneous Establishments. Journal of Political Economy, 101, 915-38.

[6] Grafton R. Q., R. Arnason, T. Bjørndal, D. Campbell, H. F. Campbell, C. W. Clark, R. Connor, D. P. Dupont, R. Hannesson, R. Hilborn, J. E. Kirkley, T. Kompas, D. E. Lane, G. R. Munro, S. Pascoe, D. Squires, S. I. Steinshamn, B. R. Turris, and Q. Weninger, 2006. Incentive-based approaches to sustainable Fisheries. Canadian Journal Fisheries and Aquatic Sciences, Vol. 63.

[7] Grafton R. Q., D. Squire and K.J. Fox, 2000. Private Property and Evonomic Efficiency: A Study of a Common-Pool Resource. Journal of Law and Economics, 43, 679-713.

[8] Kompas T. and T. Nu Che, 2005. Efficiency Gains and Cost Reductions from Individual Transferable Quotas: A Stochastic Cost Frontier for the Australian South East Fishery. Journal of Productivity Analysis, 23, 285-307.

[9] Kulmala S., H. Peltomäki, M. Lindroos, P. Söderkultalahti, S. Kuikka, 2005. Individual transferable quotas in the Baltic Sea herring fishery: A socio.bioeconomic analysis. Fisheries Research, 84, 368-377.

[10] E. Luttmer, 2007. Selection, Growth, and the Size Distribution of Firms. Quarterly Journal of Economics, 122, 1103-1144.

[11] Weninger, Q. and R.E. Just, 2002. Firm Dynamics with Tradable Output Prices. American Journal of Agricultural Economics 84, 562-584.

[12] Weninger, Q., 2008. Economic Benefits of Management Reform in the Gulf of Mexico Grouper Fishery: A Semi-Parametric Analysis, Environmental and Resource Economics Vol. 41.

European Commission

EUR 24900 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen
Title: Scientific, Technical and Economic Committee for Fisheries. Impact Assessment of multi-annual plans for Southern hake, angler fish and Nephrops (STECF-11-06).

EWG-11-07 members: Nick Bailey, Francois Bastardie, Jörg Berkenhagen, Massimiliano Cardinale, Santiago Cerviño, Jose Maria Da Rocha, Chris Darby, Ralf Döring, Margit Eero, Norman Graham, Steven Holmes, Tore Jakobseb, Katharina Jantzen, Eskild Kirkegaard, Sarah Kraak, Alexander Kempf, Sasha Maguire, Rasmus Nielsen, Maris Plikshs, John Powell, Krzysztof Radtke, Tiit Raid, M. Paz Sampedro, Pieter-Jan Schon, Robb Scott, Cristina Silva, John Simmonds (Chair), Clara Ulrich Rescan, Willy Vanhee,Chris Zimmermann.

STECF members: Casey, J., Abella, J. A., Andersen, J., Bailey, N., Bertignac, M., Cardinale, M., Curtis, H., Daskalov, G., Delaney, A., Döring, R., Garcia Rodriguez, M., Gascuel, D., Graham, N., Gustavsson, T., Jennings, S., Kenny, A., Kirkegaard, E., Kraak, S., Kuikka, S., Malvarosa, L., Martin, P., Motova, A., Murua, H., Nowakowski, P., Prellezo, R., Sala, A., Somarakis, S., Stransky, C., Theret, F., Ulrich, C., Vanhee, W. & Van Oostenbrugge, H.

Luxembourg: Publications Office of the European Union
2011 – 110 pp. – 21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1831-9424 (online), ISSN 1018-5593 (print)
ISBN 978-92-79-20806-5
doi:10.2788/40340

Abstract

A joint ICES / STECF meeting was held in Hamburg 20-24 June 2011, to prepare an impact assessment for Southern hake, Nerphrops and Angler fish and Baltic cod and an Evaluations of existing plans for Kattegat, North Sea, West of Scotland and Irish Sea cod. The meeting involved STECF, ICES scientists dealing with Economy and Biology and included Observers (Commission staff, Managers, Stakeholders). Three separate reports to the STECF were prepared by the EWG-11-07, one on the Impact Assessment of Southern hake, Nerphrops and Angler fish (STECF 11-06) and the second on the Impact Assessments for Baltic cod (STECF 11-05) and the third on the Evaluation of Cod in Kattegat, North Sea, West of Scotland and Irish Sea (STECF 11-07). All reports were reviewed by the STECF during its 37th plenary meeting held from 11 to 15 July 2011 in Copenhagen, Denmark. The following observations, conclusions and recommendations represent the outcomes of that review for Southern hake, Nerphrops and Angler fish report.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

LB-NA-24900-EN-N

JRC
EUROPEAN COMMISSION

Publications Office

ISBN 978-92-79-20806-5