WKSHAKE2 2010

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ICES Workshop on Iberian mixed fisheries management plan evaluation of Southern hake, *Nephrops* and anglerfish (WKSHAKE2)

22 – 26 November 2010

Lisbon, Portugal

ICES
International Council for the Exploration of the Sea
CIEM
Conseil International pour l'Exploration de la Mer

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Executive summary

The ICES' Workshop on Iberian mixed fisheries management plan evaluation of Southern hake, *Nephrops* and anglerfish [WKSHAKE2] (Chair: Carl O'Brien (UK)) was established in response to an EC request to develop harvest control rules (HCRs) for the mixed fishery of Southern hake, *Nephrops* and anglerfish.

Council Regulation (EC) N° 2166/2005 of 20 December 2005 established the rules for the recovery of the southern hake and *Nephrops* stocks in the Cantabrian Sea and Western Iberian Peninsula; and amended Council Regulation (EC) N° 850/98 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. The plan aims at recovering the stock to a spawning stock biomass above 35 000 t and to reduce fishing mortality to 0.27 by 2015. The main elements of the plan are a 10% annual reduction in F and a ±15% constraint on TAC change over the years, following the Policy statement's rules.

WKSHAKE2 met at IPIMAR, Lisbon, Portugal, 22-26 November 2010 to consider the three Terms of Reference (ToRs):

a) Develop Harvest Control Rules for the Iberian mixed fishery of S. hake, *Nephrops* and anglerfish in order to achieve F_{MSY} by 2015.

b) Calculate the probability P ($F_{2015} \leq F_{MSY}$).

c) Propose any other effort regime adaptation of the current one and evaluate its options, if appropriate.

Initially, evaluations were performed separately for each stock and the single stock outcomes of this workshop are summarised next.

<u>Southern hake in Divisions VIIIc and IXa</u>: The EC's F policy with a 10% annual reduction does not achieve F_{MSY} in 2015. In addition, none of the HCRs considered in this workshop achieved F_{MSY} in 2015 in the presence of TAC overshoot. Conditioning an HCR to achieve F_{MSY} in 2015 with a multiplicative F reduction and either a ±15% or ±25% TAC constraint leads to similar probabilities of achieving F_{MSY} in 2015 but the ±15% TAC constraint produces slightly higher SSB in 2015.

<u>Anglerfish in Divisions VIIIc and IXa (*Lophius piscatorius* and *Lophius budegassa*)</u> : Due to the starting conditions of *L. budegassa*, with F_{2009} below F_{msy} (F_{2009}/F_{msy} =0.45), all scenarios tested keep *F* below F_{msy}. So the analysis of results within the report is mainly focused on *L. piscatorius* - when no TAC constraint is applied in the scenarios investigated, the *L. piscatorius* biomass increases slowly towards B_{msy}. The effect of TAC constraints (±15% and ±25% were explored) is dominant, all HCRs examined perform in the same way when the same TAC constraint is applied. This is because these TAC constraint levels force F(2011) below F_{MSY}. Different TAC constraints have clear impact on the development of SSB and yield during the next 10 years and a choice should result from a compromise between various aspects. TAC overshoot reduces the probability of *F* being equal to or below F_{msy} in 2015 to levels below 95% and slows down the recovery of the biomass. None of the HCRs considered in this workshop will achieve F_{msy} in 2015 if the TAC is overshot.

<u>*Nephrops* (FUs 28 and 29)</u>: New CPUE standardization accepted as the basis of a stock assessment at this workshop – stock annex revised. Recruitment has been at a low/median level with SSB presenting an increasing trend in recent years. Underexploited at present with respect to F_{MSY} and with the potential for F to increase. An

increase in F on *Nephrops* is to be expected if the future rose shrimp abundance decreases because *Nephrops* are caught in a crustacean fishery that targets rose shrimp.

Nephrops (FU 30): 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 that the bottom trawl fleet of the Gulf of Cadiz consists of only one, highly multi-specific *métier*, any F reduction measures applied to the fleet catching hake should also cause a reduction on the fishing pressure applied to *Nephrops*. The strong seasonality of the *Nephrops* fishery, with most of the landings between April and September, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

Nephrops (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, 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*. The strong seasonality of the *Nephrops* fishery, with most of the landings between May and August, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

This workshop considered explicitly the biological implications of management options within HCRs and TAC overshoot scenarios and the participants note that an economic and social impact assessment of a long-term management plan has recently been undertaken by STECF.

The analytical evaluations above have all been undertaken on a stock by stock basis in the first instance. Subsequently, the description of the fisheries was updated and considerations of mixed fishery issues investigated and discussed:

Description of the fisheries and seasonality of landings – There are differences between the seasonality of the Portuguese and Spanish catches which are further explained in the report. In general, however, the trawl fleets are concentrated in the second and third quarters, while gillnets show no clear seasonality in catches. For long-liners catches are concentrated in the second quarter. A possible way to improve the impact of static gears could be to enforce continuous closed periods so that fishermen will have to bring their gear ashore and stop fishing during certain periods.

Southern hake/anglerfish linkage – Hake is the most over-exploited of these two stocks and hence, the management of anglerfish might exploit the fact that there is one fleet (Rasco) that does not catch hake. However, the "Rasco" fleet must also undergo a reduction in *F* in order to bring the *F* of *L. piscatorius* to F_{msy} in 2015 with a high probability. This reduction does not need to be as severe as for the other fleets which also catch hake. Conversely, if the fleets that catch both hake and anglerfish do not follow the intended F reductions corresponding to the hake management, just reducing F on the "Rasco" fleet will not be enough for *L. piscatorius* to reach Fmsy by 2015. Using hake as the key driver for the management of the mixed fisheries would lead to a loss in yield for anglerfish.

Spatial management of anglerfish - Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce and the stock structure remains unclear. The scientific sampling programmes 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 is almost null where the percentage of *L. budegassa* is more than 90%. 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.

1 Introduction

1.1 Terms of reference

The ICES' Workshop on Iberian mixed fisheries management plan evaluation of Southern hake, *Nephrops* and anglerfish [WKSHAKE2] (Chair: Carl O'Brien (UK)) was established in response to an EC request to develop harvest control rules (HCRs) for the mixed fishery of Southern hake, *Nephrops* and anglerfish.

WKSHAKE2 met at IPIMAR, Lisbon, Portugal, 22-26 November 2010 to consider the three Terms of Reference (ToRs):

a) Develop Harvest Control Rules for the Iberian mixed fishery of S. hake, *Nephrops* and anglerfish in order to achieve F_{MSY} by 2015.

b) Calculate the probability P ($F_{2015} \leq F_{MSY}$)

c) Propose any other effort regime adaptation of the current one and evaluate its options, if appropriate.

WKSHAKE2 will report by 29 November 2010 for the attention of ACOM.

1.2 Background

The workshop will provide the scientific background for the advice on a special request on mixed species management plan evaluations.

Council Regulation (EC) N° 2166/2005 of 20 December 2010 established the rules for the recovery of the southern hake and *Nephrops* stocks in the Cantabrian Sea and Western Iberian Peninsula; and amended Council Regulation (EC) N° 850/98 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. The plan aims at recovering the stock to a spawning stock biomass above 35 000 t and to reduce fishing mortality to 0.27 by 2015. The main elements of the plan are a 10% annual reduction in F and a ±15% constraint on TAC change over the years, following the Policy statement's rules.

ICES received this special request in February 2010 from the EC for the evaluation of harvest control rules for southern hake, anglerfish and *Nephrops*. The ToRs of this workshop (see Section 1.1) have been chosen to address this request.

Initially, with the agreement of ACOM, scientists in IPIMAR (Portugal) undertook an evaluation earlier in the year (ICES 2010a) but it was concluded from ICES' review of their study that further work was necessary (see Section 1.4). The ACOM leadership decided to set up WKSHAKE2 to address the request more fully between the two countries, Spain and Portugal, involved in the fisheries under the chairmanship of the ACOM Vice-chair (Carl O'Brien, UK) and hence, provide advice to the EC.

The proposal of a recovery plan for southern hake and *Nephrops* started in 2003 (Anon., 2003) with a meeting in Lisbon, where scientists from IEO and IPIMAR gathered together to discuss the best strategy for driving the stock to F_{MSY} in 2015. At the time, no TAC overshoot was evident and recruitments were at a very low level. The recommended strategy from amongst those tested was an annual 10% decrease in F from that of the previous year.

The Recovery Plan (RP) was implemented in 2006, with some effort control measures already in place from 2005.

Five years after the implementation of the RP, F does not appear to have reduced towards F_{MSY} and the analyses performed in 2010, using updated data and more sophisticated modelling, show once again that a decrease in F is required, now at a pace of approximately 20% per year. Additionally, the present analysis clearly shows that failing to implement the suggested management strategy will result in a failure to achieve the desired objective.

1.3 Structure of the report

The structure of the report is as follows:

- general introduction, terms of reference and the background to the process so far within ICES in Section 1.4;
- technical descriptions of the harvest control rules (HCRs) and TAC overshoot scenarios for southern hake and anglerfish in Section 2;
- multi-annual management options for southern hake in Section 3;
- multi-annual management options for anglerfish in Section 4;
- multi-annual management options for *Nephrops* (FUs 28 and 29; FU 30; FUs 25, 26-27 and 31) in Sections 5, 6 and 7, respectively;
- mixed fisheries considerations in Section 8;
- discussion and conclusions in Section 9;
- working papers and documents are listed in Section 10; and
- references are collated in Section 11.

1.4 Reviewers' comments on the previous IPIMAR study

ICES noted the intense effort by IPIMAR to answer the request and the work was seen as important in beginning the process of addressing and answering the special request. Specifically, the following suggestions were proposed to allow ICES to answer the special request.

MSE: *Move towards a Management Strategy Evaluation (MSE) approach rather than using a projection based approach. This would allow consideration of the HCRs with respect to: alternative plausible values of growth and natural mortality (in the case of hake); account for assessment error (in particular, effects of retrospective patterns on the current hake assessment, suggesting that the assessment might underestimate SSB and overestimate F, could be examined); and account for implementation error (hake and anglerfish catches well above TAC).*

> WKSHAKE2 response and approach – This remains an aspiration for the future. Adoption of an MSE approach was discussed extensively by the participants of the workshop and a decision taken not to pursue this further at the present time. Preliminary analyses undertaken in the months leading up to this workshop indicated that the EC's F policy with a 10% annual reduc-

tion has a low probability of achieving F_{MSY} by 2015 for the stock in the weakest state (southern hake), even in the absence of assessment and implementation errors. Alternative multi-annual control rules have been explored and the results are presented; together with an evaluation of the implications of TAC overshoot.

RECRUITMENT ASSUMPTIONS: *For all species, examine the robustness of results from HCRs with respect to alternative assumptions of recruitment in the projection years. For hake, the coefficient of variation considered for the recruitment distribution in the projection years seems too low. Ideally, more realistic recruitment assumptions (e.g. incorporating autocorrelation in time) should be considered. If this is not possible, then the range of recruitment values in the projection years should at least encompass the range observed in the historic period.*

WKSHAKE2 response and approach – Alternative recruitment assumptions have been incorporated into the evaluations based upon analyses of the historical time series. However, the potential effects of autocorrelation were not investigated and remain a possibility for the future.

NEPHROPS*: None of the Nephrops FUs covered by the plan has an analytical assessment accepted by ICES and none have defined reference points. At present, only FUs 28-29 (southwest and south Portugal) and FU 30 (Gulf of Cádiz) are worth considering in the analysis, as the other FUs covered by the plan are depleted (ICES recommends zero catch for them). What should be done about the FUs that are worth considering but that do not have an ICES accepted analytical assessment or reference points?*

WKSHAKE2 response and approach – This workshop's report presents a new assessment for *Nephrops* (FUs 28 and 29) which the participants have accepted and which has been further evaluated in the context of HCRs. Exploratory investigations only have been undertaken for *Nephrops* (FU 30) and *Nephrops* (25, 26-27 and 31) and no new assessments are presented for these two stocks.

ToR a): *Suggesting other potential HCRs to achieve F_{MSY} by 2015; this should be done and compare them on the basis of their implications for yield (both amount of yield and interannual variability/stability) and risk to population. For example, one might consider constant annual decreases from current F to F_{MSY} on a linear scale (as in ICES' MSY transition approach) or on a multiplicative scale (i.e. F decreases by a constant percentage every year). Additionally, if a TAC constraint applies in a particular year, implying that the F reduction in that year is not as large as originally intended, then the rate of annual decrease could be recomputed and modified appropriately so that the HCR still achieves F_{MSY} by 2015. All these possibilities correspond to different plausible HCRs, and comparing their consequences for yield and risk to population would help to choose among them.*

WKSHAKE2 response and approach - Alternative harvest control rules (HCRs) and TAC overshoot scenarios for southern hake and anglerfish have been proposed and evaluated. The performance of these rules and scenarios has been judged against the objective of achieving F_{MSY} by 2015.

MIXED FISHERIES: *Time and resources will determine the potential to develop complex simulations. Simplification and the use of assumptions are appropriate. However, in the current evaluation two extremes were considered: no interaction whatsoever between fisheries (so each stock has its own transition scheme towards F_{MSY}, independently of the other stocks); and fisheries are completely common (so the annual F reductions are the same for all stocks). ICES considers that these two simplified scenarios are not enough to address the request.*

WKSHAKE2 response and approach – The descriptions of the fisheries have been updated from those presented in ICES (2010a). Fishery linkages between southern hake and anglerfish have been investigated further and discussed.

*F_{MSY} **TARGETS:** ICES recommends consideration of the methodology used by WGHMM to test F_{MSY} candidates. The current evaluation did not use this approach.*

WKSHAKE2 response and approach – This was discussed by the participants of the workshop. Southern hake was discussed during this year's WGHMM meeting (ICES, 2010b), $F_{0.1}$ was adopted by this workshop as an F_{MSY} for *Nephrops* (FUs 28 and 29), and the current values for F_{MSY} as used by ICES in their assessment were adopted for anglerfish.

***WORKING METHOD:** The EC request is very challenging - evaluations of HCRs for the mixed fishery of hake, Nephrops and anglerfish, in order to achieve F_{MSY} by 2015. Properly addressing this request would require at least one physical meeting by relevant scientists (ideally with managers and stakeholders: the original plan for this, as was discussed at the end of 2009, was to have a joint ICES/STECF meeting), it is very difficult to discuss these issues by correspondence, as some of them are very technical whereas others (e.g. simplifying mixed fisheries assumptions) may require considerable discussion and agreement between different scientists and input from those that know more about the fisheries. One possibility might be to have a first physical meeting, in which preliminary work should be presented and issues discussed, followed by inter-sessional work and concluding the work in a second physical meeting.*

WKSHAKE2 response and approach – The establishment of this workshop and its meeting in Lisbon address the points raised.

2 Harvest control rules and TAC overshoot scenarios

This section describes the harvest control rules (HCRs) and TAC overshoot scenarios tested for southern hake and anglerfish.

2.1 Definition of harvest control rules

The HCRs will be referenced as follows:

HCR 0: "Fstquo";

HCR 1: "10% Annual Decrease";

HCR 2: "Fmsy in 2015"; and

HCR 3: "Fmsy in 2011"

with each defined below.

TAC constraints (maximum change allowed in the TAC between consecutive years):

HCR 0 is only examined under no TAC constraints, as it is just considered as a "control" case and not a real HCR.

HCRs 1-3 are examined under no TAC constraints and in combination with TAC constraints of ±15% and ±25%.

A distinction is made between $F_{\mathrm{HCR}}(y)$ and $F_{\mathrm{real}}(y)$, the former denoting the F corresponding to application of the HCR in year y and the latter being the F value that actually happens in that year. In other words, when conducting projections under a given HCR, the value of F proposed by the HCR in year y is $F_{\text{HCR}}(y)$ but the population evolves to year (y+1) according to $F_{\text{real}}(y)$. Even though $F_{\text{HCR}}(y)$ and $F_{\text{real}}(y)$ may be different it is assumed that they are linked (otherwise there would be no point in having an HCR). Under an HCR, the TAC in year y is assumed to be set as the landings corresponding to $F_{\text{HCR}}(y)$. For hake, discards are incorporated in the analysis and $F_{\text{HCR}}(y)$ relates to the total catch. Landings are computed as a proportion of the catch, with this proportion depending on length. If the TAC is overshot then $F_{\text{real}}(y) > F_{\text{HCR}}(y)$. In HCRs 1 and 2 $F_{\text{HCR}}(y)$ will be defined based on $F_{\text{HCR}}(y-1)$ instead of $F_{\text{real}}(y-1)$, to avoid that TAC overshoot prevents the HCRs from advising the F reductions originally intended. The latter was found to be a problem in the application of the current recovery plan for southern hake and Iberian *Nephrops*, so the distinction between $F_{\text{HCR}}(y)$ and $F_{\text{real}}(y)$ is explicitly made in this report.

It is assumed that fishing mortality in 2010 is equal to F_{stquo} (defined in Section 3 for southern hake and Section 4 for anglerfish, respectively), i.e. $F_{\text{real}}(2010) = F_{\text{stquo}}$. HCRs start being applied in 2011.

In HCR 0 ("Fstquo") $F_{\text{real}}(y) = F_{\text{stquo}}$ in all years.

HCRs 1-3 start from $F_{\text{HCR}}(2010) = F_{\text{stquo}}$ and $\text{TAC}(2010)$ (the TAC the EU set for the stock for 2010). For y>2010, $F_{\text{HCR}}(y)$ is defined in two steps.

<u>FIRST STEP</u>: Define $F_{\text{HCR,first}}(y)$. This step depends on the HCR.

HCR 1 ("10% Annual Decrease"): For each y>2010,

(2.1) $$F_{\text{HCR,first}}(y) = \max\{0.9F_{\text{HCR}}(y-1), F_{\text{MSY}}\}.$$

HCR 2 ("Fmsy in 2015"):

(2.2) $$F_{\text{HCR,first}}(y) = \max\left\{F_{\text{HCR}}(y-1)\left(\frac{F_{\text{MSY}}}{F_{\text{HCR}}(y-1)}\right)^{1/(2015-y+1)}, F_{\text{MSY}}\right\}$$, for 2010<y<2015,

(2.3) $$F_{\text{HCR,first}}(y) = F_{\text{MSY}},$$ for y ≥2015.

HCR 3 ("Fmsy in 2011"): For all y>2010,

(2.4) $$F_{\text{HCR,first}}(y) = F_{\text{MSY}}.$$

<u>SECOND STEP</u>: Define $F_{\mathrm{HCR}}(y)$ taking TAC constraints into account. This step is the same for all HCRs. Let $L(F(y))$ denote the landings (in weight) corresponding to fishing mortality $F(y)$ and $\mathrm{TAC}(y)$, the TAC in year y.

If there are no TAC constraints, then $F_{\mathrm{HCR}}(y) = F_{\mathrm{HCR,first}}(y)$ and $\mathrm{TAC}(y) = L(F_{\mathrm{HCR}}(y))$.

If there are TAC constraints three situations may arise (where $\mathrm{TAC_{const}}$ denotes the percentage change in TAC allowed between consecutive years):

(2.5) If $\mathrm{TAC}(y-1)\left(1-\frac{\mathrm{TAC_{const}}}{100}\right) \le L(F_{\mathrm{HCR,first}}(y)) \le \mathrm{TAC}(y-1)\left(1+\frac{\mathrm{TAC_{const}}}{100}\right)$, then $F_{\mathrm{HCR}}(y) = F_{\mathrm{HCR,first}}(y)$ and $\mathrm{TAC}(y) = L(F_{\mathrm{HCR}}(y))$.

(2.6) If $L(F_{\mathrm{HCR,first}}(y)) > \mathrm{TAC}(y-1)\left(1+\frac{\mathrm{TAC_{const}}}{100}\right)$, then $\mathrm{TAC}(y) = \mathrm{TAC}(y-1)\left(1+\frac{\mathrm{TAC_{const}}}{100}\right)$ and $F_{\mathrm{HCR}}(y)$ is the value that fulfills $L(F_{\mathrm{HCR}}(y)) = \mathrm{TAC}(y)$.

(2.7) If $L(F_{\mathrm{HCR,first}}(y)) < \mathrm{TAC}(y-1)\left(1-\frac{\mathrm{TAC_{const}}}{100}\right)$, then $\mathrm{TAC}(y) = \mathrm{TAC}(y-1)\left(1-\frac{\mathrm{TAC_{const}}}{100}\right)$ and $F_{\mathrm{HCR}}(y)$ is the value that fulfills $L(F_{\mathrm{HCR}}(y)) = \mathrm{TAC}(y)$.

For southern hake, the latter equation is occasionally found either not to have a solution or the solution corresponds to a very large value of F. To handle these instances, a maximum value of 2 is imposed on $F_{\mathrm{HCR}}(y)$. When this upper bound is reached, $F_{\mathrm{HCR}}(y) = 2$ and $L(F_{\mathrm{HCR}}(y)) < \mathrm{TAC}(y)$, i.e. the landings corresponding to $F_{\mathrm{HCR}}(y)$ are below the set TAC for year y.

Additional Comments

HCR 1 applies a 10% annual reduction every year (unless prevented by TAC constraints) until F_{MSY} is reached. The EC request to ICES on 20 January 2010, specifically asked for advice concerning HCR 1.

HCR 2 has been designed in order to reach F_{MSY} exactly in 2015 starting from F_{stquo} in 2010 and taking equal annual steps on a multiplicative scale, so F is reduced by the same percentage every year. Because TAC constraints can change the F value originally intended by the HCR (i.e. the $F_{\mathrm{HCR,first}}(y)$ value resulting from "First Step" above), it is necessary to re-compute the equal annual steps each year y starting from

$F_{\mathrm{HCR}}(y-1)$ and taking into account the number of years remaining until 2015. In the absence of TAC overshoot, the only thing that may prevent HCR 2 from reaching F_{MSY} in 2015 is a TAC constraint acting in 2015.

HCRs 0 and 3 represent the two extremes considered in this document. HCR 0 ("Fstquo") represents a situation where HCRs are not implemented at all and fishing mortality remains at current levels (F_{stquo}). At the other extreme, HCR 3 ("Fmsy in 2011") aims for fishing at F_{MSY} already from 2011, unless TAC constraints prevent this.

2.2 TAC overshoot scenarios

Given that southern hake and anglerfish TACs have been substantially exceeded since 2004, it is important to examine the performance of the HCRs under TAC overshoot situations.

Possible mechanisms for TAC overshoot are next presented. The aim is not to find the best possible model to fit the TAC overshoot levels observed in the past, but to have reasonably realistic formulations that allow testing the performance of HCRs in this kind of situation.

TAC overshoot is assumed to occur only when F corresponding to application of the HCR in year y is lower than the realised F in the previous year, i.e. when $F_{\mathrm{HCR}}(y) < F_{\mathrm{real}}(y-1)$, so that the HCR implies a reduction in F.

Two different overshoot mechanisms are considered – Type 1 and Type 2.

Type 1

TAC overshoot is caused by a "resistance" to reduce F. This is most easily modelled as F overshoot and the following formulation is used:

(2.8)
$$F_{\mathrm{real}}(y) = F_{\mathrm{HCR}}(y)\left\{\frac{F_{\mathrm{real}}(y-1)}{F_{\mathrm{HCR}}(y)}\right\}^{z},$$

where the exponent z is randomly drawn from a $\mathrm{Beta}(s1, s2)$ distribution (using a different draw in every projection year and replicate). A Beta distribution can take any value in the range (0,1). The maximum level of TAC overshoot occurs when z is equal to 1, in which case the realised F in year y equals the F realised in the previous year. If z is equal to 1 in all years, this corresponds to HCR 0 ("Fstquo"), i.e. the situation where F remains at current levels. The other extreme occurs if z is equal to 0, in which case the TAC is not overshot. How close z is to 0 or 1 is controlled by the values of the parameters $s1$ and $s2$, which determine the mean and variance of the Beta distribution. Two options are examined:

- **"TAC overshoot Type 1, Medium overshoot"**: $z \sim \mathrm{Beta}(1,1)$
- **"TAC overshoot Type 1, Very high overshoot"**: $z \sim \mathrm{Beta}(15,1)$

Figure 2.1 plots $F_{\mathrm{real}}(y)/F_{\mathrm{HCR}}(y)$ (the amount of F overshoot) as a function of $F_{\mathrm{HCR}}(y)/F_{\mathrm{real}}(y-1)$, for the two options considered. The figure shows that $F_{\mathrm{real}}(y)/F_{\mathrm{HCR}}(y)$ decreases as $F_{\mathrm{HCR}}(y)/F_{\mathrm{real}}(y-1)$ increases towards 1. This makes sense under the assumption that there is a resistance to reduce F: if that is the case, the amount by which $F_{\mathrm{HCR}}(y)$ is overshot is likely to depend on how far apart $F_{\mathrm{HCR}}(y)$ and $F_{\mathrm{real}}(y-1)$ are and may be expected to decrease as these two quantities approach each other. If $F_{\mathrm{HCR}}(y)$ is close to $F_{\mathrm{real}}(y-1)$, high TAC overshoot seems unlikely, as this would imply an increase (possibly a big one) in the realised value of F, which would not be expected under recovery or management plan regulations specifically aimed at reducing F (even if F does not decrease as intended by the regulations, neither does it seem reasonable to expect significant increases in F). The green line in each of the panels of Figure 2.1 corresponds to the upper bound z=1, which is the situation where the realised F in year y stays the same as in year y-1.

Type 2

The TAC in year y (obtained from application of the HCR, as explained in Section 2.1) is exceeded by a certain percentage. In other words, $F_{\mathrm{real}}(y)$ is the value which fulfills

(2.9) $$L(F_{\mathrm{real}}(y)) = \mathrm{TAC}(y)(1+z),$$

where $L(F(y))$ denotes the landings (after taking due account of discards in the case of hake) corresponding to fishing mortality $F(y)$ and z is randomly drawn from a $\mathrm{Beta}(s1, s2)$ distribution (using an independent draw for each projection year and replicate). $F_{\mathrm{real}}(y-1)$ is imposed as an upper bound on $F_{\mathrm{real}}(y)$, so that TAC overshoot will not cause the realised F to increase from the previous year. This feature is also present in the other mechanism for TAC overshoot, described by equation (2.8). Two options are examined:

- **"TAC overshoot Type 2, Medium overshoot"**: $z \sim \mathrm{Beta}(1,1)$
- **"TAC overshoot Type 2, Very high overshoot"**: $z \sim \mathrm{Beta}(15,1)$

The 5th, 50th and 95th percentiles of a Beta(1,1) distribution are 0.05, 0.5 and 0.95, so under "Medium overshoot" there is 90% probability that the TAC is exceeded by some amount between 5 and 95 per cent. Under "Very high overshoot", there is 90% probability that the TAC is exceeded by at least 85%.

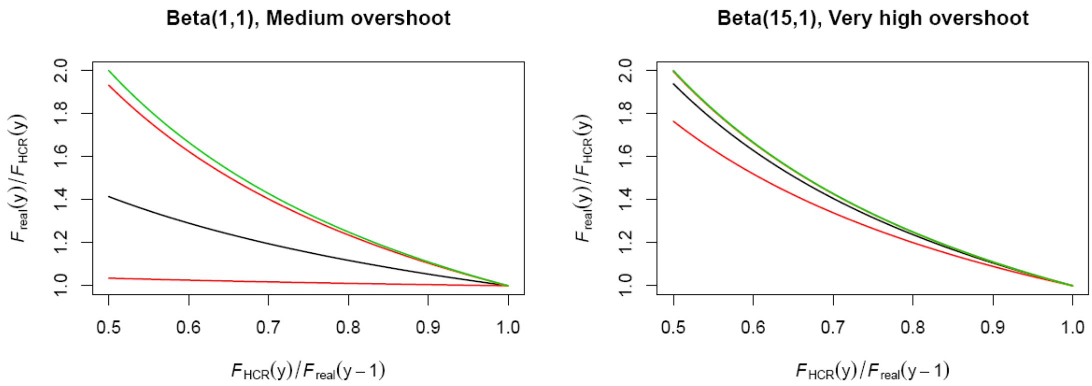


Figure 2.1: TAC overshoot Type 1: $F_{real}(y)/F_{HCR}(y)$ plotted as a function of $F_{HCR}(y)/F_{real}(y-1)$, for the two levels of overshoot considered. Median (black curves) and 90% probability intervals (red curves). Green curves correspond to *z*=1, in which case $F_{real}(y)=F_{real}(y-1)$ is obtained.

3 Southern hake in Divisions VIIIc and IXa

3.1 Simulation settings

The performance of HCRs 1-3 defined in Section 2.1 ("10% Annual Decrease", "Fmsy in 2015", "Fmsy in 2011"), with the 3 TAC constraint options described therein (15% constraint, 25% constraint and no TAC constraint), has been tested by conducting forward projections. Three different scenarios for recruitment during projection years are considered (Average, Low and High recruitment, described below). Each recruitment scenario is combined with no TAC overshoot and with the 4 TAC overshoot scenarios described in Section 2.2 (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 ("Fstquo") is considered only without TAC constraint and TAC overshoot (but under the 3 recruitment scenarios).

Projections start in 2010 and last until 2020. The starting point for projections is given by the results of the southern hake assessment conducted by WGHMM 2010 using a length-age-based assessment model (Gadget), with a quarterly time step. The work presented in this document uses the same population dynamics model as the hake assessment, implemented in R. A full description of the equations governing the population dynamics is provided in Annex 3.

The assessment conducted by WGHMM in 2010 does not provide measures of uncertainty, so all projections start from the same values, which correspond to the Gadget point estimates for the final assessment year (2009). WGHMM 2010 did not accept the recruitment estimate for 2009, which is unrealistically high, and replaced it by the geometric mean of the recruitment estimates for the period 1989-2008. In this work the estimate of F(2009) is also replaced, so that the observed catches (by fleet and quarter) in 2009 are still fit exactly.

Recruitment during projection years is randomly drawn and 1000 projection replicates are performed. From a plot of SSB and recruitment estimates from the Gadget assessment (Figure 3.1) no relationship can be appreciated between SSB and recruitment. Therefore, no attempt was made to use a stock-recruitment relationship during the projection years. Instead, annual recruitment values are drawn randomly using a Log-Normal distribution with independent draws for each projection year and replicate.

The three recruitment scenarios considered correspond to the following values for the median and CV of the Log-Normal distribution:

1. **"Average" recruitment**: Median = median of 1989-2008 estimates; CV=0.35.
2. **"Low recruitment"**: Median = first quartile of 1989-2008 estimates; CV=0.1.
3. **"High recruitment"**: Median = third quartile of 1989-2008 estimates; CV=0.1.

F_{stquo} is taken as the average F at length (as Annex 3 explains, fishing mortality is most naturally interpreted in terms of lengths rather than ages), by quarter, of the final 3 assessment years (2007-2009), scaled so that Fbar(15-80cm) by quarter corresponds to the values in the final assessment year after replacing the F(2009) estimate (i.e. F=0.76 was replaced by F=0.79). For each length, the proportions of the catch that are landed and discarded in each quarter are computed from the Gadget estimates of the numbers landed and discarded for that length, averaged (for each quarter separately) over the final 3 assessment years. These proportions are kept constant throughout the projection years. These are the same settings used in the yield-per-recruit analysis, presented in Annex 3.

As stated in Section 2.1, fishing mortality in 2010 is assumed to be equal to F_{stquo} and HCRs are applied starting in 2011. F_{stquo} corresponds to Fbar(15-80cm)=0.79, when averaged over the 4 quarters of the year.

HCRs are applied using F_{max} as F_{MSY} proxy, as proposed by WGHMM 2010 and subsequently adopted by ICES. From the YPR analysis conducted in Annex 3, $F_{max} = 0.25$ when expressed as the average of lengths 15-80 cm (and averaging over the 4 quarters of the year).

3.2 Results

An extensive set of detailed outputs (e.g. graphs and figures) can be downloaded from ftp:\\ftp.ices.dk\pub\WKSHAKE2 (available from 3rd December 2010).

Four performance measures are considered:

- $F_{real}(2015)/F_{MSY}$
- SSB(2015)/SSB(2010).
- Accumulated landings between 2011 and 2015.
- SSB(2020).

The first performance measure is explicitly based on $F_{real}(2015)$. When there is no TAC overshoot, F_{real} is the same as F_{HCR}, the value of F proposed by the HCR, but under TAC overshoot, F_{real} is bigger than F_{HCR}. The performance measure must be based on F_{real} rather than on F_{HCR}, so as to be able to assess the impact of potential TAC overshoot.

The 1000 projection replicates provide 1000 values of each of these measures. These values are summarised through probabilities and quantiles, as follows:

Table 3.1 presents the $P\{F_{real}(2015) \leq F_{MSY}\}$ and the median of the other 3 performance measures. Figure 3.2 presents the 5th, 50th and 95th percentile for the first 3 performance measures.

Figure 3.3 shows box-plots of $F_{real}(2015)/F_{MSY}$ for the different HCRs and TAC overshoot levels (very high, medium and none). The 2 different types of TAC overshoot (Type 1 and 2, described in Section 2.2), recruitment levels (high, average and low) and TAC constraints are collapsed. In the case of very high overshoot none of the HCRs achieves the objective. The probability of achieving the objective in the case of medium overshoot level is generally very small and only in the case of HCR 3 is this probability non-zero. If no TAC overshoot occurs, then HCR 2 ("Fmsy in 2015") achieves the objective of reaching F_{MSY} in 2015, given that it has been designed to do this. HCR 3 ("Fmsy in 2011") shows a suboptimal performance since it drives the fishery below F_{MSY} due to the combination of the effect of the TAC constraint and the quicker recovery of SSB.

The performance of HCRs 1-3 is now described individually.

HCR 1 "10% Annual F Decrease":

As Table 3.1(a) and Figure 3.2 (top panels) show, this HCR does not allow to reach F_{MSY} by 2015. Even in the most favourable of circumstances (when combined with a 15% TAC constraint and under a high recruitment scenario without TAC overshoot), the probability of reaching F_{MSY} by 2015 is only 0.24.

Figure 3.2 also shows that the distance between $F_{real}(2015)$ and F_{MSY} increases with increasing levels of TAC overshoot.

Starting from F_{stquo}=0.79 in 2010, it is straightforward to see that with this HCR F_{MSY}=0.25 would be reached in 2021, if there was no TAC constraint and no TAC overshoot. Additional results from simulations (not displayed) show that with a 15% TAC constraint, 2018 is the first year in which $F \leq F_{MSY}$ with very high probability (at least 0.95), in average or low recruitment scenarios and still assuming no TAC overshoot.

In conclusion, the HCR in the current Southern Hake and *Nephrops* Recovery Plan (10% annual F reduction with a TAC constraint of 15%) does not allow to reach the target F_{MSY} by 2015.

Figure 3.4 summarises the trends in median F, landings and SSB, for years 2010-2020, without TAC overshoot and with average recruitment, for the different TAC constraints. The HCR does not reach the F_{MSY} objective in 2015. The plot shows a stronger reduction in F with the 15% TAC constraint, implying a reduction in landings at the beginning of the period and higher landings after 2015. SSB shows a quicker recovery along the time series with the 15% TAC constraint. With a 25% TAC constraint, F decreases less at the beginning, resulting in higher landings before 2015 but lower landings after 2015 (in comparison with the 15% TAC constraint). Consequently, SSB shows slightly slower recovery along the time series.

HCR 2 "Fmsy in 2015":

$F_{real}(2015)$/ F_{MSY}:

The rule is designed to reach F_{MSY} exactly in 2015 if there is no TAC overshoot. The only thing that may prevent this from happening is a TAC constraint acting in 2015. From Table 3.1(a), $P\{F_{real}(2015) \leq F_{MSY}\}$ is always 1 if there is no TAC overshoot. However, this probability decreases virtually to zero for medium or higher levels of TAC overshoot.

Figure 3.2 (top panels) shows that the distance between $F_{real}(2015)$ and F_{MSY} increases with increasing levels of TAC overshoot.

Figure 3.2 also shows that all 3 TAC constraint levels examined (15%, 25% or none) lead to similar 90% probability intervals for $F_{real}(2015)/F_{MSY}$, except under average or low recruitment scenarios with very high TAC overshoot of Type 2, when a 15% TAC constraint performs worse. TAC constraints interact with recruitment levels and TAC overshoot, making the different TAC constraints more or less effective depending on the situation. For hake, current landings are more than twice above the TAC, so the tighter the TAC constraint the bigger the proposed reduction in F in 2011. However, as the population evolves in time, the opposite may happen, i.e. a tight TAC constraint may preclude achieving the intended F reduction. This may happen when population abundance is reduced as a consequence of low recruitments and/or high overshoot. We stress, however, that under very high levels of TAC overshoot $F_{real}(2015)$ is much larger than F_{MSY} irrespective of the TAC constraint.

SSB(2015)/SSB(2010):

Table 3.2(b) indicates an SSB increase from 2010 to 2015 under all recruitment scenarios with up to medium levels of TAC overshoot. However, SSB(2015) can be substantially lower than SSB(2010) if higher TAC overshoot levels occur.

Although differences are not big, SSB(2015) is higher under a 15% TAC constraint in most scenarios (middle panels of Figure 3.2), the only exception being under average or low recruitment scenarios and very high TAC overshoot of Type 2. Hence, in general terms, a 15% TAC constraint seems best in terms of stock health in 2015.

Accumulated landings during 2011-2015:

Cumulative landings do not show any clear differences to evaluate the different TAC constrains for HCR 2. The median and 90% probability intervals are always quite similar (bottom panels of Figure 3.2). Under these circumstances a more stable strategy (15% TAC constraint) may be more useful since it would promote yield stability (in the absence of TAC overshoot).

Another argument in favour of a 15% TAC constraint (versus 25% or no TAC constraint) is the stronger F reduction at the beginning of the HCR application period. Da Rocha et al. (2010) have shown that the economic performance of a recovery plan improves if F is reduced as much as possible at the start of the plan.

Figure 3.5 summarises the trends in median F, landings and SSB, for years 2010-2020, without TAC overshoot and with average recruitment, for the different TAC constraints. The relative behaviour of the TAC constraints shows a similar pattern as for HCR 1 (Figure 3.4).

HCR 3 "Fmsy in 2011":

This HCR aims to reach F_{MSY} already in 2011, although TAC constraints may preclude this. After 2011, TAC constraints can force F to be below F_{MSY} for a number of years. For example, with a 15% TAC constraint and no TAC overshoot, there is at least 95% probability that F is strictly below F_{MSY} in 2015 (Figure 3.2). With medium levels of TAC overshoot, there is still substantial probability that $F_{real}(2015)$ is less than or equal to F_{MSY}. This probability goes to zero if TAC overshoot levels become very high (Table 3.1(a) and Figure 3.2).

This HCR imposes the strongest F reductions, hence it produces the highest SSB in 2015, the lowest cumulative landings from 2011 to 2015 and no TAC stability.

3.3 Summary and conclusions

TAC overshoot does not allow to achieve F_{MSY} in 2015 in any case.

HCR 1 (10% Annual decrease) does not allow to achieve F_{MSY} in 2015.

When comparing HCR 2 with 15% or 25% TAC constraints, they both lead to similar probability of achieving F_{MSY} in 2015. The 15% constraint produces slightly higher SSB in 2015, promotes high yield stability and is a better candidate in terms of economic performance (da Rocha *et al.*, 2010).

Note that the working document W2 presents a more extensive analysis of a wider set of HCR candidates; considering different ways to reduce F and a wider variety of TAC constrains. Given the poor performance of some of them and in order to avoid extending this report unnecessarily, the final analysis presented above only refers to the HCRs that have been considered as the best candidates to address the workshop's ToRs.

3.4 Collated tables and figures for southern hake

Table 3.1(a): P(F_{real}(2015)≤F_{MSY}) for Recruitment scenarios: High HR (Top Block); Average AR (Middle Block); Low LR (Bottom Block).

Columns: TAC Overshoot: None (OvN), Type 1(Med Ov1M; Very high Ov1VH) or Type 2 (Med Ov2M; Very high Ov2VH).

Rows: HCR-TAC constraint combinations (NA means no TAC constraint).

	HR	HR	HR	HR	HR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0	NA	NA	NA	NA
HCR1,15%	0.24	0	0	0.01	0
HCR1,25%	0	0	0	0	0
HCR1,NA	0	0	0	0	0
HCR2,15%	1	0.03	0	0.01	0
HCR2,25%	1	0	0	0	0
HCR2,NA	1	0	0	0	0
HCR3,15%	1	0.92	0	0.49	0
HCR3,25%	1	0.8	0	0.26	0
HCR3,NA	1	0	0	0	0

	AR	AR	AR	AR	AR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0	NA	NA	NA	NA
HCR1,15%	0.12	0.01	0	0	0
HCR1,25%	0	0	0	0	0
HCR1,NA	0	0	0	0	0
HCR2,15%	1	0.03	0	0.01	0
HCR2,25%	1	0	0	0	0
HCR2,NA	1	0	0	0	0
HCR3,15%	1	0.78	0	0.29	0
HCR3,25%	1	0.5	0	0.1	0
HCR3,NA	1	0	0	0	0

	LR	LR	LR	LR	LR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0	NA	NA	NA	NA
HCR1,15%	0	0	0	0	0
HCR1,25%	0	0	0	0	0
HCR1,NA	0	0	0	0	0
HCR2,15%	1	0	0	0	0
HCR2,25%	1	0	0	0	0
HCR2,NA	1	0	0	0	0
HCR3,15%	1	0.65	0	0.1	0
HCR3,25%	1	0.17	0	0.01	0
HCR3,NA	1	0	0	0	0

Table 3.1(b): Median(SSB(2015)/SSB(2010)) for Recruitment scenarios: High HR (Top Block); Average AR (Medium Block); Low LR (Bottom Block).

Columns: TAC Overshoot: None (OvN), Type 1(Med Ov1M; Very high Ov1VH), or Type 2 (Med Ov2M; Very high Ov2VH).

Rows: HCR-TAC constraint combinations (NA means no TAC constraint).

	HR	HR	HR	HR	HR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0.8	NA	NA	NA	NA
HCR1,15%	2.7	2.2	1	1.7	0.8
HCR1,25%	2.2	1.9	1	1.4	0.8
HCR1,NA	1.4	1.2	0.9	0.9	0.8
HCR2,15%	2.7	2.2	1	1.8	0.9
HCR2,25%	2.6	2.1	1	1.6	0.9
HCR2,NA	2.2	1.8	1	1.4	0.9
HCR3,15%	4	3.2	1.1	2.7	1.3
HCR3,25%	4	3.1	1.1	2.8	1.4
HCR3,NA	3.3	2.9	1.2	2.7	1.4

	AR	AR	AR	AR	AR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0.6	NA	NA	NA	NA
HCR1,15%	1.9	1.6	0.8	1.1	0.6
HCR1,25%	1.7	1.4	0.8	1	0.6
HCR1,NA	1.1	1	0.7	0.7	0.6
HCR2,15%	2.1	1.7	0.8	1.3	0.6
HCR2,25%	2	1.6	0.8	1.2	0.7
HCR2,NA	1.8	1.4	0.8	1.1	0.7
HCR3,15%	2.9	2.3	0.9	2	1
HCR3,25%	2.8	2.3	0.9	2.1	1.1
HCR3,NA	2.7	2.3	0.9	2.1	1.1

	LR	LR	LR	LR	LR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	0.5	NA	NA	NA	NA
HCR1,15%	1.6	1.3	0.6	0.9	0.5
HCR1,25%	1.4	1.2	0.6	0.9	0.5
HCR1,NA	0.9	0.8	0.6	0.6	0.5
HCR2,15%	1.8	1.4	0.6	1	0.5
HCR2,25%	1.7	1.3	0.7	1	0.6
HCR2,NA	1.5	1.2	0.6	0.9	0.6
HCR3,15%	2.4	1.9	0.7	1.6	0.7
HCR3,25%	2.3	2	0.8	1.8	0.9
HCR3,NA	2.3	2	0.8	1.9	0.9

Table 3.1(c): Median (Accumulated Landings during 2011-2015, in thousands of tonnes) for Recruitment scenarios: High HR (Top Block); Average AR (Bottom Block); Low LR (Bottom Block).

Columns: TAC Overshoot: None (OvN), Type 1(Med Ov1M; Very high Ov1VH), or Type 2 (Med Ov2M; Very high Ov2VH).

Rows: HCR-TAC constraint combinations (NA means no TAC constraint)

	HR OvN	HR Ov1M	HR Ov1VH	HR Ov2M	HR Ov2VH
HCR0,NA	79	NA	NA	NA	NA
HCR1,15%	70	72	78	74	77
HCR1,25%	74	74	78	75	78
HCR1,NA	76	76	78	77	78
HCR2,15%	69	70	78	73	76
HCR2,25%	69	71	78	72	76
HCR2,NA	68	71	78	72	76
HCR3,15%	53	61	78	68	79
HCR3,25%	57	64	78	70	81
HCR3,NA	68	68	78	72	81

	AR OvN	AR Ov1M	AR Ov1VH	AR Ov2M	AR Ov2VH
HCR0,NA	66	NA	NA	NA	NA
HCR1,15%	61	62	67	64	67
HCR1,25%	63	64	66	64	67
HCR1,NA	65	66	66	65	67
HCR2,15%	59	60	66	62	65
HCR2,25%	58	60	66	62	65
HCR2,NA	58	60	66	62	65
HCR3,15%	51	54	66	59	66
HCR3,25%	56	57	66	60	68
HCR3,NA	58	58	66	61	69

	LR OvN	LR Ov1M	LR Ov1VH	LR Ov2M	LR Ov2VH
HCR0,NA	60	NA	NA	NA	NA
HCR1,15%	56	56	60	58	60
HCR1,25%	57	57	60	58	60
HCR1,NA	58	58	60	59	60
HCR2,15%	53	54	60	57	60
HCR2,25%	53	54	59	55	58
HCR2,NA	52	54	59	55	58
HCR3,15%	49	51	59	54	58
HCR3,25%	52	52	59	55	61
HCR3,NA	52	52	60	55	62

Table 3.1(d): Median SSB in 2020 (thousand tonnes) for Recruitment scenarios: High HR (Top Block); Average AR (Medium Block); Low LR (Bottom Block).

Columns: TAC Overshoot: None (OvN), Type 1(Med Ov1M; Very high Ov1VH), or Type 2 (Med Ov2M; Very high Ov2VH).

Rows: HCR-TAC constraint combinations (NA means no TAC constraint).

	HR	HR	HR	HR	HR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	17	NA	NA	NA	NA
HCR1,15%	86	81	33	66	30
HCR1,25%	82	76	31	60	28
HCR1,NA	59	53	25	39	18
HCR2,15%	86	83	33	71	31
HCR2,25%	85	81	33	68	31
HCR2,NA	85	80	32	66	31
HCR3,15%	126	114	36	91	33
HCR3,25%	95	89	37	80	33
HCR3,NA	88	86	36	77	33

	AR	AR	AR	AR	AR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	13	NA	NA	NA	NA
HCR1,15%	66	60	24	46	20
HCR1,25%	62	56	24	45	21
HCR1,NA	46	40	19	30	14
HCR2,15%	68	66	25	55	25
HCR2,25%	66	63	25	52	25
HCR2,NA	66	62	24	51	24
HCR3,15%	79	74	28	64	27
HCR3,25%	70	68	28	60	26
HCR3,NA	69	67	28	59	25

	LR	LR	LR	LR	LR
	OvN	Ov1M	Ov1VH	Ov2M	Ov2VH
HCR0,NA	11	NA	NA	NA	NA
HCR1,15%	53	49	19	36	16
HCR1,25%	50	46	19	37	17
HCR1,NA	38	34	16	25	12
HCR2,15%	55	53	20	44	19
HCR2,25%	55	52	21	43	20
HCR2,NA	54	51	20	43	20
HCR3,15%	58	57	22	49	20
HCR3,25%	57	56	24	49	21
HCR3,NA	57	55	23	50	21

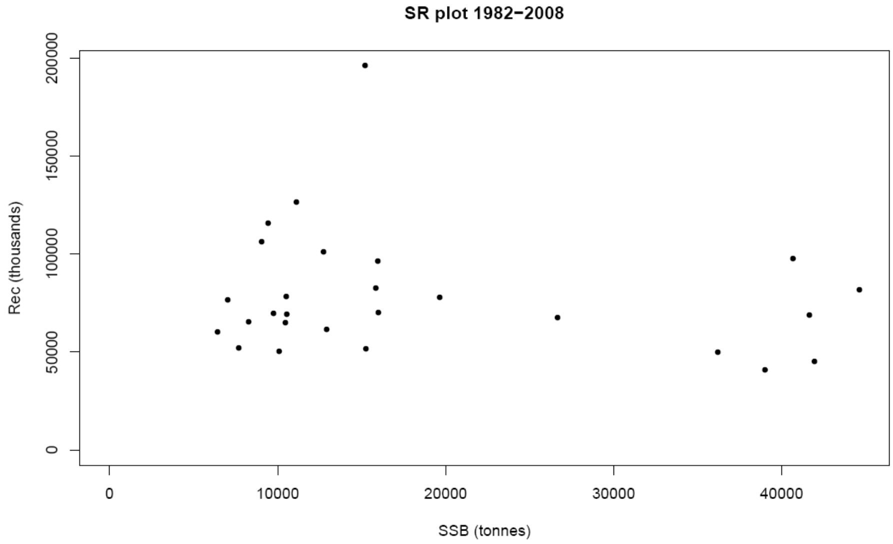


Figure 3.1: Stock-recruitment plot from Gadget assessment conducted by WGHMM 2010 (Rec in 2009, rejected by WGHMM 2010, is not included in the plot).

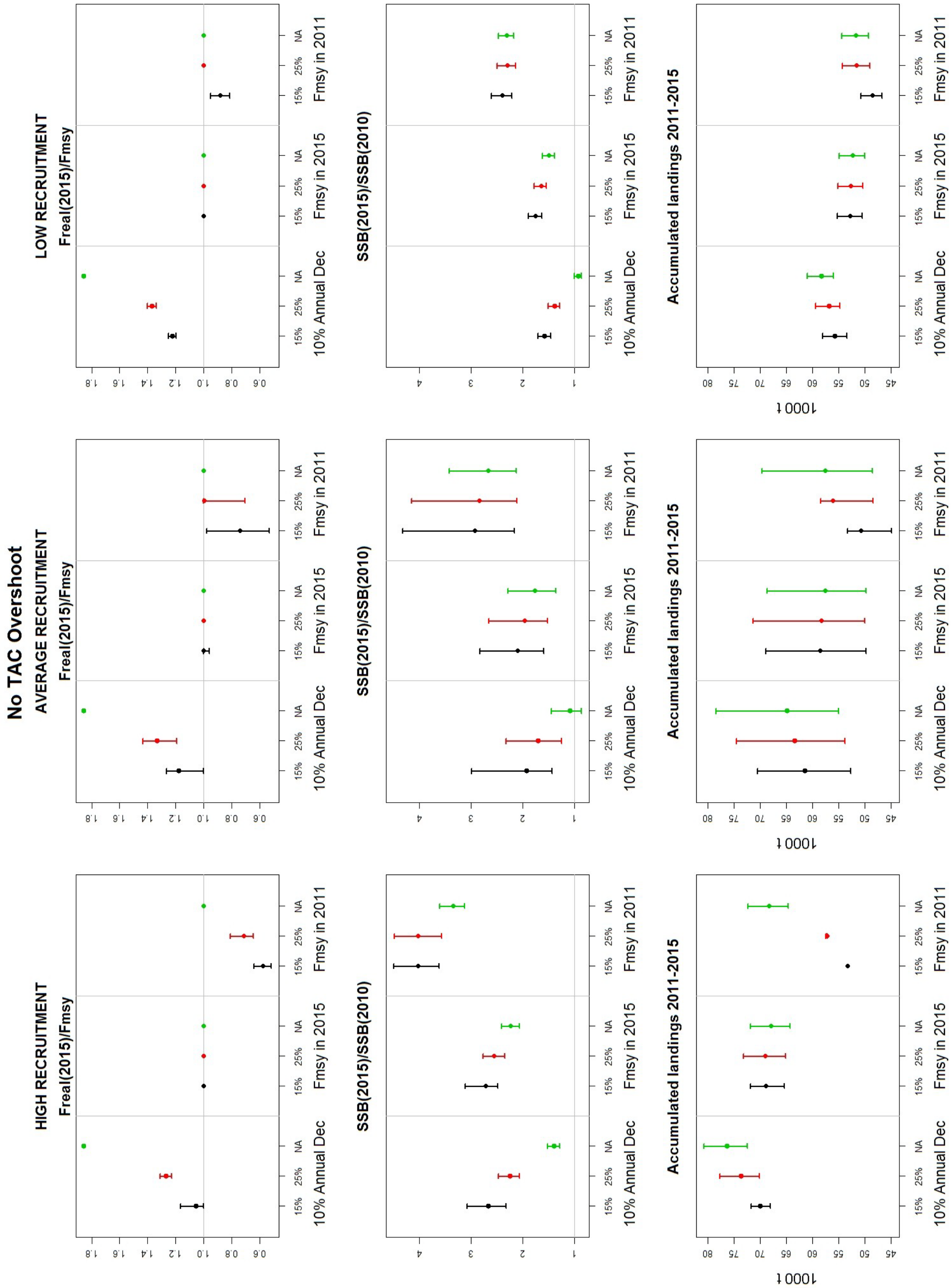

No TAC Overshoot
LOW RECRUITMENT
Freal(2015)/Fmsy
AVERAGE RECRUITMENT
Freal(2015)/Fmsy
HIGH RECRUITMENT
Freal(2015)/Fmsy
SSB(2015)/SSB(2010)
Accumulated landings 2011-2015
1000 t
10% Annual Dec
Fmsy in 2015
Fmsy in 2011
15%
25%
NA

Figure 3.2(a):

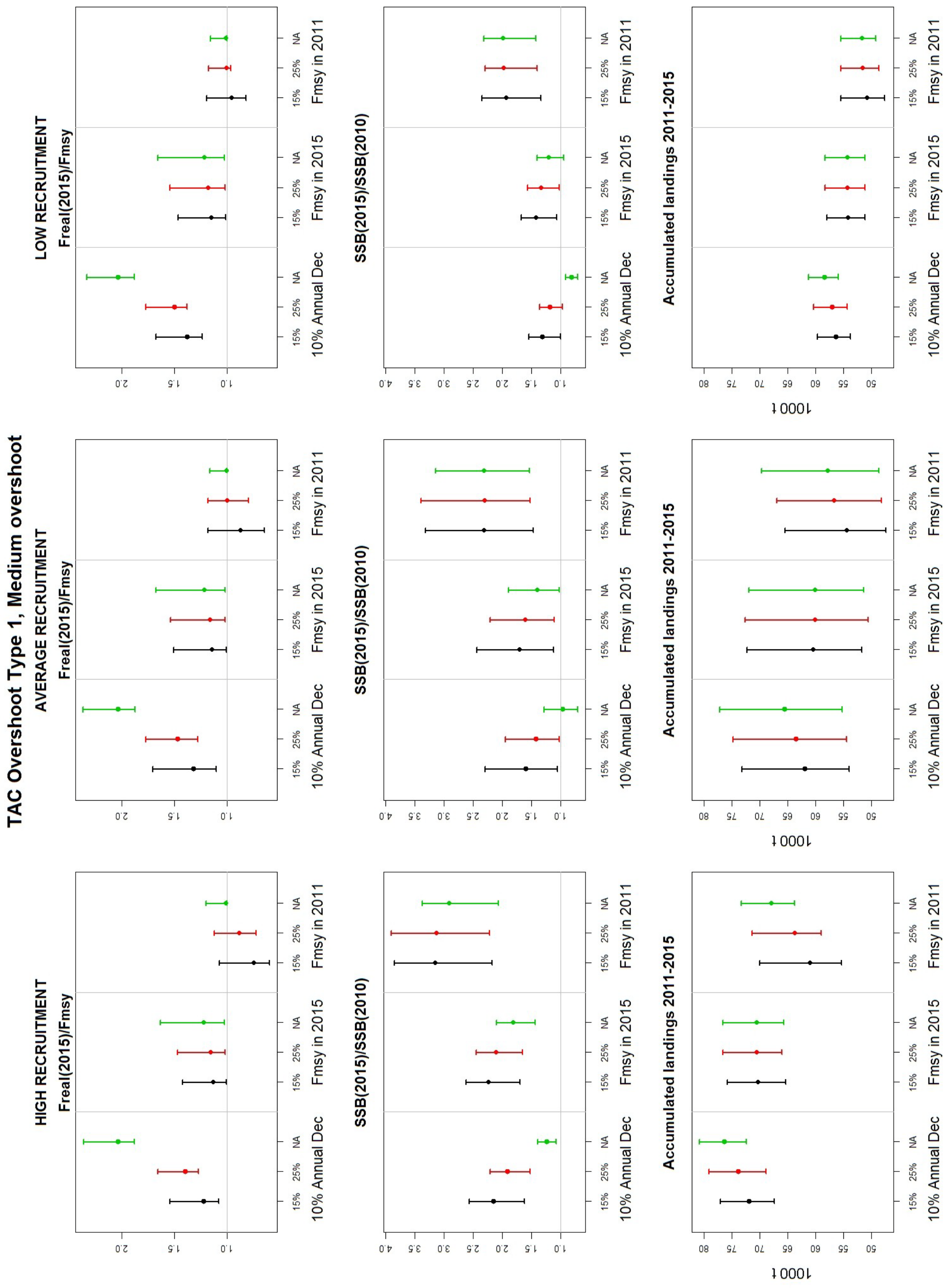

TAC Overshoot Type 1, Medium overshoot
HIGH RECRUITMENT
AVERAGE RECRUITMENT
LOW RECRUITMENT
Freal(2015)/Fmsy
SSB(2015)/SSB(2010)
Accumulated landings 2011-2015
1000 t
15% 25% NA
10% Annual Dec
Fmsy in 2015
Fmsy in 2011

Figure 3.2(b):

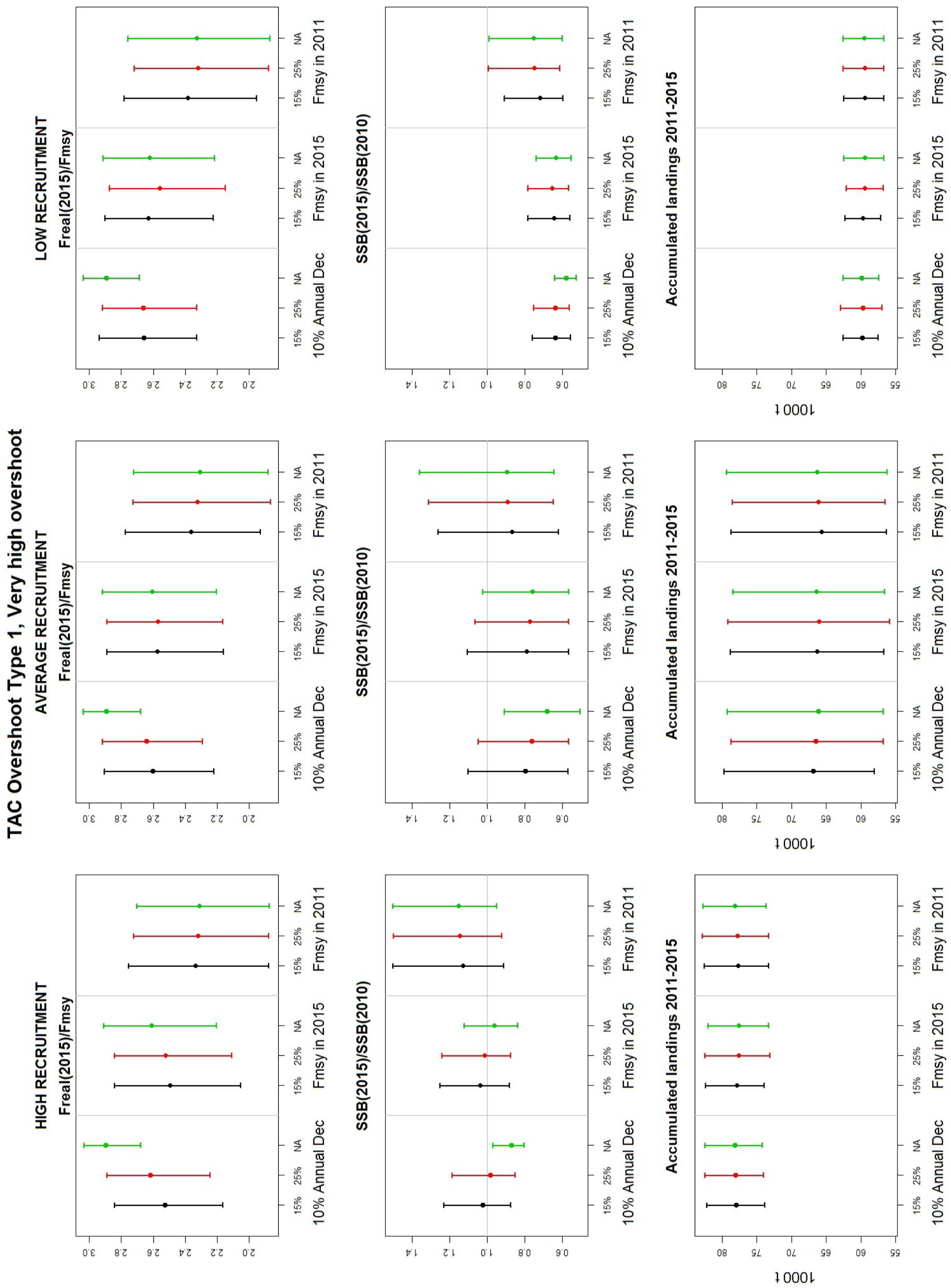

TAC Overshoot Type 1, Very high overshoot
LOW RECRUITMENT
AVERAGE RECRUITMENT
HIGH RECRUITMENT
Freal(2015)/Fmsy
SSB(2015)/SSB(2010)
Accumulated landings 2011-2015
1000 t
10% Annual Dec
Fmsy in 2015
Fmsy in 2011
15%
25%
NA

Figure 3.2(c):

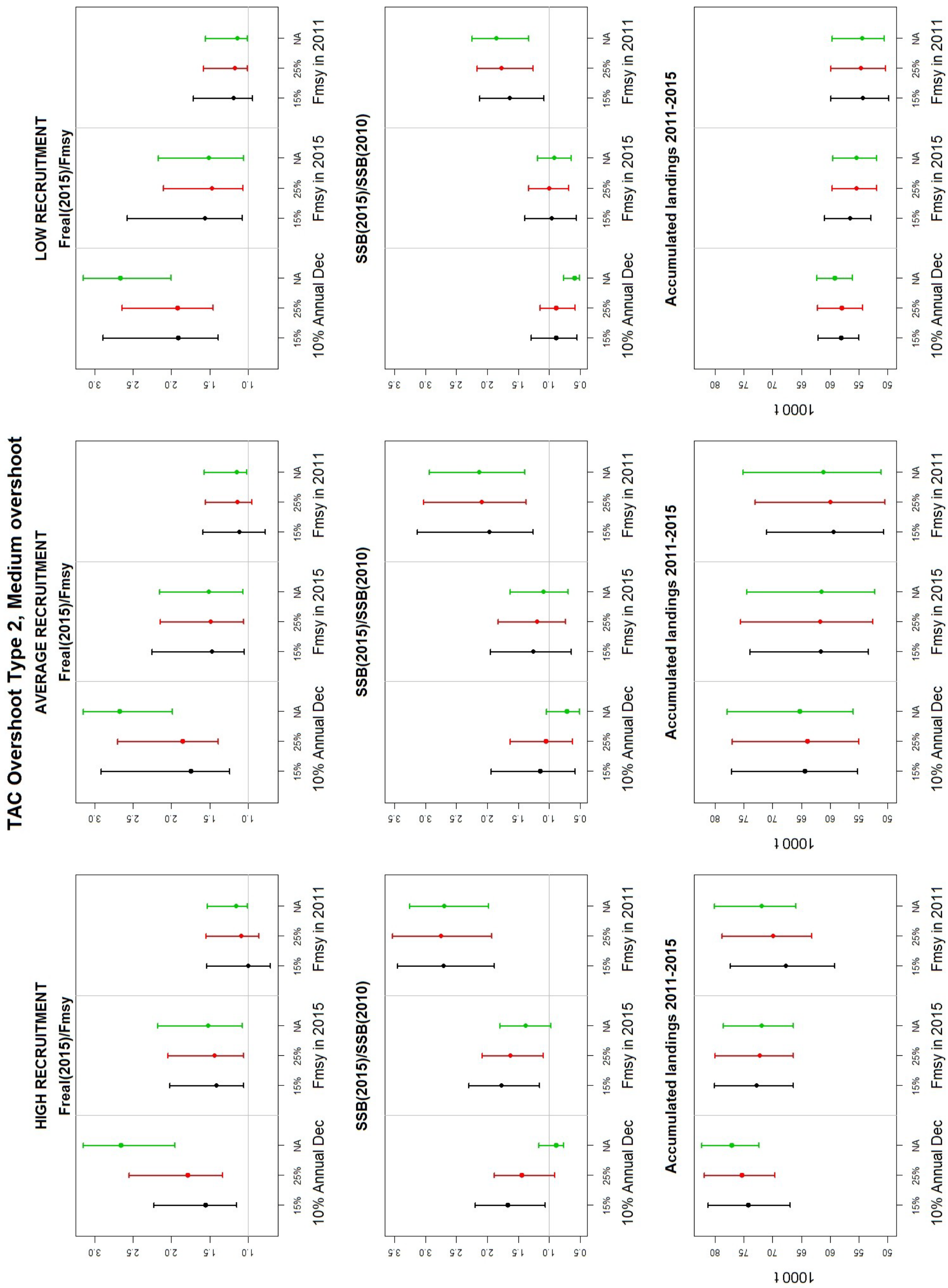

TAC Overshoot Type 2, Medium overshoot
LOW RECRUITMENT
AVERAGE RECRUITMENT
HIGH RECRUITMENT
Freal(2015)/Fmsy
SSB(2015)/SSB(2010)
Accumulated landings 2011-2015
1000t
10% Annual Dec
Fmsy in 2015
Fmsy in 2011
15%
25%
NA

Figure 3.2(d):

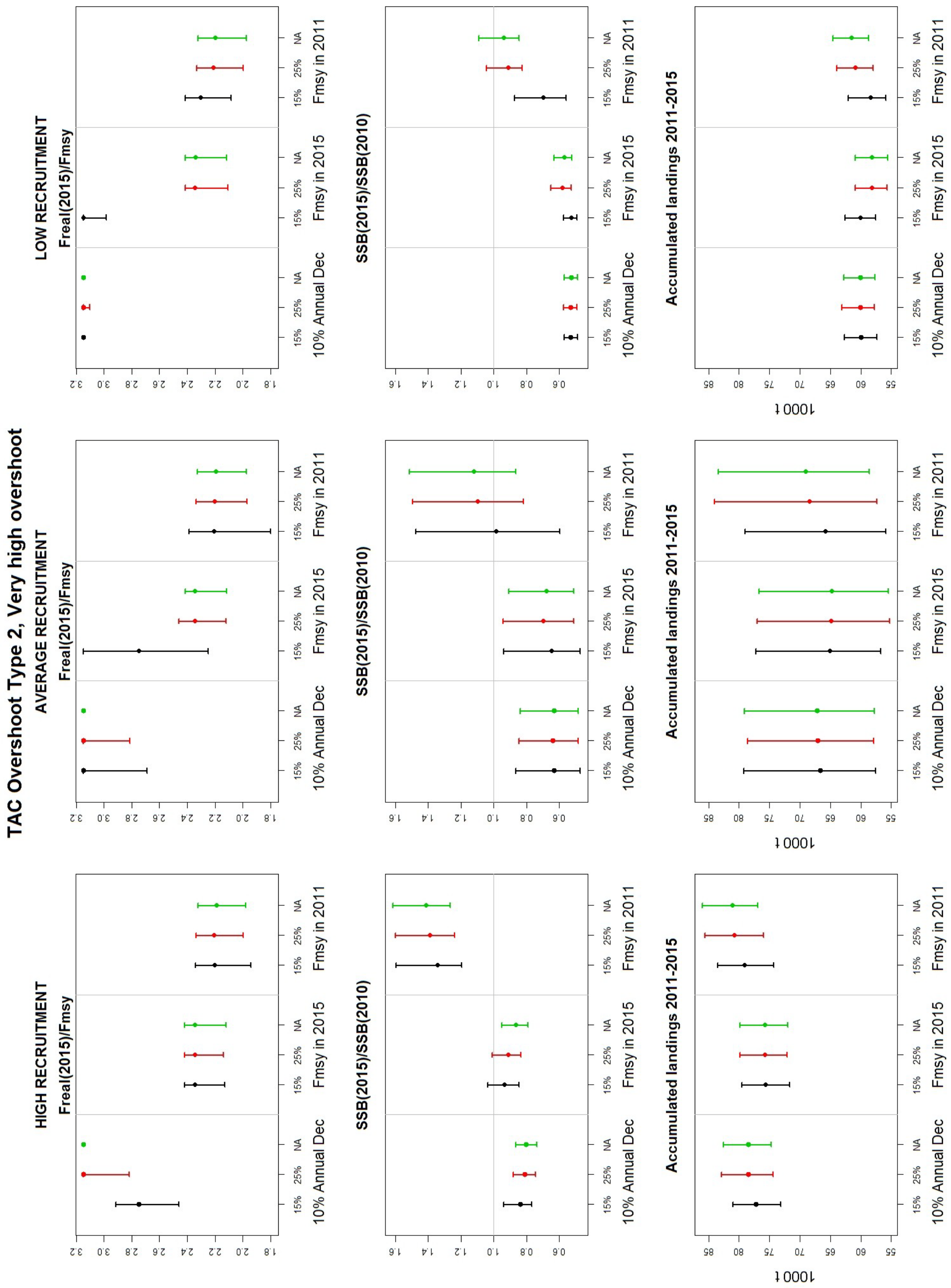

TAC Overshoot Type 2, Very high overshoot
LOW RECRUITMENT
AVERAGE RECRUITMENT
HIGH RECRUITMENT
Freal(2015)/Fmsy
SSB(2015)/SSB(2010)
Accumulated landings 2011-2015
1000 t
15% 25% NA
10% Annual Dec
Fmsy in 2015
Fmsy in 2011

Figure 3.2(e):

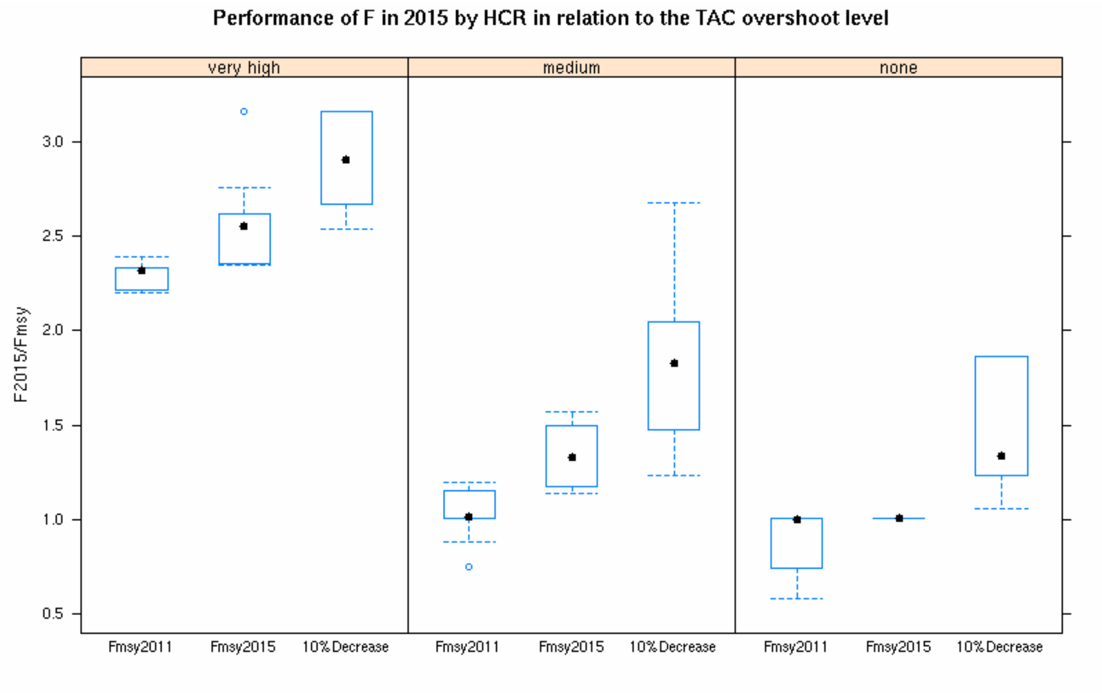


Figure 3.3: Impact of different TAC overshoot levels on $F_{real}(2015)/F_{MSY}$ for the different HCRs

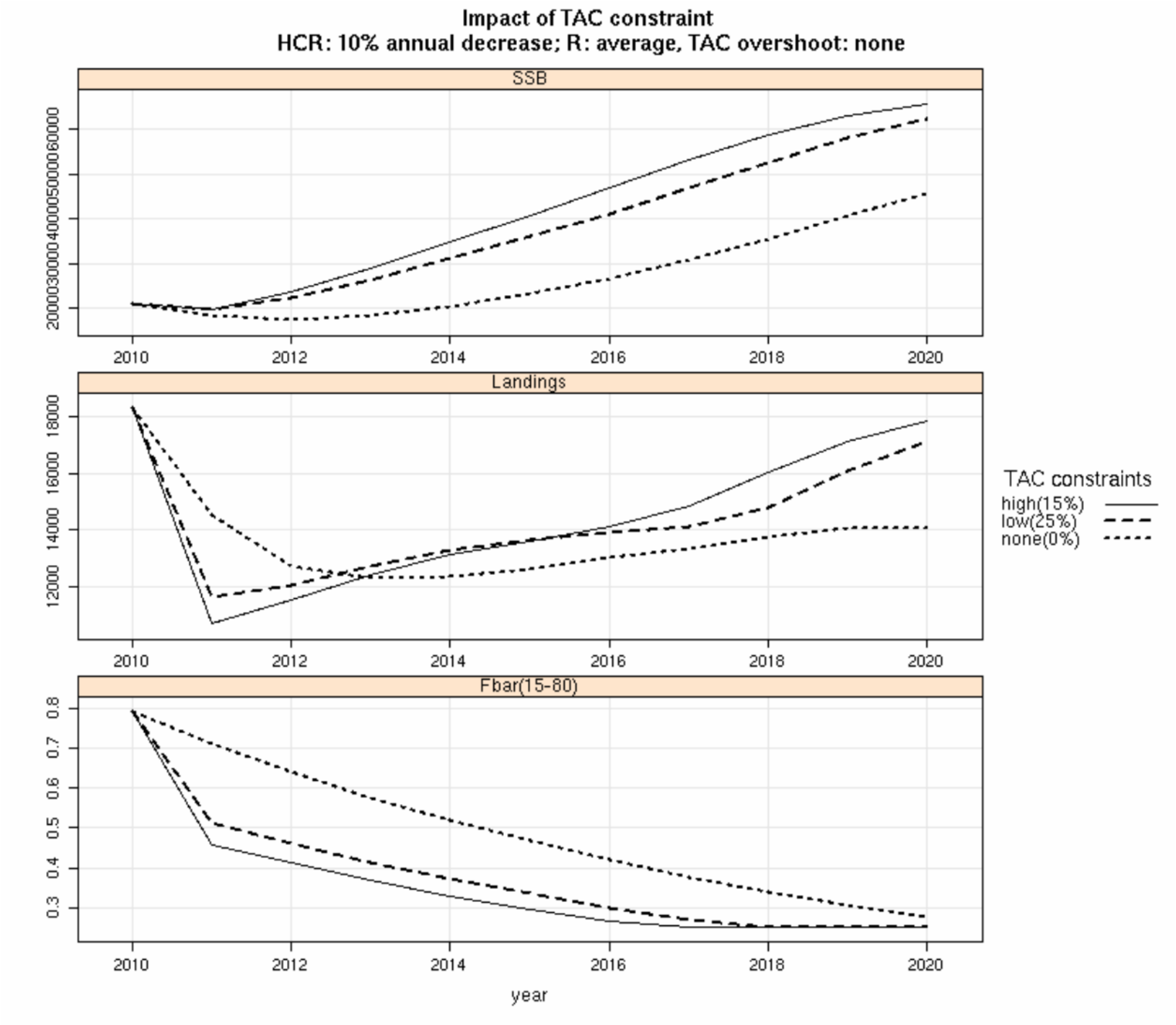


Figure 3.4: Effect of TAC constraint on performance of HCR 1

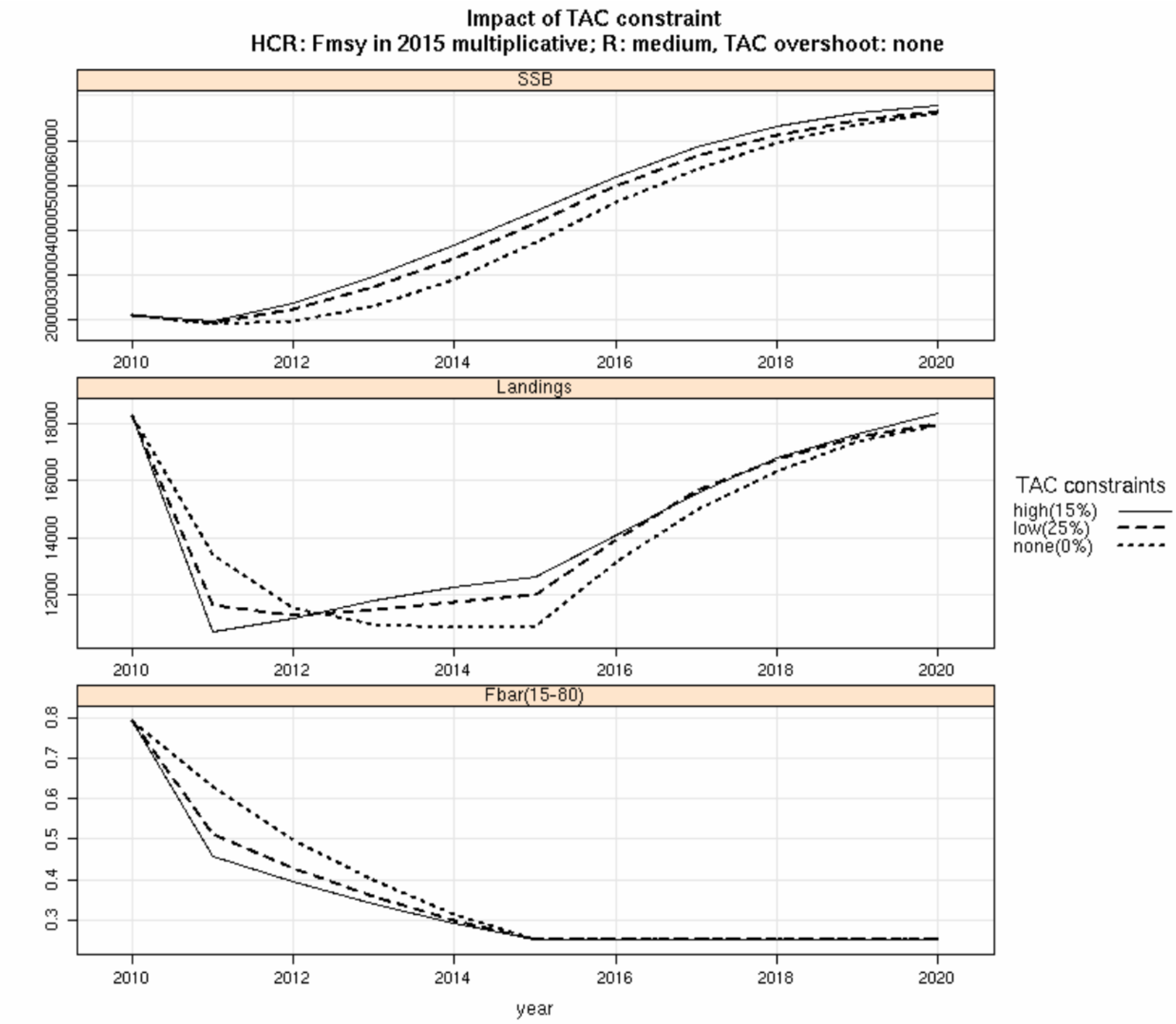


Figure 3.5: Effect of TAC constraint on performance of HCR 2

4 Anglerfish in Divisions VIIIc and IXa (*Lophius piscatorius* and *Lophius budegassa*)

Two species of anglerfish, *Lophius piscatorius* and *L. budegassa*, are found in ICES Divisions VIIIc and IXa. Both species are caught in mixed bottom trawl fisheries and in artisanal fisheries using mainly fixed nets.

The two species are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the ports' statistics. Therefore, estimates of each species in Spanish landings from Divisions VIIIc and IXa and Portuguese landings of Division IXa are derived from their relative proportions in market samples.

4.1 Population dynamics and input data

A benchmark assessment of anglerfish in Divisions VIIIc and IXa was carried out in 2007. Due to the inconsistencies found in catch-at-age data, the Working Group did not accept the age-structured assessment. The latest assessments for anglerfish (*L. piscatorius* and *L. budegassa*) were carried out with a Schaefer biomass dynamic model using the software ASPIC (Prager, 1994; 2004), a non-equilibrium stock production model incorporating covariates with bootstrapping (1000 iterations). There is a separate assessment for each species (ICES, 2010b).

Biomass in 2010 of *L. piscatorius* is estimated to be below B_{MSY} and, despite the decrease in fishing mortality since 2005, F in 2009 is still above F_{MSY}. Fishing mortality equal to zero is not expected to bring the stock back to B_{MSY} before 2015 (ICES, 2010b).

Fishing mortality for *L. budegassa* shows a decreasing trend since 1999 and in 2009 is below F_{MSY}. This has led to an increase in biomass but it is still below B_{MSY}. Fishing mortality equal to *F status quo* is expected to bring the stock back to B_{MSY} in 2011 (ICES, 2010b).

4.1.1 Input data

Projections were performed separately for each species, using as input data the 1000 bootstrap estimates of (K, r, F_{msy}, B_{msy}, F_{2009}, B_{2010}) based on the results of the two assessments conducted by WGHMM (ICES, 2010b).

For each value of r, K, B_y and F_y where the subscript y refers to year, the population dynamics follows the model:

$$B_{y+1} = \frac{(r-F_y)B_y e^{r-F_y}}{(r-F_y)+\frac{r}{k}B_y(e^{r-F_y}-1)} \qquad \text{equation (4.1.1.1)}$$

and the corresponding yield is:

$$Y_y = \frac{F_y}{\frac{r}{k}}\ln\left(1-\frac{\frac{r}{k}B_y(1-e^{r-F_y})}{r-F_y}\right) \qquad \text{equation (4.1.1.2)}$$

The output of the ASPIC assessments gives 1000 values of F_{msy} (for each species separately), which each value of F_{msy} related with the r, K, B_y and F_y values corresponding to the same bootstrap replicate. The 1000 bootstrap replicates are used to estimate uncertainty and the probability of F achieving F_{msy} by 2015. The lower and upper levels of the 90% confidence interval correspond to the 5th and 95th percentiles based on the bootstrap replicates and the estimated parameter value to the median (50th percentile).

4.2 Simulations

Projections were done for *L. budegassa* and *L. piscatorius* separately. Because *L.piscatorius* is the species in poorer condition, the F multiplier defined by the corresponding HCR applied to *L.piscatorius* is also used to do the projections for *L. budegassa*.

The sum of projected landings for both species is considered in scenarios with TAC constraint and, when necessary, a new F multiplier is calculated so that the combined landings of both species fulfill the TAC constraint.

The application of the different HCRs starts in 2011 and it is assumed that fishing mortality in 2010 is equal to F_{2009} (F_{sq}).

The population dynamic and the scenarios of HCR for anglerfish were coded in R.

4.2.1 Scenarios considered

Several HCRs and projection scenarios were analyzed in the W6, the ones presented in this report are the same ones presented for hake (see Section 2.1).

4.2.1.1 TAC constraints (maximum change allowed in the TAC between consecutive years):

In HCR 0 the *F*multiplier=1 in all projection years for both anglerfish species.

For HCRs 1-3, the same rationale that is explained in Section 2.1 was applied, but the following differences were necessary in order to have a common F multiplier for both species and to account for the fact that the TAC is for both species combined:

> Projections start from F_{HCR} 2010= F_{sq} and TAC 2010=1496 t. For y>2010, F_{HCR} is defined in two steps:
>
> > *First step:* Calculate the F multiplier, $F_{\text{multiplier,first}}(y)$, required to get from $F_{\text{HCR}}(y$-1) to $F_{\text{HCR,first}}(y)$ based on the application of the corresponding HCR to *L. piscatorius* and use the same F multiplier for *L. budegassa*.
> >
> > *Second step:* Define the final F multiplier taking TAC constraints into account. This step is the same for all HCRs. Let $L(F_{\text{multiplier}})$ denote the sum of landings (in weight) for *L. piscatorius* and *L. budegassa* corresponding to using the F multiplier value $F_{\text{multiplier}}$. If $L(F_{\text{multiplier,first}}(y))$ is within the TAC constraint range, then $F_{\text{multiplier}}(y)$= $F_{\text{multiplier,first}}(y)$. Otherwise, the appropriate $F_{\text{multiplier}}(y)$ value is calculated so that the TAC constraint is fulfillled.
> >
> > The resulting fishing mortalities $F_{\text{HCR}}(y)$ of the two species are obtained by applying the common $F_{\text{multiplier}}(y)$ obtained in this Second Step to their individual $F_{\text{HCR}}(y$-1) values (one value for each species).

4.2.1.2 TAC overshooting

The anglerfish TAC has been overshot since 2004. During these six years the TAC was overshot between 1.6 and 2.3 times, the landings being 1.7 times the TAC in 2009

(Figure 4.2.1.2.1). In order to analyse the impact of TAC overshoot on the performance of the HCRs, the TAC overshoot Type 1, described in Section 2.2, was tested.

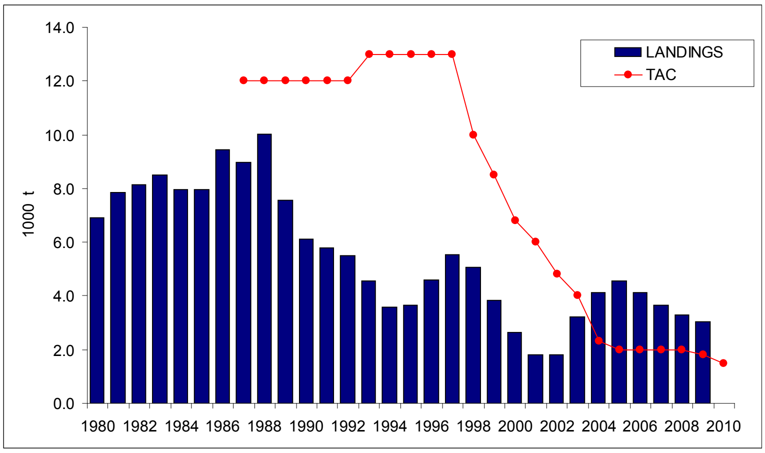


Figure 4.2.1.2.1. Historical relationship between landings and TAC values.

4.3 Results

Performance metrics similar to the ones used for hake were calculated for each species:

- Probability that *F* in 2015 is below or equal to *Fmsy* ($F_{2015} \leq F_{msy}$);
- Yield cumulated from 2011 to 2015 (Ycum2015);
- Biomass in 2015 and 2020 over B_{msy} (Brel2015 and Brel2020),

as well as cumulative landings for both species combined. Results are presented in Table 4.3.1 for all combinations of HCR-TAC constraint-TAC overshoot scenarios tested.

Table 4.3.1

	L.piscatorius				*L.budegassa*				*L.pis+L.bud*
Scenarios	F2015≤Fmsy	Ycum2015	Brel2015	Brel2020	F2015≤Fmsy	Ycum2015	Brel2015	Brel2020	Ycum2015
HCR: Fsq	0.11	15062	0.34	0.43	1.00	7944	1.49	1.54	23025
HCR 10%AnnualDecrease & TACc=15%	0.98	8471	0.76	1.35	1.00	3126	1.79	1.84	11600
HCR 10%AnnualDecrease & TACc=15% & Overshoot1=Medium	0.90	9625	0.65	1.25	1.00	4019	1.74	1.82	13459
HCR 10%AnnualDecrease & TACc=15% & Overshoot1=Very High	0.37	14031	0.40	0.66	1.00	7013	1.55	1.66	20957
HCR 10%AnnualDecrease & TACc=25%	0.97	11092	0.68	0.94	1.00	4121	1.74	1.69	15347
HCR 10%AnnualDecrease & TACc=25% & Overshoot1=Medium	0.76	11723	0.59	0.87	1.00	4809	1.70	1.68	16247
HCR 10%AnnualDecrease & TACc=25% & Overshoot1=Very High	0.28	14453	0.39	0.59	1.00	7219	1.54	1.61	21657
HCR 10%AnnualDecrease	0.72	13647	0.45	0.75	1.00	6531	1.58	1.67	20213
HCR 10%AnnualDecrease & Overshoot1=Medium	0.11	13941	0.42	0.72	1.00	6875	1.56	1.67	20712
HCR 10%AnnualDecrease & Overshoot1=Very High	0.10	14870	0.36	0.52	1.00	7773	1.50	1.58	22637
HCR Fmsyin2015 & TACc=15%	1.00	8471	0.76	1.35	1.00	3129	1.79	1.84	11600
HCR Fmsyin2015 & TACc=15% & Overshoot1=Medium	0.88	9566	0.65	1.26	1.00	4022	1.74	1.82	13342
HCR Fmsyin2015 & TACc=15% & Overshoot1=Very High	0.35	14050	0.40	0.66	1.00	6978	1.56	1.66	20965
HCR Fmsyin2015 & TACc=25%	0.99	11092	0.68	0.94	1.00	4122	1.74	1.69	15347
HCR Fmsyin2015 & TACc=25% & Overshoot1=Medium	0.76	11692	0.59	0.87	1.00	4794	1.70	1.68	16276
HCR Fmsyin2015 & TACc=25% & Overshoot1=Very High	0.27	14438	0.40	0.60	1.00	7164	1.54	1.61	21561
HCR Fmsyin2015	1.00	13813	0.42	0.73	1.00	6622	1.58	1.67	20633
HCR Fmsyin2015 & Overshoot1=Medium	0.11	14032	0.40	0.69	1.00	6958	1.55	1.67	21098
HCR Fmsyin2015 & Overshoot1=Very High	0.10	14889	0.35	0.51	1.00	7773	1.50	1.58	22770
HCR Fmsyin2011 & TACc=15%	1.00	8471	0.76	1.35	1.00	3096	1.79	1.84	11600
HCR Fmsyin2011 & TACc=15% & Overshoot1=Medium	0.93	9536	0.66	1.27	1.00	3964	1.75	1.82	13346
HCR Fmsyin2011 & TACc=15% & Overshoot1=Very High	0.35	14088	0.40	0.66	1.00	7034	1.55	1.65	21036
HCR Fmsyin2011 & TACc=25%	0.99	11092	0.68	0.94	1.00	4062	1.74	1.69	15347
HCR Fmsyin2011 & TACc=25% & Overshoot1=Medium	0.75	11683	0.59	0.88	1.00	4740	1.71	1.68	16350
HCR Fmsyin2011 & TACc=25% & Overshoot1=Very High	0.28	14440	0.39	0.59	1.00	7182	1.54	1.61	21577
HCR Fmsyin2011	1.00	13853	0.50	0.78	1.00	6009	1.62	1.67	20023
HCR Fmsyin2011 & Overshoot1=Medium	0.11	13825	0.46	0.75	1.00	6318	1.60	1.67	20217
HCR Fmsyin2011 & Overshoot1=Very High	0.10	14810	0.37	0.54	1.00	7579	1.51	1.59	22404

Table 4.3.2 presents the same results as Table 4.3.1 but only for the scenarios where the probability that $F_{2015} \leq F_{msy}$ for *L. piscatorius* is at least 0.95. None of the TAC overshoot scenarios achieve this objective and neither does HCR 1 ("10% Annual Decrease in F") without TAC constraints. W6 presents others HCRs that also achieved

this objective but their performance does not differ from the ones presented in this report, so there is no need to comment on them.

Table 4.3.2:

	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

The performance of each of the HCRs under the different scenarios has been graphically represented.

For each species:

- Plots of F_{real}/Fmsy
- Plots of F_{HCR}/Fmsy (different from F_{real}/Fmsy in scenarios with TAC overshoot)
- Plots of B/Bmsy

For both species:

- Plots of combined landings (including landings by species)
- Plots of TACs 1987-2020
- Plots of ratio Landings / TAC (from 2010 to 2020)

For all these plots the median with the 5th and 95th percentile were represented.

In this report it is only presented the scenarios *HCR: Fsq* (Fig. 4.3.2.1.) and *HCR: Fmsyin2015 & TACc=25%* (Fig. 4.3.2.2.) as examples, the rest of the summary plots are included as a background document.

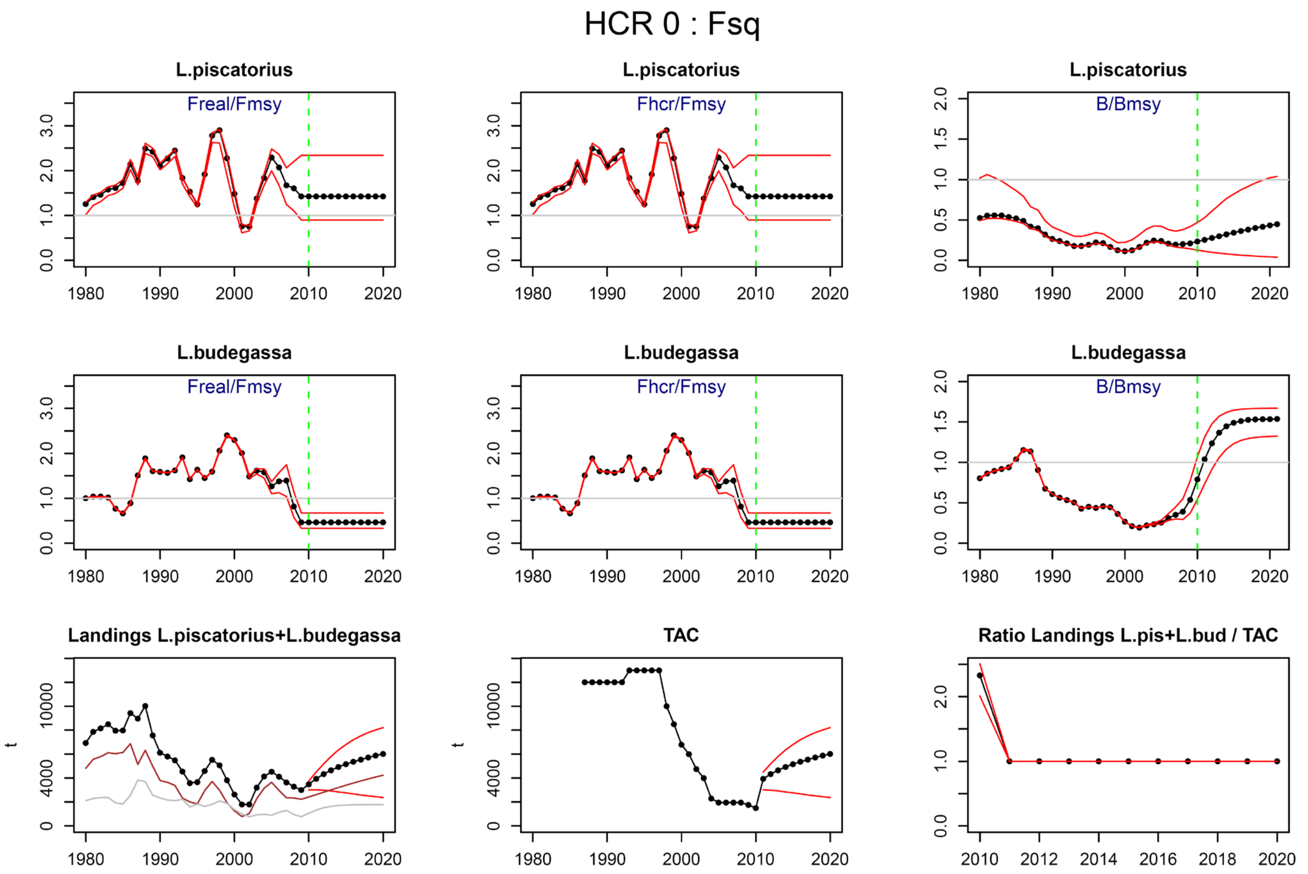


Figure 4.3.2.1. HCR 0 : Fsq performance.

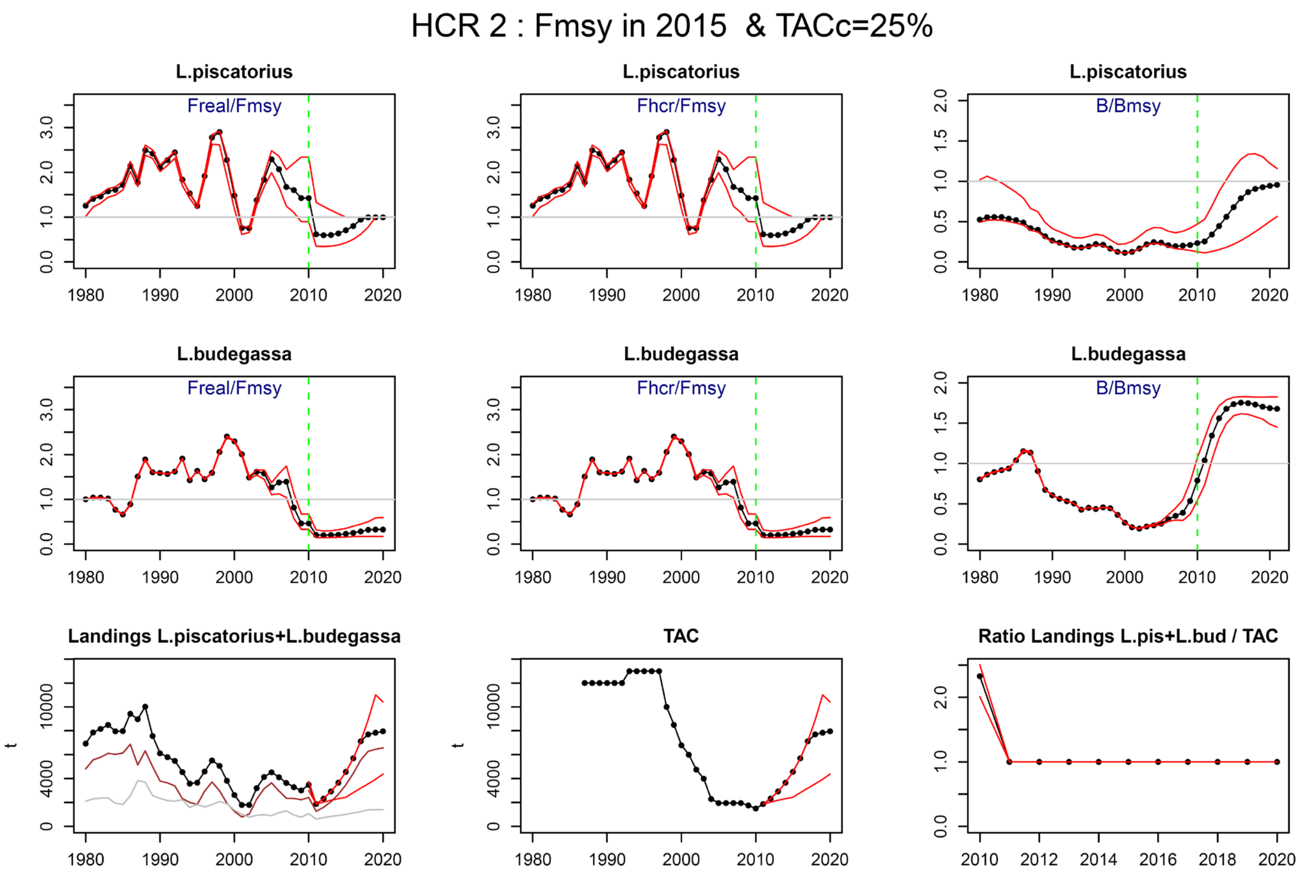


Figure 4.3.2.2. HCR: Fmsyin2015 & TACc=25%.

Figure 4.3.2.3 summarizes for the HCR 2 the trends in median F/F_{msy} for *L.piscatorius*, B/B_{msy} for *L. piscatorius* and landings for species, for years 2010-2020 for the different levels of TAC constraints (15%, 25 % and no TAC constraint).

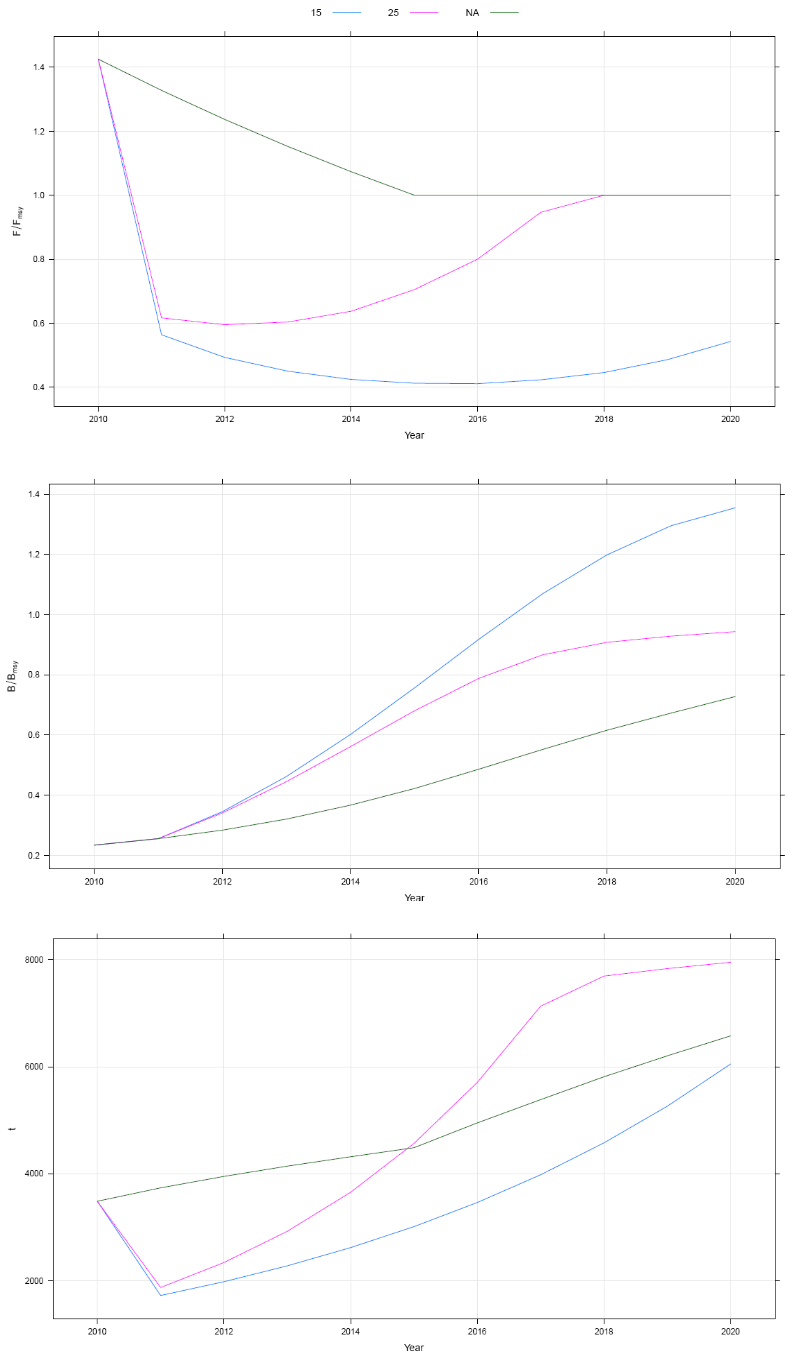


Figure 4.3.2.3: Effect of TAC constraint on performance of HCR 2

Figure 4.3.2.4. shows box-plots of Freal(2015)/FMSY for *L. piscatorius* for the different TAC overshoot levels (very high, medium and none). The TAC constraints are collapsed.

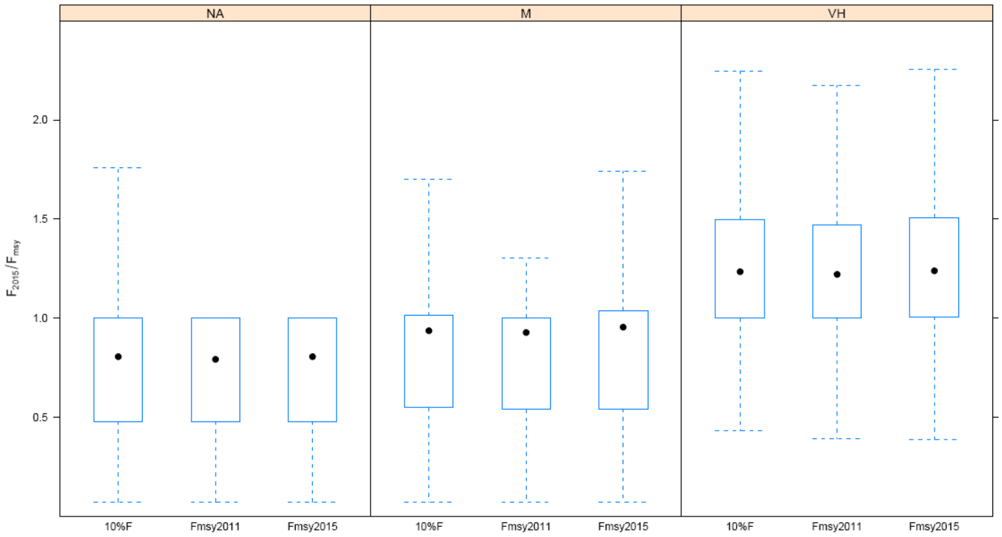


Figure 4.3.2.4. Impact of different TAC overshoot levels on Freal(2015)/FMSY for the different HCRs

If no TAC overshoot occurs, only HCR 2 and 3 ("Fmsy in 2015" and "Fmsy in 2011") have high probability to achieve the objective of reaching FMSY in 2015.

4.4 Summary and conclusions

Due to the starting conditions of *L. budegassa*, with F_{2009} below F_{msy} (F_{2009}/F_{msy} =0.45), all scenarios tested keep *F* below F_{msy}. So the analysis of results is mainly focused on *L. piscatorius*.

When no TAC constraint is applied, for all HCRs 1-3 the *L. piscatorius* biomass increases slowly towards B_{msy}. Assuming no TAC overshoot, the probability of *F* in 2015 being below or equal to F_{msy} is 1 for HCRs 2 and 3, but only 0.72 for HCR1 ("10% Annual Decrease"). The effect of TAC constraints (15% and 25% were explored) is dominant, all HCRs examined perform in the same way when the same TAC constraint is applied. This is because these TAC constraint levels force F(2011) below Fmsy. Different TAC constraints have clear impact on the development of SSB and yield during the next 10 years and a choice should result from a compromise between various aspects.

Performance plots and metrics show that the effect of TAC constraints is dominant and results obtained with HCRs 1-3 are virtually identical if the same TAC constraint is applied. In order to fulfill the TAC constraint *F* must decrease below F_{msy} in 2011, for all levels of TAC constraint considered, promoting fast biomass recovery. The most restrictive constraint, 15 %, gets *B2015/* B_{msy} to 0.76 for *L. piscatorius* and makes the biomass go above B_{msy} before *F* achieves F_{msy}. The scenarios with TAC constraint of 25 % lead the *B* and *F* corresponding to MSY early than TAC constraint of 15%.

TAC overshoot reduces the probability of *F* being equal to or below F_{msy} in 2015 to levels below 95% and slows down the recovery of the biomass. None of the HCR will achieve F_{msy} in 2015 if the TAC is overshot.

The choice of an HCR between the ones that achieve with high probability the target of *F* being equal to or below F_{msy} in 2015 (i.e. those in Table 4.3.2.) should take in 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 things.

5 *Nephrops* (FUs 28 and 29)

In FUs 28 and 29, *Nephrops* is mainly caught by the Portuguese crustacean trawl fleet and to a less extent by the artisanal fishery working with creel.

There are two main target species in the crustacean trawl fishery, the deepwater rose shrimp (*Parapenaeus longirostris*) and the Norway lobster (*Nephrops norvegicus*), sharing partly the same grounds. Although their distribution areas overlap at depths 200 – 500 m, rose shrimp highest yields occur at depths below 400 m whereas Norway lobster highest catch rates are at 500 – 600 m. Due to the high market value of rose shrimp and to the fact that its fishing grounds are closer to the coast, in periods of high abundance of rose shrimp the vessels spend less effort on *Nephrops*. In 2006-2009, the landings of rose shrimp increased showing a change in the objectives of the fishery (Figure 5.1).

5.1 CPUE standardization

In the last two working groups, a trial to standardize the *Nephrops* CPUE (in kg/day) was carried out using GLMs, but the final model never explained more than 20% of the variability (ICES, 2010b). The explanatory variables used were *year*, *month* and *vessel-category*. Considering the behaviour of the fleet in periods of high abundance of rose shrimp, new variables related to the daily catches of this species and the proportion of *Nephrops* in the total daily catch were incorporated and two approaches for the CPUE standardization with GLMs were presented in W3.

The first approach used a delta model to model the probability of obtaining a zero catch (binomial distribution with logit link function) and the catch rate (Gamma distribution with log link function), given that the catch is non-zero, separately. The final unconditioned CPUE estimate is the product of separate estimates of the probability of positive catch and the catch rates from the second step model.

The second approach modelled only the non-zero catches assuming that when the catch of *Nephrops* is zero, the fishery is not directed at this species. This assumption is based on the different depth distribution of rose shrimp and *Nephrops*, although some overlap occurs. This second approach used a Gamma distribution with log link function.

The logistic model fitted to the presence/absence of *Nephrops* explains 31% of the total variability. The most influential explanatory variable was the daily catch rate of rose shrimp. The Gamma model fitted to the positive values of NEP_{CPUE} explains 45% of the total variability, with the proportion of *Nephrops* in the total daily catches as the most important factor.

Although the CPUE estimates differ in the scale, the year effects resulting from both models are similar (Figure 5.2). Taking into account the knowledge of the fishery, the more consistent results in the assessment and improved diagnostics (catchability residuals and retrospective patterns), the second model – with non-zero catches, Gamma distribution with log link function – was accepted for stock assessment.

5.2 Assessment

The updated assessment performed in the WGHMM 2010, separately for males and females, using the data from the period 1984-2009, was only accepted for trends mainly due to the strong retrospective pattern. In this workshop, the assessment was carried out with the same settings of the previous assessment (ICES, 2010b) but using the new standardized CPUE series. As before and according to the recommendations of the WGMG (ICES, 2009), a very weak shrinkage was used.

Figures 5.3 to 5.6 show the log catchability residuals and the retrospective patterns, for males and females, comparing with the WGHMM 2010 assessment. The residuals pattern has improved (Figures 5.3-5.4), though year effects are not completely removed. Full diagnostics can be found in W3.

The retrospective pattern (Figures 5.5-5.6) has also been reduced with the new CPUE series for Fbar and SSB. In what concern Recruitment, although there is some reduction, the retro pattern is still high.

The summaries of the assessment results are presented in Table 5.1 and 5.2, for males and females, respectively. Comparative plots of the results from the assessments performed in WGHMM2010 and in this workshop are shown in Figure 5.7. With the new CPUE series, Fbar and SSB show the same trends but with lower values of F and higher values of SSB, in the most recent years.

The assessment results for males and females indicate a decreasing trend in F since 2006, which is in line with the increase of rose shrimp abundance in the last four years. The effort decrease on *Nephrops* stocks is probably not only due to the Recovery Plan effort regulations but mainly to an effort shift to target rose shrimp.

5.3 Biological reference points

Biological reference points were estimated on the basis of the Yield per Recruit curve. Considering the retrospective pattern, WGHMM 2010 estimated the biological reference points based on the convergent part of the XSA, the selection pattern and weights-at-age being the average of the years 2002-2004.

However, since the extent to which the fishery targets *Nephrops* depends on rose shrimp abundance, and this might potentially impact on the relative exploitation pattern-at-age, a sensitivity analysis of the potential Fmsy proxies was conducted, with the average selection pattern of a three-year moving window since the beginning of the series. The $F_{0.1}$ shows some stability over the time series, either for males or females, and may be considered as a Fmsy proxy. At $F_{0.1}$ the %SPR are above 35% (table below). The Y/R curves for this species are flat-top and Fmax is not well defined.

The following table summarizes the BRPs for males and females:

	Males		**Females**	
BRPs	**F**	**%SPR**	**F**	**%SPR**
$F_{0.1}$	0.21	40%	0.18	42%
$F_{35\%SPR}$	0.26	35%	0.24	35%

Fbar in 2009 is 0.09 year^{-1} and 0.06 year^{-1} for males and females, respectively, both well below $F_{0.1}$. Figure 5.8 shows the Y/R and B/R curves for males and females, relative to the F2009. $F_{0.1}$ is 2.3 times the value of F2009 for males and 3.1 times the value for females.

5.4 Summary of the assessment

The summary of assessment results for both males and females shows that:

- F in 2009 was below $F_{0.1}$
- The recruitment has been at the same level in the most recent period (2003-2008)
- SSB presents an increasing trend in recent years

Taking into account the status of the stocks in these FUs, the potential for F increase if the abundance of rose shrimp drops and the little interaction between this fishery and the other fisheries in Division IXa, the group decided not to proceed with the HCR developed for hake and anglerfish but rather simulate a quick increase in F to catch the Portuguese quota but having $F_{0.1}$ as target (adopted as proxy for F_{msy}) . The quota was set at the level of 2010 (≈250t). As the TAC is set for the entire Division IXa, no TAC constraint was considered.

5.5 Projections

To account for uncertainty around model fitting, residuals from the XSA fit were randomly re-sampled (bootstrapped, 1000 samples) generating new abundance indices and the XSA model was refitted by bootstrap sample.

Stochastic projections were performed for the period 2010-2020 on each of the 1000 samples, assuming a mean stock-recruitment relationship, and scaling the average F-at-age of the last three years to 2009 F-value. Recruitment values for the projected years of each bootstrap line were sampled from the recruitments of the same line for the period 1990-2009. This period includes low and medium level recruitments. Natural mortality (M of 0.3 for males and of 0.2 for adult females), weights-at-age and proportion mature-at-age (averaged over 2007-2009) were assumed to be time-invariant and without error.

Males and females are caught together during the main fishing season (spring and summer) but the availability of females is reduced during the egg-bearing period (autumn and winter). As *Nephrops* males constitute the most exploited component of the stock, they will drive the strategies to be applied to females. Therefore, the F-multipliers vector, resulting from the simulation of the HCR on males stock, was applied to females.

The HCR applied was the increase in F by 50% until Fmsy and keep F at this level for the following years. With this increase, the male F reach Fmsy before 2015 for male stock but the female F is kept below Fmsy.

The results of this scenario are presented in Figures 5.9 and 5.10.

For males, the probability of reaching Fmsy is 1 in 2013. For males, median SSB in 2015 and 2020 will be, respectively, 1.17 and 1.14 of the reference level of 2010 and for females, will be around the same level of 2010.

The total Yield (males and females combined) will reach a maximum of 260t in 2012 decreasing to ~250t in 2020, which is the level of the Portuguese quota for 2010.

5.6 Summary and conclusions

In FUs 28-29, *Nephrops* is caught in a crustacean fishery that also targets rose shrimp. Work is in progress aiming to understand the dynamic processes behind the large fluctuations in the abundance of this species, which are difficult to predict. Rose shrimp occurs in shallower grounds closer to the coast and its market value is very high. When the abundance of this species is high, most of the effort of the crustacean fleet is directed at this species reducing the pressure on *Nephrops* stocks. This was the situation of the period 1999-2003 and of the most recent years (2006-2009).

Nephrops stocks are at present underexploited with potential for F increase. Recruitment has been at a low/median level. An increase in F is expected if the rose shrimp abundance drops but this increase should be limited by the level of Fmsy.

New CPUE standardization accepted as the basis of a stock assessment at this workshop which improves the XSA model diagnostics (retrospective pattern). This report includes the analytical assessment; together with a short-term forecast. A proxy for an F_{MSY} is proposed and the ICES' stock annex has been revised and updated (see Annex 4).

5.7 Collated tables and figures for *Nephrops* (FUs 28 and 29)

Table 5.1. FU 28-29. *Nephrops* males. Summary of assessment results.

Year	R	SSB	Yield	Fbar
1984	16491	844	292	0.4335
1985	14634	827	353	0.6473
1986	16356	706	315	0.6523
1987	20684	699	277	0.5147
1988	16838	786	249	0.3901
1989	16960	870	318	0.6347
1990	12458	847	350	0.5295
1991	12076	726	344	0.7253
1992	12945	576	305	0.7712
1993	8542	458	232	0.6566
1994	5337	355	139	0.6080
1995	4811	293	98	0.3732
1996	6990	307	64	0.2274
1997	8154	442	74	0.1627
1998	8647	461	88	0.2095
1999	7980	567	116	0.2359
2000	8205	627	117	0.2209
2001	9028	687	190	0.3434
2002	8449	685	222	0.4099
2003	10458	636	201	0.3963
2004	11392	647	245	0.5109
2005	10299	579	230	0.4807
2006	8151	553	136	0.2744
2007	7803	535	128	0.2612
2008	6970	692	105	0.1631
2009	10290	663	60	0.0922

Table 5.2. FU 28-29. *Nephrops* females. Summary of assessment results

Year	R	SSB	Yield	Fbar
1984	12639	760	169	0.2844
1985	13112	743	156	0.2068
1986	13542	763	150	0.2300
1987	15242	809	232	0.2350
1988	13523	745	171	0.2445
1989	12470	729	151	0.2790
1990	11600	723	174	0.3324
1991	13751	694	134	0.1828
1992	13463	744	165	0.2250
1993	9989	733	145	0.1879
1994	8527	685	97	0.1439
1995	8024	685	174	0.4361
1996	10166	615	67	0.1781
1997	9394	661	62	0.0777
1998	8501	720	72	0.1281
1999	8352	721	95	0.1649
2000	8502	774	84	0.1226
2001	8719	741	79	0.1294
2002	9926	780	135	0.2255
2003	11812	786	126	0.2398
2004	13612	809	170	0.2482
2005	12166	813	152	0.2122
2006	10756	776	95	0.1620
2007	11290	801	90	0.1123
2008	12230	893	67	0.0982
2009	15394	941	48	0.0593

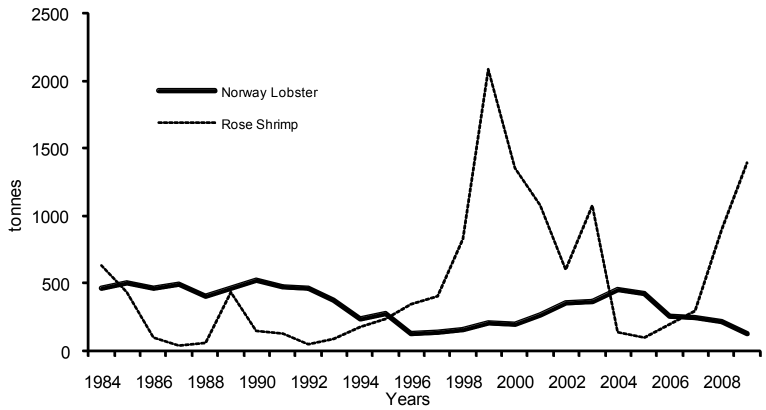


Figure 5.1. Rose shrimp and Norway lobster Portuguese landings in the period 1984-2009.

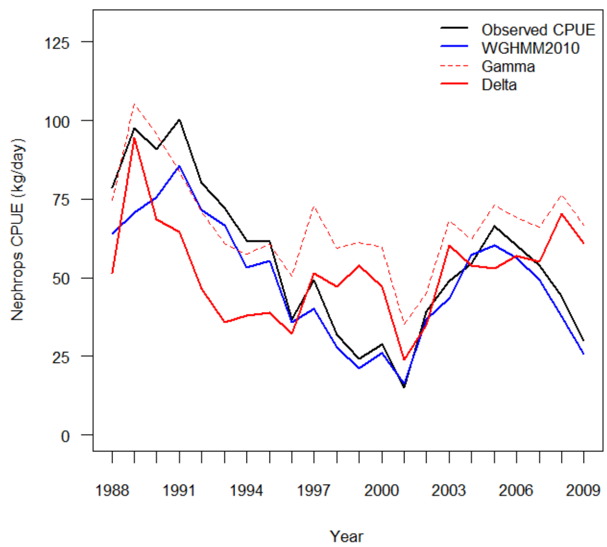
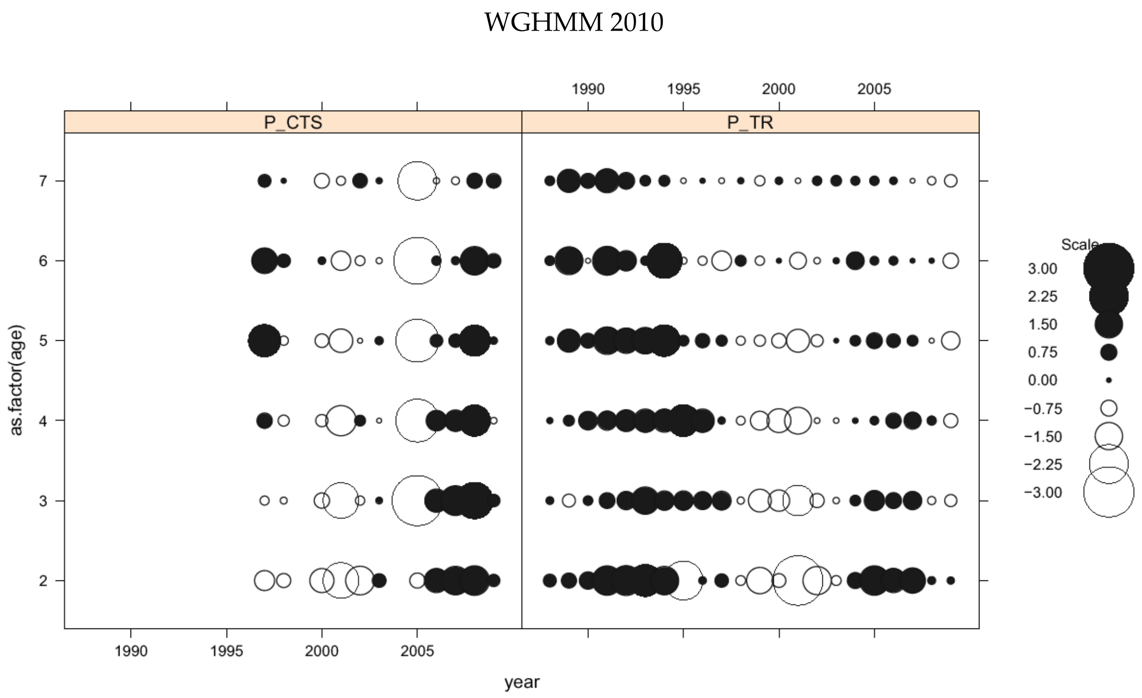


Figure 5.2. Comparison of average observed CPUE and the CPUE estimates from WGHMM 2010, the Delta model and the Gamma model.



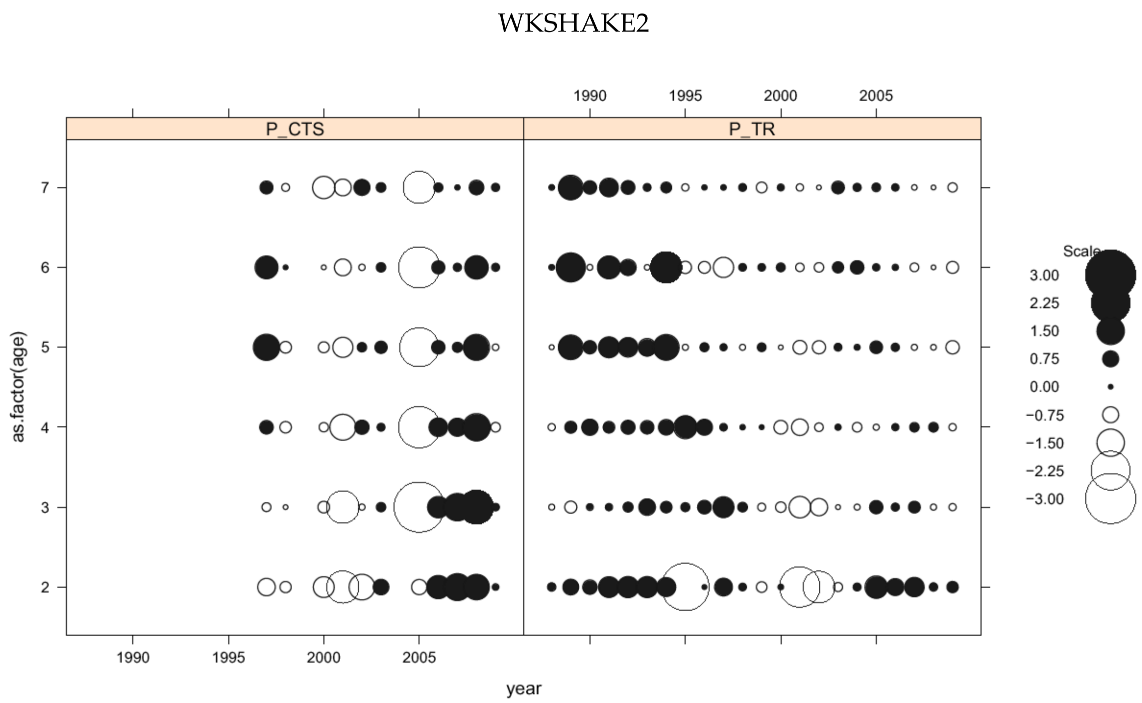


Figure 5.3. ***Nephrops*** **Males Log catchability residuals by fleet (P-CTS: Crustacean Survey, P-TR: Commercial Trawl), using different models for the standardization of commercial trawl effort.**

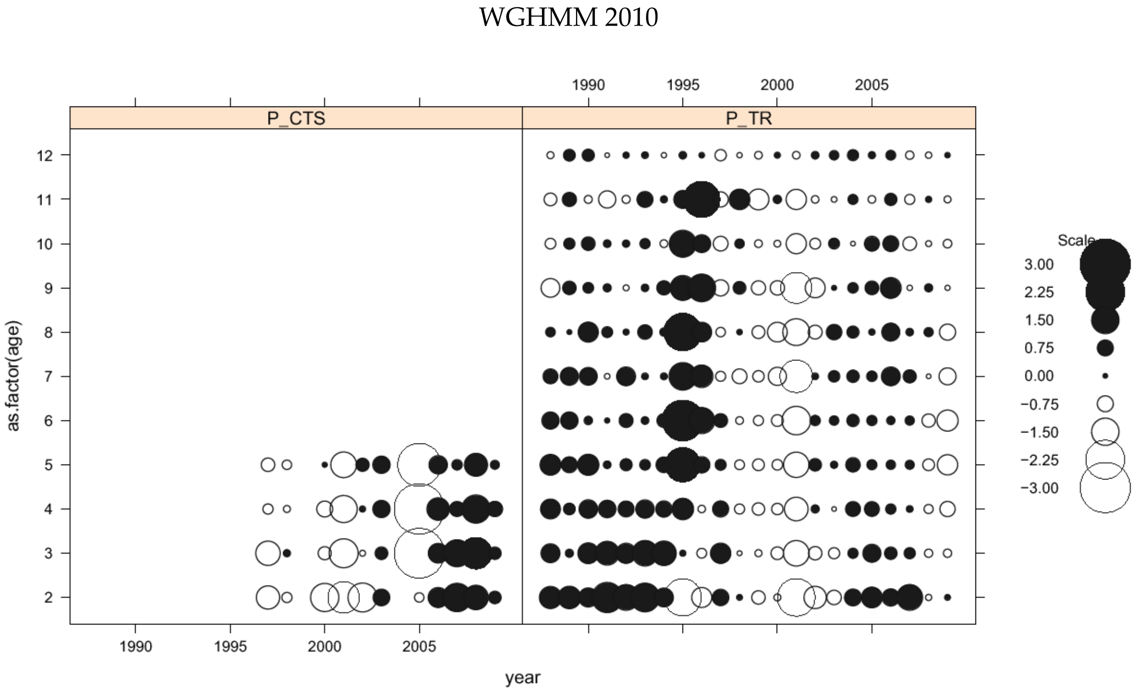


Figure 5.4. ***Nephrops*** **Females Log catchability residuals by fleet (P-CTS: Crustacean Survey, P-TR: Commercial Trawl), using different models for the standardization of commercial trawl effort.**

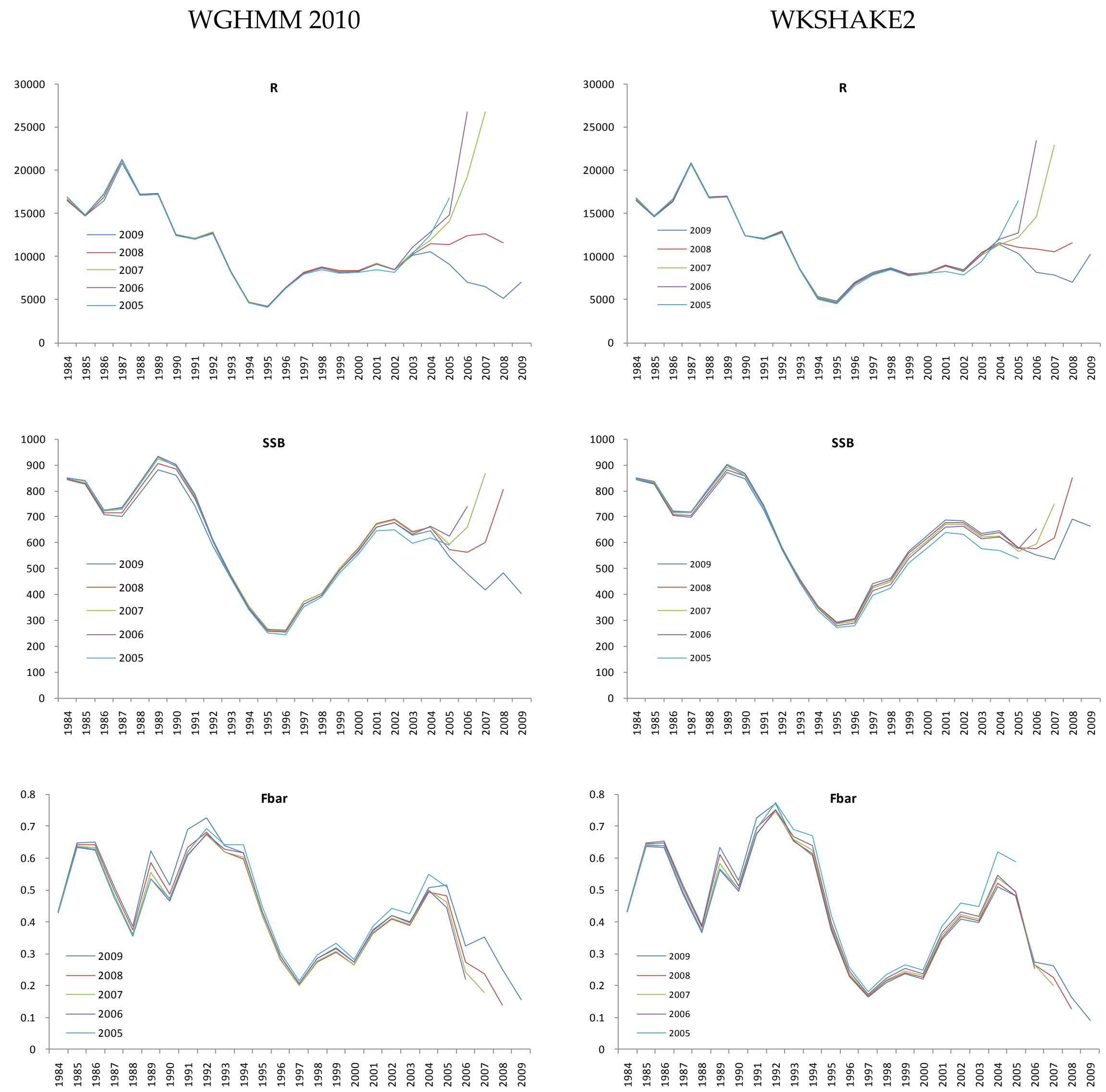


Figure 5.5. ***Nephrops*** **Males. Retrospective pattern.**

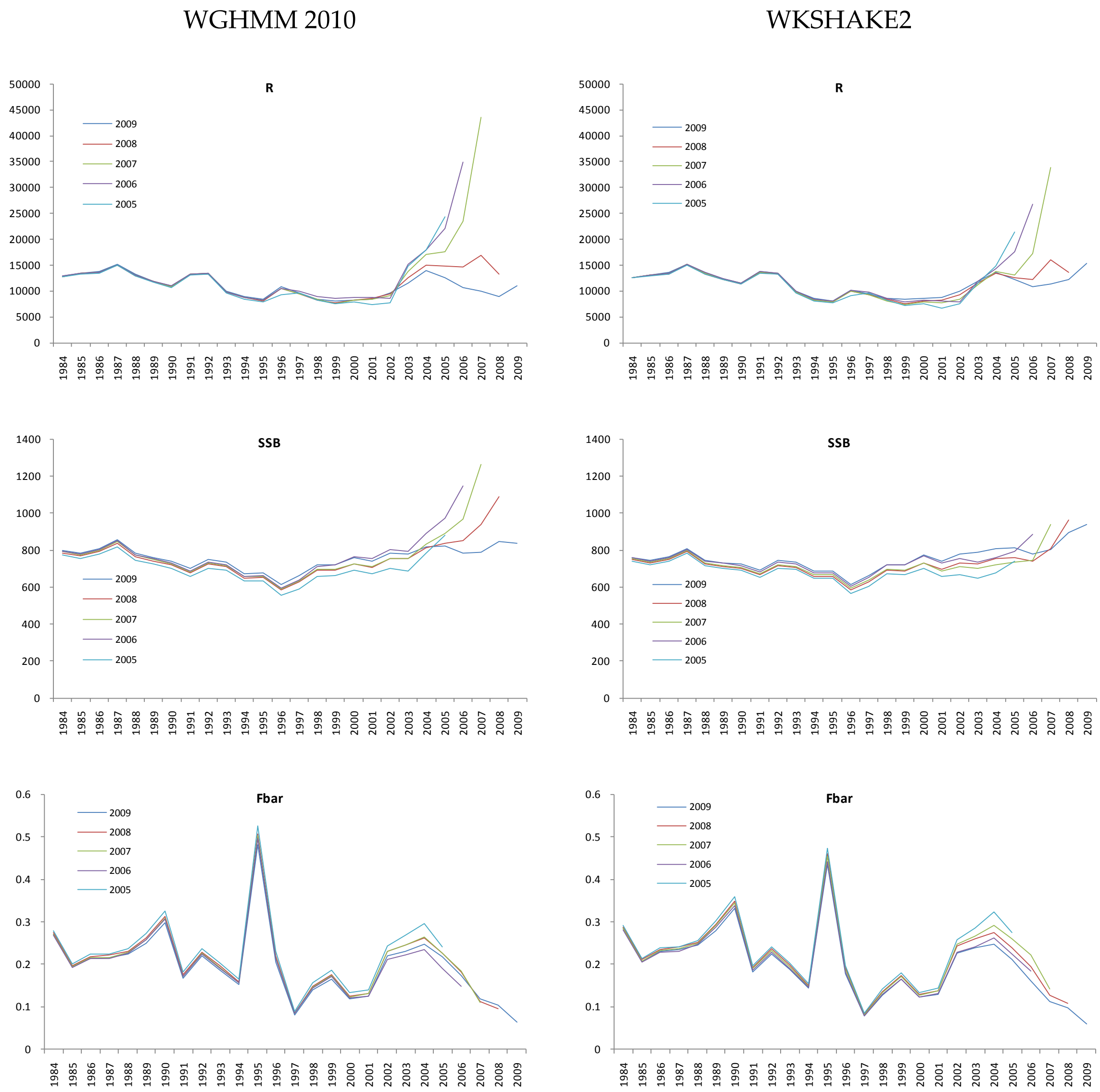


Figure 5.6. ***Nephrops*** **Females. Retrospective pattern.**

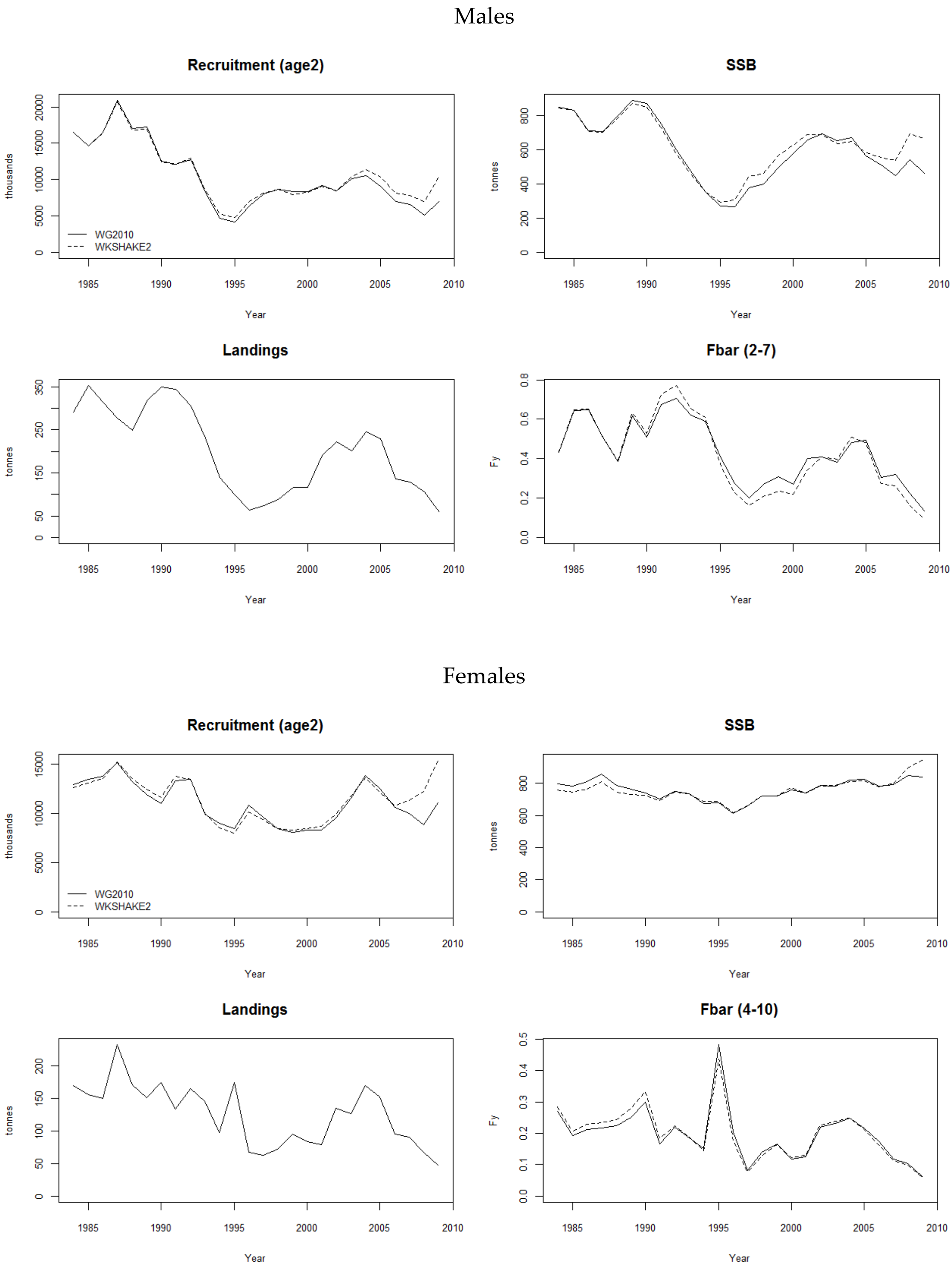


Figure 5.7. Comparative plots of results assessments for *Nephrops* Males and Females.

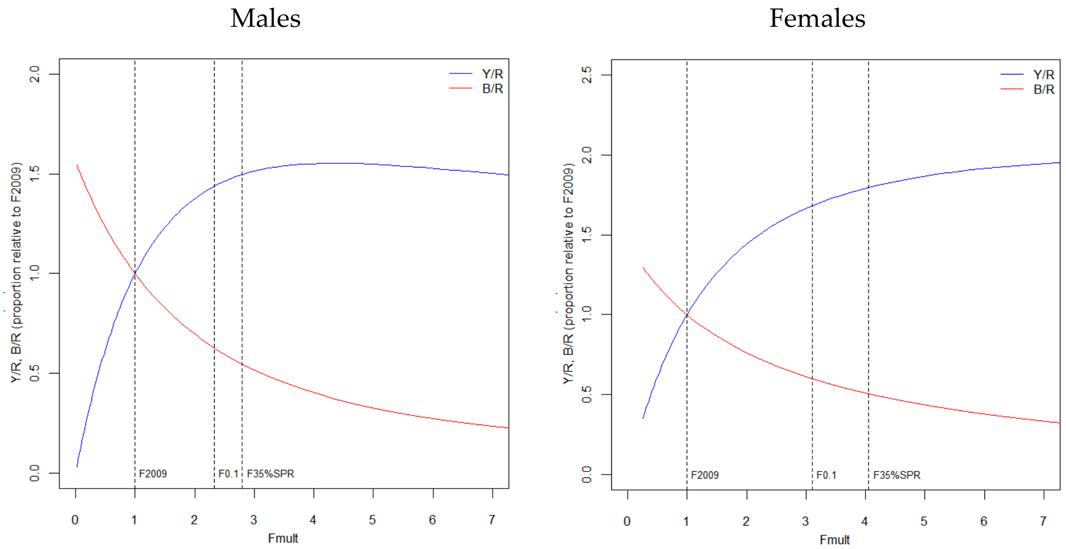


Figure 5.8. Y/R and B/R curves for *Nephrops* males and females. Units relative to F_{2009}.

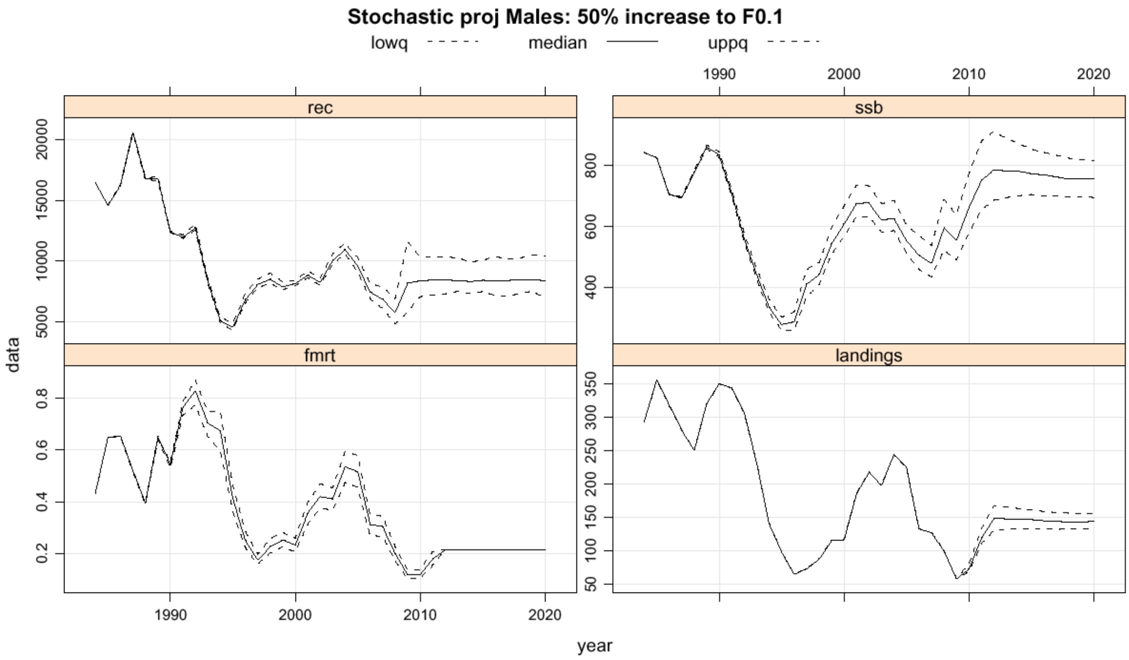


Figure 5.9. *Nephrops* Males. Projection scenario for 50% increase in F until Fmsy.

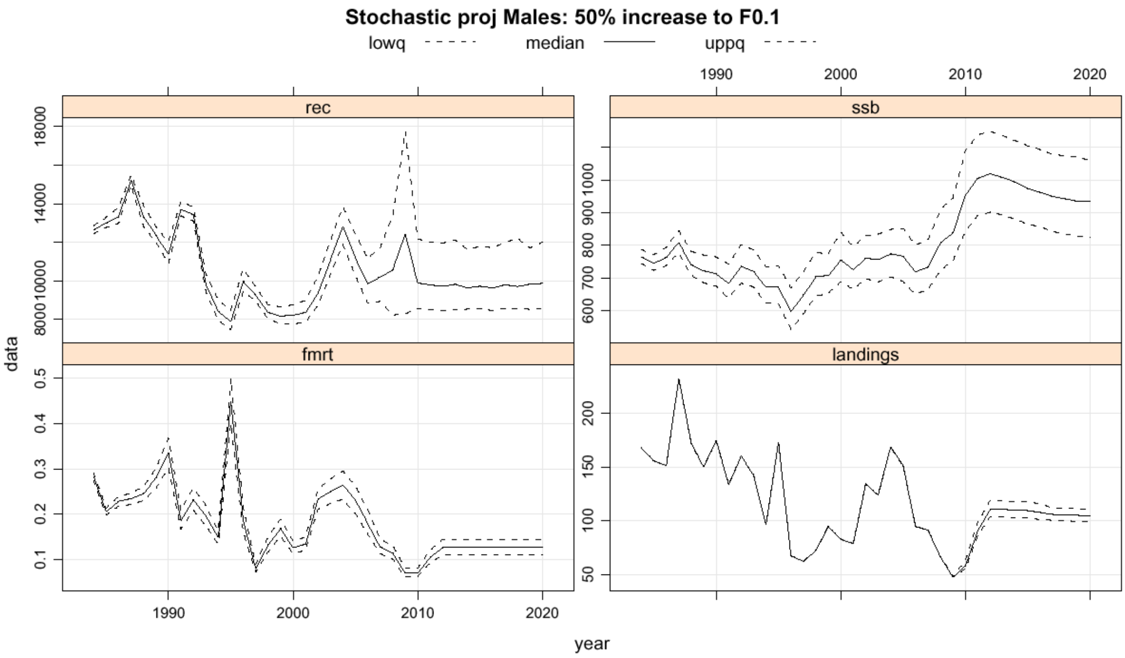


Figure 5.10. ***Nephrops*** **Females. Projections scenario using the F multipliers from the male projection (50% increase in males F until Fmsy).**

6 *Nephrops* (FU 30)

The *Nephrops* stock from FU30 is included in ICES Division IXa and it comprises the Spanish waters of the Gulf of Cadiz, defined as the Spanish Suratlantic Region. The western limit of the stock is at the Portuguese border, on the Guadiana River estuary, whereas the eastern border is at the Gibraltar Strait.

6.1 Description of fishery and spatial distribution from surveys

Nephrops in FU30 is mostly caught in a mixed fishery by the bottom trawl Spanish fleet. *Nephrops* landings are clearly seasonal in this area with the highest values from April to September (Jiménez, 2002) (see Figure 6.1). The seasonality of the fishery is related to the reproductive behaviour of this species. Females go out of their burrows for mating and fertilization during spring and summer, the whole of the resource then becoming more accessible to the fishery.

The spatial distribution pattern of *Nephrops* from the annual Spanish bottom trawl spring and autumn (SP-GFS-cdspr and SP-GFS-cdaut) survey data shows that it is distributed at more than 200 m of depth, in a patchwork configuration on muddy and sandy substrate (Figure 6.2). It must be kept in mind that the ARSA surveys take place at times of the year when a fraction of the female population is hidden in burrows due to their reproductive behavior.

Nephrops fishing grounds include the whole of the species distribution (Ramos et al., 1996). These authors indicated higher yield per haul at more than 400 m of depth, especially in the so-called *Laberinto,* which is an area far from the coast and with very intricate topography (see Figure 6.3). Information obtained from two experimental surveys (conducted for gear selectivity studies) (Sobrino et al., 2007, 2008) carried onboard 8 commercial vessels in 2007 and 2008 during the *Nephrops* fishing season suggests that, at present, the traditional *Nephrops* fishing grounds are not often exploited, with the bottom trawl fleet operating mostly in the 200-400 m depth range (Figure 6.3). At these lower depths, the *Nephrops* fishing grounds overlap with those of other target species of the bottom trawl fleet, particularly rose shrimp (*Parapenaeus longirostris*) and hake.

The *Modernization Plan of the Andalusian Fishing Sector,* implemented by the Regional Administration at the end of the nineties, homogenized considerably this fleet in terms of technical characteristics and fishing capacity. After this fleet conversion, differences between fishing vessels were lessened and more vessels could access the more remote and deeper fishing grounds, resulting in an increase of *Nephrops* directed effort and landings between 2000 and 2004. At present, the Gulf of Cadiz bottom trawl fleet corresponds to a unique and highly multi-specific *métier* with vessels behaving in a very flexible and adaptable way regarding the species they target during fishing trips (Silva et al. 2007).

6.2 Management measures currently in place

Different Fishing Plans for the Gulf of Cadiz have been established by the Spanish Administration since 2004 in order to reduce the fishing effort of the bottom trawl fleet (ORDENES APA/3423/2004, APA/2858/2005, APA/2883/2006, APA/2801/2007, ARM/2515/2009, ARM/58/2010). The first of these Fishing Plans (which started in October 2004 and lasted for 1 year) restricted the maximum number of fishing hours per day to 18, which could have an effect on *Nephrops* directed effort, because vessels may not have enough time to access the traditional *Nephrops* fishing grounds, which are deep and are located far from the coast. However, the Fishing Plans that followed from the end of 2005 onwards imposed this maximum number of fishing hours per day only as an annual average. All the Fishing Plans establish a continued period of 56 hours per week without fishing and a single landing event per vessel per day. Since the first Fishing Plan in 2004 a closed fishing season with a gradual increase in the number of days has been implemented (45, 60, and 90 days per year).

The latest Fishing Plan (ARM/58/2010) is being applied since September 2010 and will last for 2 years. This plan reduces the length of the closed fishing season to 45 days, between September 24 and November 7 2010, plus 5 additional days to be selected by the ship owner during the duration of this Plan. The potential effect of the closed seasons on the *Nephrops* population has not been evaluated. However, from 2006 to 2008, total fleet effort and *Nephrops* directed effort decreased, even though the closed seasons were established outside the main *Nephrops* fishing months. As a proxy for *Nephrops* directed effort, the set of trips for which *Nephrops* represents at least 10% of the landed weight is used. All Fishing Plans starting from the one in 2007 state that by the end of the Fishing Plan, the fishing capacity of the Gulf of Cadiz bottom trawl fleet must have been reduced by 6% on a permanent basis. Additionally, an increase of mesh size to 55 mm or more was implemented at the end of 2009 in order to reduce discards of individuals below the minimum landing size.

New regulations were recently established by the Regional Administration with the aim of distributing the fishing effort throughout the year (Resolutions: 13th February 2008, BOJA nº 40; 16th February 2009, BOJA nº 36; 23th November 2009, BOJA nº 235; 15th October 2010, BOJA nº 209). These regional regulations control the days and times when the Gulf of Cadiz bottom trawl fleet can enter or leave fishing ports. Although the regulations vary between them, they generally permit a lot of flexibility during late spring and summer months (*e.g.* the 2010 Regulation establishes a continued period from Monday 3 am to Thursday 9 pm during May-August), which is the main *Nephrops* fishing season, with more restricted times in other months. This flexibility in summer months might have induced fleets from the ports closer to *Nephrops* grounds, such as Ayamonte or Isla Cristina, to direct their fishing effort to this species. However, the *Nephrops* directed fishing and landings decreased sharply in 2008 and remained at similarly low levels in 2009. The increased abundance of rose shrimp is believed to have led to a change in the objectives of the fishery, as rose shrimp achieves a higher market value and its fishing grounds are easier to access because they are less deep (90-380 m) and closer to the coast.

6.3 Assessment

The ICES assessment of *Nephrops* FU 30 is based on visual inspection of trends in directed effort and LPUE, abundance indices from the ARSA survey in March and mean sizes in the survey and commercial catch. Given the inconsistencies in the length compositions of commercial catch in 2001-2005 (Silva et al., 2005), caused by problems in the sampling scheme, and the absence of additional information, analytical assessment of this FU has not been carried out so far. The results of the latest ICES assessment can be found in the WGHMM 2010 report (ICES, 2010b). A Shaefer biomass dynamic model using the software ASPIC (Prager, 1994; Prager, 2004) was carried out in an attempt of assessment this FU. However, very severe difficulties with convergence of the ASPIC runs were encountered, which determined to a very large extent the input settings that could be used. In particular, no convergence was achieved unless B1/K (stock biomass in the first assessment year relative to virgin biomass) was fixed (rather than estimated) at a value of at least 0.95. The assessment starts in 1994 and the *Nephrops* stock had by then been exploited for a long time, hence the value B1/K=0.95, which had to be used to attain convergence, does not seem realistic (W4 Vila *et al*., 2010).

6.4 Results

WGHMM 2010 concluded that the stock seems stable at recent levels of fishing, but its long-term potential is unknown. Nonetheless, current biomass is lower than at the beginning of the 1990s. This vision was reinforced in the ICES advice for 2011, which was different for the Precautionary Approach (do not increase recent level of landings) and the MSY Approach (reduce recent landings at a rate greater than the overall rate of stock decrease).

Overall, the results of the ASPIC model agree with the conclusions of WGHMM 2010, although they are perhaps a bit more positive (the overall rate of stock decrease is attenuated and there are even some signs of increase in the last 5 years). The results from the ASPIC model also indicate that B has been above Bmsy and F below Fmsy (Figure 6.4) throughout the entire assessment period, but this could be strongly influenced by having to fix B1/K at 0.95 (in order to achieve model convergence) and, hence, it is not considered to be a reliable conclusion. Therefore, we do not consider that the ASPIC results can be used as a basis to conduct stock projections.

6.5 Summary and conclusions

Lacking an analytical assessment, it is not possible to assess the distance from current F to a potential Fmsy level.

Given that the bottom trawl fleet of the Gulf of Cadiz consists of only one, highly multi-specific *métier*, the F reduction measures that will be applied to hake (for which current F is 3 times above Fmsy) should also cause a reduction on the fishing pressure applied to *Nephrops*. The strong seasonality of the *Nephrops* fishery, with most of the landings between April and September, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months. It might be appropriate to apply the restriction on the number of fishing hours per day established in the Gulf of Cadiz Fishing Plans on a daily basis instead of as an annual average, at least during the main *Nephrops* fishing season. This would make it difficult for the fleet to access the deeper *Nephrops* fishing grounds, hence reducing fishing pressure on the species. In any case, the development of the stock should continue to be monitored on an annual basis, so that additional measures can be taken, if necessary.

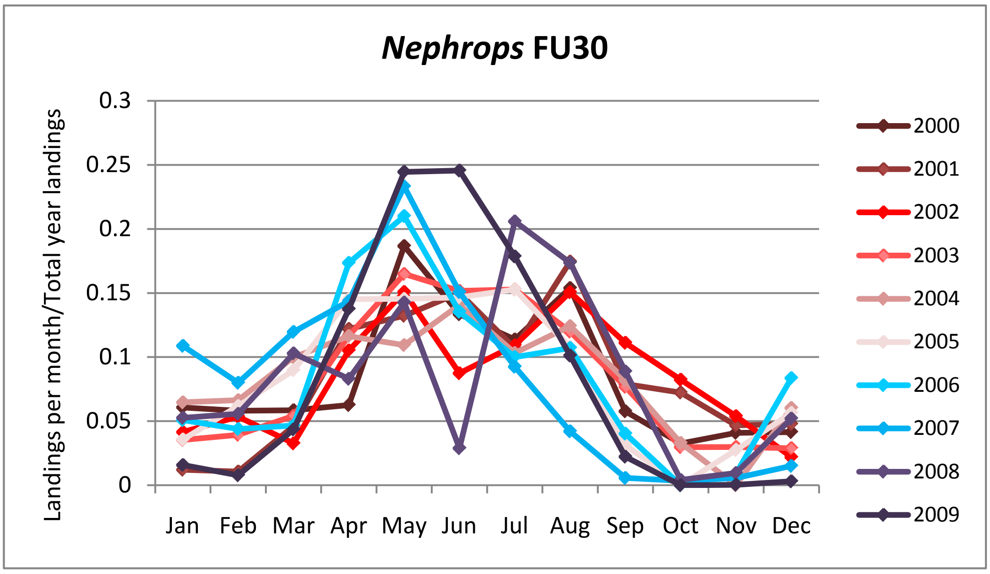


Figure 6.1: Seasonal pattern of *Nephrops* FU30 landings (Landings per month/ Total year landings for 2000-2009 period).

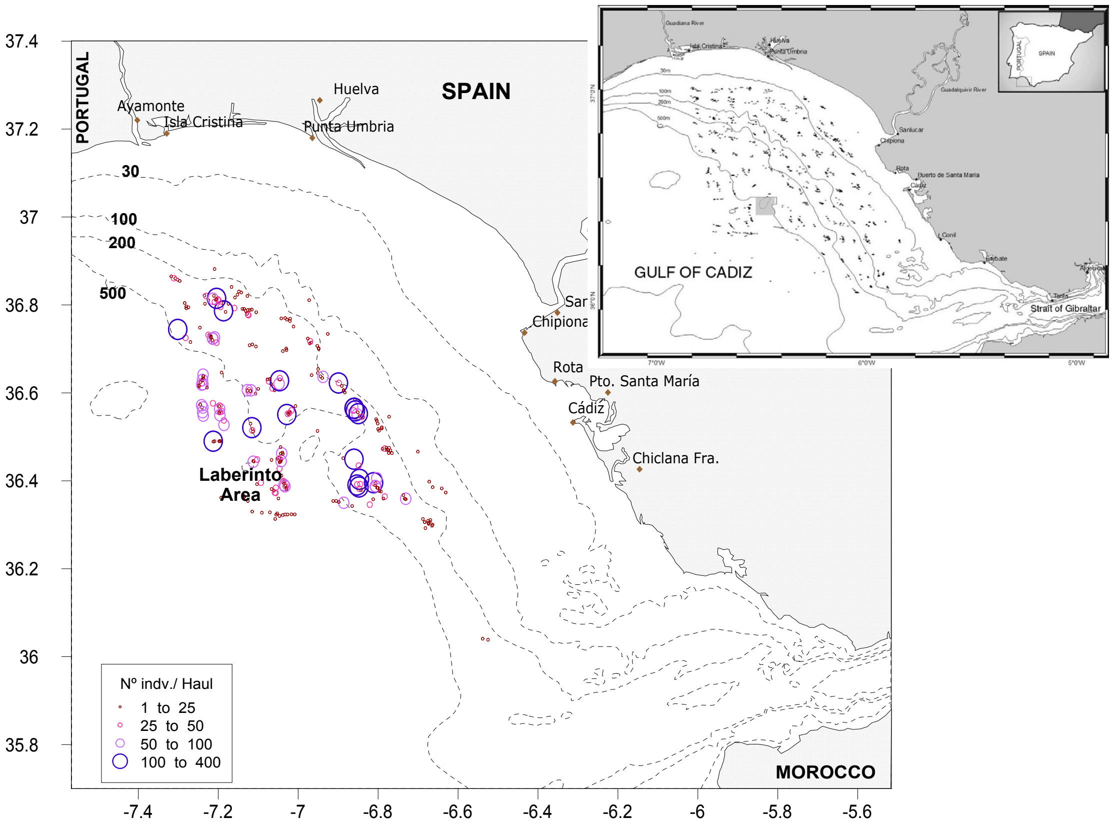


Figure 6.2: *Nephrops* distribution from ARSA survey data. Surveyed area and location of haul in ARSA surveys (1994-2009) are represented on the right top corner.

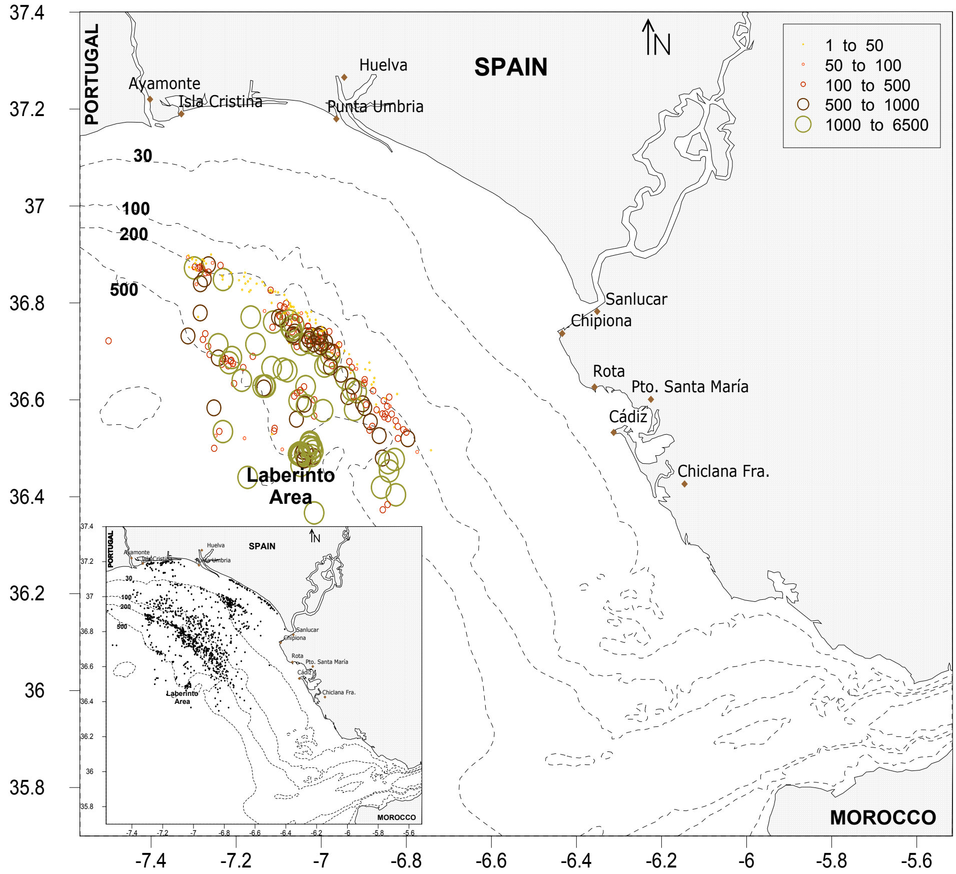


Figure 6.3: ***Nephrops*** **yields per haul obtained from two experimental surveys carried out in 2007 and 2008 by commercial vessels operating in their usual fishing areas. Location of hauls carried out during the surveys is represented on the left bottom corner.**

Figure 6.4: Results from ASPIC run: B/Bmsy and F/Fmsy.

7 *Nephrops* (FUs 25, 26-27 and 31)

Nephrops in ICES Division VIIIc consists of 2 functional units (FUs): 25 (North Galicia) and 31 (Cantabrian Sea), which are both assessed by ICES to be at very low levels. For these FUs, ICES has been recommending zero catch since 2002. The situation is similar for FUs 26-27 (West Galicia and North Portugal), in ICES Division IXa, for which ICES recommendation has been zero catch since 2003.

7.1 Fisheries description

FUs 25 and 31 are exploited exclusively by the Spanish bottom trawl fleet operating in ICES Division VIIIc, whereas FU 26-27 are exploited mostly by the Spanish bottom trawl fleet operating in ICES Division IXa (North) and, to a much lesser extent, by Portuguese trawl and artisanal fleets operating in the same area.

Landings in all these FUs have been very low for about one decade. Discards are believed to be minimal (only soft or damaged individuals are discarded).

The Spanish bottom trawl fleet operates a mixed fishery in VIIIc and IXa (North), catching a variety of species, mainly hake, anglerfish, megrim and horse mackerel. *Nephrops* can no longer be considered a target species of this fleet and, as already indicated, *Nephrops* landings have been very low for about 1 decade.

7.2 Assessment

FUs 25 and 26-27 were last assessed using an analytical procedure (XSA, after applying slicing to the length frequency distributions of the landings) in WGHMM 2006, with the results being considered only indicative of stock trends. At that time, landings of FU 31 were already considered too low to conduct an analytical assessment of this FU. Since then, landings have been so low in all FUs that no further analytical assessment has been attempted and their status has been assessed by examination of trends in landings, commercial LPUE and mean size in the landings.

7.3 Exploring a relationship between landings of hake and anglerfish and landings of *Nephrops*

An attempt has been made to examine if a relationship could be found between landings of *Nephrops* and landings of either hake or anglerfish which could allow us to get an estimate of *Nephrops* future landings from projections of landings of these other species. In principle, it is expected that a relationship with anglerfish could be more likely than with hake. The reason is that this bottom trawl fleet operates with two different gears (often within the same trip) and one of the gears catches mostly hake and horse mackerel, whereas the other one catches mostly hake, anglerfish, megrim and *Nephrops*. Hence, *Nephrops* catches are expected to be more closely associated with anglerfish than with hake catches.

7.4 Results

Figure 7.1 displays time series of landings of FU25, 26-27 and 31 (top left panel), white anglerfish (*Lophius piscatorius*, labelled as "P") landed by Spanish bottom trawl in VIIIc, IXa and VIIIc-IXa together (top right panel), black anglerfish (*Lophius budegassa*, labelled as "B") landed by Spanish bottom trawl in VIIIc, IXa and VIIIc-IXa together (bottom left panel) and hake (labelled as "H") landed by Spanish bottom trawl in VIIIc-IXa together (bottom right panel). The data come from the WGHMM 2010 report.

Figure 7.2 displays pairwise scatterplots of these same time series, to try and see whether a relationship can be visually seen between landings of these *Nephrops* FUs and landings of P, B or H. Although there seems to be some positive association between landings of *Nephrops* and landings of anglerfish when the whole time series is considered (because, essentially, landings have decreased substantially for *Nephrops* and for anglerfish over the range of years analysed), this does not hold in the last 8-10 years, when *Nephrops* landings have been extremely low and do not seem to be associated with anglerfish landings (W5 provides detailed graphs illustrating this). Also, results from linear fits of data did not present statistical significance.

Clearly, landings depend on effort, catchability and stock abundance. It might be expected that fishing effort is more or less similar for *Nephrops* and anglerfish, but the same will not necessarily hold for catchability and/or stock abundance trends. Therefore, it is not surprising to find that *Nephrops* landings can not be predicted from anglerfish landings.

As a final comment, we point out the marked seasonal character of the *Nephrops* landings. Figure 7.3 displays the monthly proportions of the Spanish bottom trawl fleet annual landings for FUs 25, 26-27 and 31 combined. It is clear from the figure that the majority of landings occur between May and August and this seasonal pattern is stable through the years.

7.5 Summary and conclusions

It does not seem possible to forecast *Nephrops* landings from hake or anglerfish landings.

Given the very low biomass level of *Nephrops* FUs 25, 26-27 and 31, the catch of these FUs 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 (for which current F is estimated to be 3 times above Fmsy) and anglerfish (*L. piscatorius* currently about 1.5 times above Fmsy) should have the effect of also reducing fishing pressure on *Nephrops*. The strong seasonality of the *Nephrops* fishery, with most of the landings between May and August, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

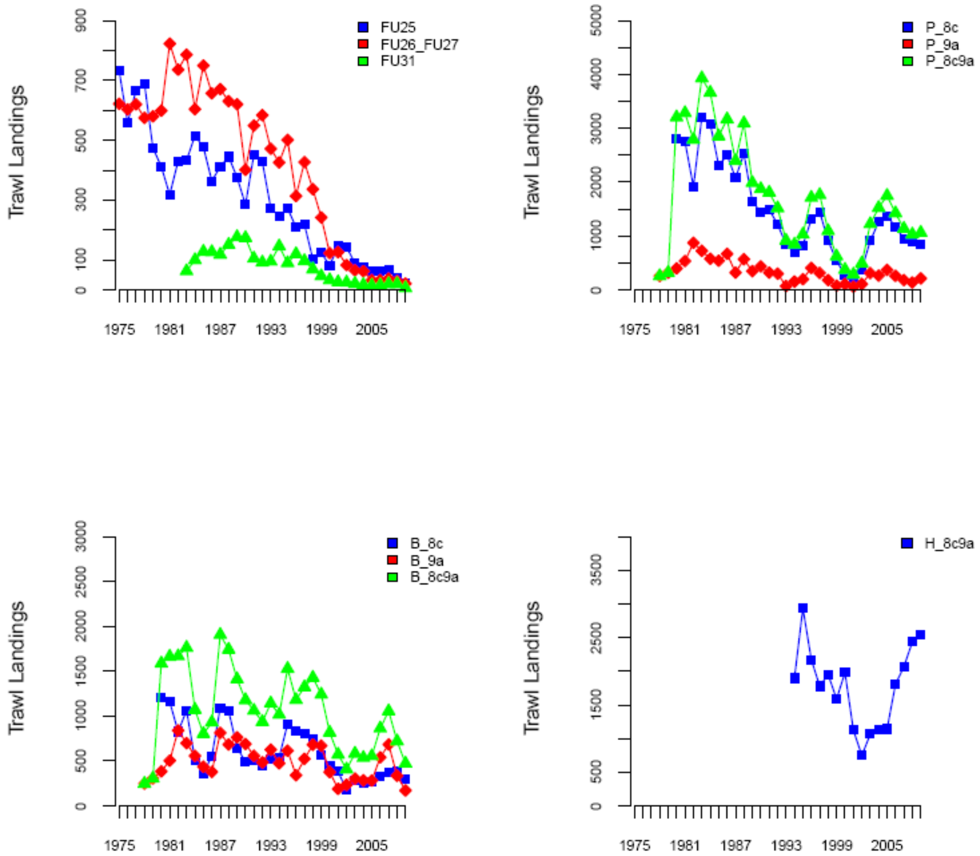


Figure 7.1: Time series of landings of *Nephrops* (top left), *L. piscatorius* (top right), *L. budegassa* (bottom left) and hake (bottom right), by the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together

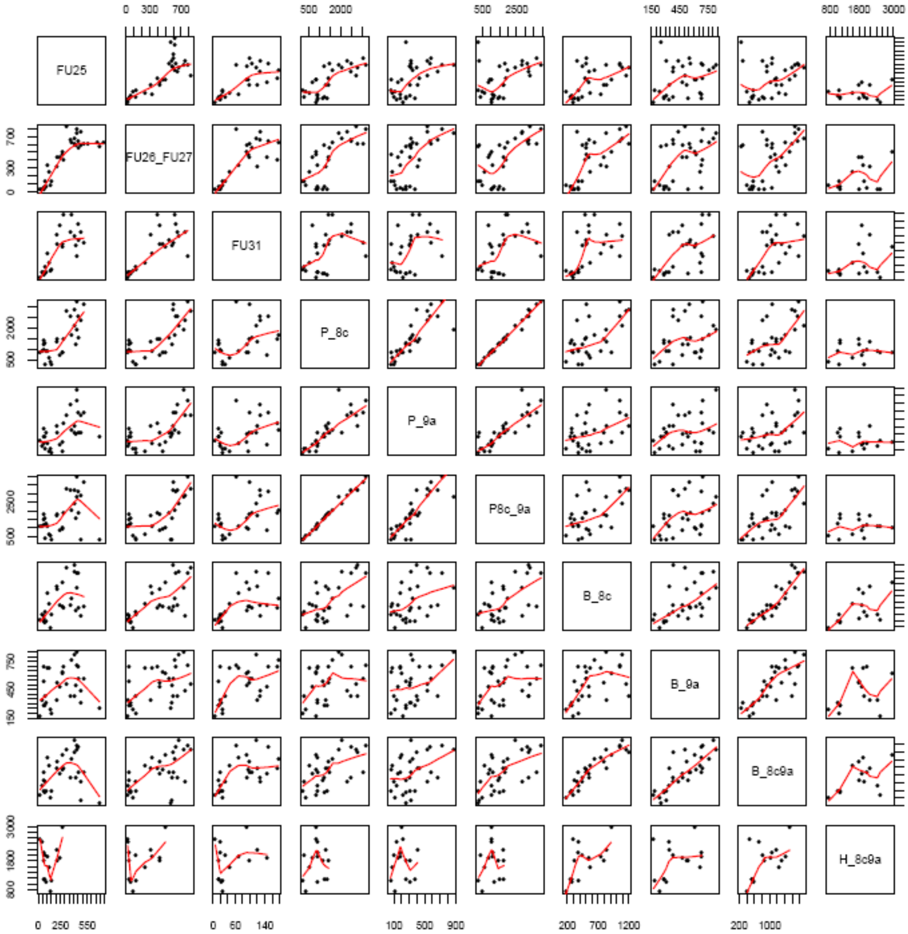


Figure 7.2: Scatterplots of landings of *Nephrops*, *L. piscatorius* (P), *L. budegassa* (B) and hake (H), by the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together

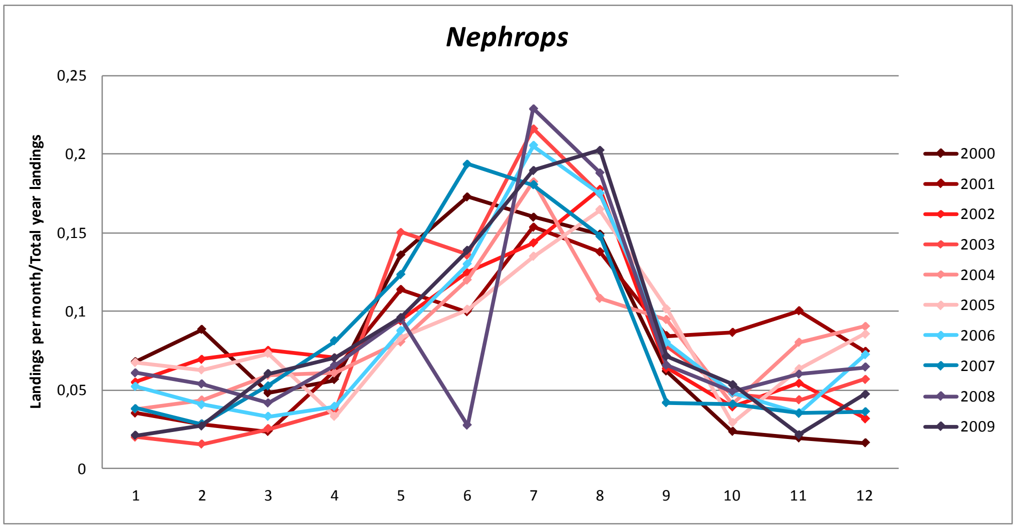


Figure 7.3: Monthly percentage of annual landings of the northern Spanish bottom trawl fleet (OTB10), for *Nephrops* FUs 25, 26-27 and 31 combined.

8 Mixed fishery considerations

8.1 Mixed demersal fisheries in the Atlantic Iberian Peninsula Shelf

The Southern stock of hake, anglerfish and Norway lobster are caught in mixed demersal fisheries in the Atlantic Iberian Peninsula Shelf (ICES Divisions VIIIc and IXa).

Landings in weight are reported by the Portuguese and Spanish fleets which operate in this region with several fishing gears and in different fishing grounds. Data adopted in this report refer to those published in the WGHMM 2010 and additionally new information concerning landings by species by quarter and gear were presented to the workshop.

8.1.1 Seasonality in landings

An attempt to analyse the seasonality in Spanish and Portuguese landings has been made.

Spanish landings

The Spanish landings have been analysed by quarter for the southern stocks of hake, white anglerfish (*L.piscatorius*), black-bellied anglerfish (*L.budegassa*) and Norway lobster (*Nephrops norvegicus*) for years 2000 to 2009. Landings data come from the IEO database, covering the northern Spanish coast (ICES divisions VIIIc and IXaN) and the Gulf of Cádiz (ICES division IXaS), and are the same data used by ICES WGHMM. The data were split by "Management Units" as defined in the "Atlas de las flotas de pesca españolas de aguas europeas atlánticas" (Castro *et al*, 2010). The Management Units used are:

- OTB10 (bottom trawl in VIIIc and IXaN)
- PTB10 (pair trawl in VIIIc and IXaN)
- LLS10 (long line in VIIIc and IXaN)
- GNS11 (gillnet "Volanta" in VIIIc and IXaN)
- GNS12 (gillnet "Rasco" in VIIIc and IXaN)
- OTB20 (bottom trawl in IXaS)

Figure 8.1.a presents quarterly percentages of annual landings of Spanish trawl fleets for the different species, averaged over years 2000-2009. More detailed graphs with data by year are also presented in W7. Both *Lophius* species, hake and *Nephrops* are caught by trawl in VIIIc and IXaN. While an important percentage of the hake landings (over 40% in weight during 2007-2009) is from pair trawlers (PTB10), catches of *Lophius* are very scarce in PTB10 unit and there are no *Nephrops* catches. For this reason, hake trawl landings in VIIIc and IXaN are presented split into OTB10 and PTB10 landings, whereas *Lophius* landings are presented jointly for OTB10+PTB10 (with almost all of the landings corresponding to OTB10).

OTB20 lands hake, *Nephrops* and *Lophius budegassa*. The graphs correspond to hake and *Nephrops* landings. No detailed data are available for *Lophius budegassa*.

For trawl fleets in VIIIc and IXaN, *Nephrops* OTB10 and hake PTB10 landings show significant differences between quarters, with clearly higher landings in the second and third quarters. In IXaS, OTB20 shows lower landings of hake in the last quarter and higher landings of *Nephrops* during the second and third quarters.

Quarterly percentages of annual landings of Spanish gillnet fleets for *Lophius* species and hake are shown in **figure 8.1.b**, averaged over years 2000-2009. Landings data for the two gillnet units (GNS11 "Volanta" and GNS12 "Rasco") are presented together for each of the *Lophius* species. *L. piscatorius* is caught mainly by GNS12 (and very little by GNS11), whereas catches of *L. budegassa* are very low in gillnet units (coming almost exclusively from trawl). GNS12 does not catch any hake.

Gillnet landings do not show clear seasonality patterns. For *L. budegassa*, greater average values are found in the first two quarters, but it must be kept in mind that these are very low landings and this pattern is not constant from year to year, as the bottom left panel of the figure illustrates. There is some tendency for higher hake landings during the first quarter.

Longline (in VIIIc and IXaN) catches only hake (no *Lophius* or *Nephrops*) and has marked seasonality, with high values in the second quarter (**Figure 8.1.c**).

Portuguese landings

Landings by quarter for the period 2000-2009 were available for Trawl combined (Crustacean and Fish segment) and Artisanal (gillnets, trammel nets and long line). The percentage by quarter was averaged for whole series and shown in **Figure 8.1.d**.

In the case of anglerfish it was not possible to split the landings by species because the proportion by species in the landings is taken in an annual basis accordingly to the sampling in the harbours.

Landings of hake in both fleets are higher in the second and third quarter and lower in the fourth quarter. This same pattern occurs for *Nephrops*. However for anglerfish the pick of the landings is in the first quarter decreasing continuously until the end of the year.

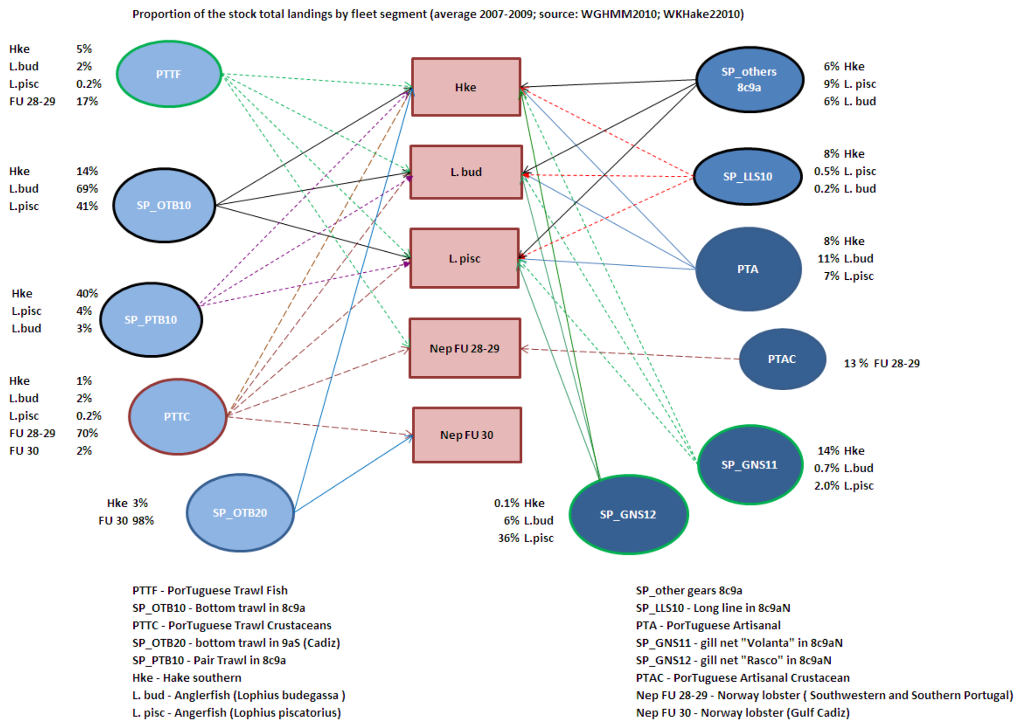
8.1.2 Landings by stock

Total annual landings for 2007-2009, and percentage averaged, by country, gear and stock are shown in table 8.1 and 8.2, for fish and *Nephrops*, respectively.

Portuguese trawl landings were possible to split into the two segments (Crustacean and Fish) for each stock concerned. However in the case of the Artisanal fleet the landings reported could not be disaggregated by segment.

The average percentage (2007-2009) of the stock total landings by country and fleet segments was used for the mixed fishery analysis.

The following flowchart shows the results:



8.1.3 Summary and conclusions

The main results concerning the interactions between stocks and fleets, derived from relative contribution of each fleet in the landings of each stock are as follows:

Spanish fleets:

- PTB10 – Pair trawl in VIIIc and IXa is the fleet which contributes with the higher landings of hake, 40%.
- OTB10 – bottom trawl in VIIIc and IXa contributes with 14% of hake, 68% of *Lophius budegassa* and 41% of *Lophius pisc*atorius.
- The GNS11 – gillnet "Volanta" in VIIIc and IXa catches the 14% of hake, being a very important fleet for this species.
- The GNS12 – gillnet "Rasco" in VIIIc and IXa is the most important gillnet fleet for white Anglerfish (*Lophius piscatorius*) with 36%, and with 6% for *L. budegassa*.
- OTB20 – bottom trawl in IXa – South (Cadiz) contributes with 3% of hake and 98% of *Nephrops* (FU 30).
- LLS10 – long line in VIIIc and IXa is a fleet with a low contribution in the landings of hake (8%) and a marginal contribution in anglerfish (< 1%).

Portuguese fleets:

- The Artisanal fleet contributes with 8% in the landings of hake stock while the bottom trawl landings represent 6% .
- Both Anglerfish species stocks are mainly landed by the artisanal fleet, contributing with 11% for *L. budegassa* and 7% for *L. piscatorius* of the total landings from these stocks.

- Crustacean bottom trawl contributes with 70% in the landings of *Nephrops* (FUs28+29) , while the Fish trawl represent 17% and the special artisanal (creel) 13%.

To conclude, there are differences between the seasonality of the Portuguese and Spanish catches. In general, however, the trawl fleets are concentrated in the second and third quarters, while gillnets show no clear seasonality in catches. For long-liners catches are concentrated in the second quarter. A possible way to improve the impact of static gears could be to enforce continuous closed periods so that fishermen will have to bring their gear ashore and stop fishing during certain periods (ICES, 2010a).

8.1.4 Collated tables and figures

Table 8.1 - LANDINGS OF HAKE AND ANGLERFISH (L. PISCATORIUS AND L. BUDEGASSA) BY COUNTRY AND FISHING GEAR

	2009			2008			2007			Average 07-09 by stock			Percentage 07-09 by stock		
	HAKE	PISCATORIUS	BUDEGASSA	HAKE	PISCATORIUS	BUDEGASSA	HAKE	PISCATORIUS	BUDEGASSA	HAKE	PISCATORIUS	BUDEGASSA	**HAKE**	**PISCATORIUS**	**BUDEGASSA**
SPANISH FLEETS															
OTB10	2530	948	421	2432	931	655	2069	987	1000	2344	956	692	13.8	41.2	68.7
PTB10	7350	97	28	6314	93	24	6709	104	27	6791	98	26	40.0	4.2	2.6
LLS10	2091	8	2	1511	17	2	889	9	2	1497	12	2	8.8	0.5	0.2
GNS11	2913	57	21	2595	53	1	1794	31	1	2434	47	7	14.3	2.0	0.7
GNS12	1	700	88	44	972	46	9	838	47	18	837	60	0.1	36.0	6.0
Other gears_VIIIcIXaN	1358	311	61	1103	134	64	813	175	48	1091	206	58	6.4	8.9	5.7
OTB20	549			528			504			527			3.1	0.0	0.0
Other gears_IXaS	48			33			13			31			0.2	0.0	0.0
TOTAL SPAIN	**16840**	**2122**	**621**	**14560**	**2200**	**792**	**12800**	**2145**	**1124**	**14733**	**2156**	**846**	**86.8**	**92.8**	**84.0**
PORTUGUESE FLEETS													0.0	0.0	0.0
ARTISANAL	1390.0	148.0	114.0	1300.0	126.5	119.0	1440.0	191.8	111.3	1377	155	115	8.1	6.7	11.4
TRAWL - CRUSTACEAN	113.1	5.0	18.0	93.9	5.63	20.6	67.55	6.62	34.09	91	6	24	0.5	0.2	2.4
TRAWL - FISH	846.9	5.0	16.0	842.2	5.18	18.98	656.4	6.1	31.41	782	5	22	4.6	0.2	2.2
TOTAL PORTUGAL	**2350.0**	**158.0**	**148.0**	**2236.1**	**137.3**	**158.6**	**2164.0**	**204.5**	**176.8**	2250	167	161	**13.2**	**7.2**	**16.0**
Total Stock	**19190.0**	**2280.0**	**769.0**	**16796.1**	**2337.3**	**950.6**	**14964.0**	**2349.5**	**1300.8**	**16983**	**2322**	**1007**	**100.0**	**100.0**	**100.0**

Spain codes
OTB10 (bottom trawl in VIIIc and IXaN)
PTB10 (pair trawl in VIIIc and IXaN)
LLS10 (long line in VIIIc and IXaN)
GNS11 (gillnet "Volanta" in VIIIc and IXaN)
GNS12 (gillnet "Rasco" in VIIIc and IXaN)
Other gears_VIIIcIXaN (including unidentified gears, in VIIIc and IXaN)
OTB20 (bottom trawl in IXaS - Cadiz)
Other gears_IXaS (unidentified gears, in IXaS - Cadiz)

Table 8.2 - Landings of Nephrops by Functional Units, country and gear

source: WGHMM 2010 **tons**

FU	division	country	gear	2007	2008	2009	Av 07-09
25	8c	sp	trawl	67.0	39.0	21.0	42.3
26	9a	sp	trawl	20.0	17.0	16.0	17.7
27	9a	pt	artisanal	8.5	6.8	4.0	6.4
	9a	pt	trawl	0.1	0.3	0.0	0.1
	9a	sp	trawl	17.0	12.0	5.0	11.3
27 Total				**25.6**	**19.0**	**9.0**	**17.9**
28+29	9a	pt	artisanal	17.8	34.8	17.0	23.2
	9a	pt	crust_trawl	177.6	144.6	78.9	133.7
	9a	pt	fish_trawl	40.9	28.3	25.9	31.7
28+29 Total				**236.3**	**207.7**	**121.8**	**188.6**
30	9a	pt	trawl	3.5	2.8	2.0	2.8
	9a	sp	trawl	211.0	117.0	117.0	148.3
30 Total				**214.5**	**119.8**	**119.0**	**151.1**
31	8c	sp	creel	0.0	0.0	0.0	0.0
	8c	sp	trawl	19.2	19.0	6.0	14.7
31 Total				**19.2**	**19.0**	**6.0**	**14.7**

FU	**name**
25	*North Galicia*
26	*West Galicia*
27	*North Portugal*
28+29	*Alentejo+Algarve*
30	*Gulf Cadiz*
31	*Cantabrian Sea*

% landings

FU	division	country	gear	2007	2008	2009	Av 07-09
25	8c	sp	trawl	100	100	100	100.0
26	9a	sp	trawl	100	100	100	100.0
27	9a	pt	artisanal	33	36	44	37.8
	9a	pt	trawl	0	1	0	0.6
	9a	sp	trawl	66	63	56	61.7
27 Total				100	100	100	**100.0**
28+29	9a	pt	artisanal	8	17	14	12.7
	9a	pt	crust_trawl	75	70	65	69.8
	9a	pt	fish_trawl	17	14	21	17.4
28+29 Total				100	100	100	**100.0**
30	9a	pt	crust_trawl	2	2	2	1.9
	9a	sp	trawl	98	98	98	98.1
30 Total				100	100	100	100.0
31	8c	sp	creel	0	0	0	0.0
	8c	sp	trawl	100	100	100	100.0
31 Total				100	100	100	100.0

FU	**name**
25	*North Galicia*
26	*West Galicia*
27	*North Portugal*
28+29	*Alentejo+Algarve*
30	*Gulf Cadiz*
31	*Cantabrian Sea*

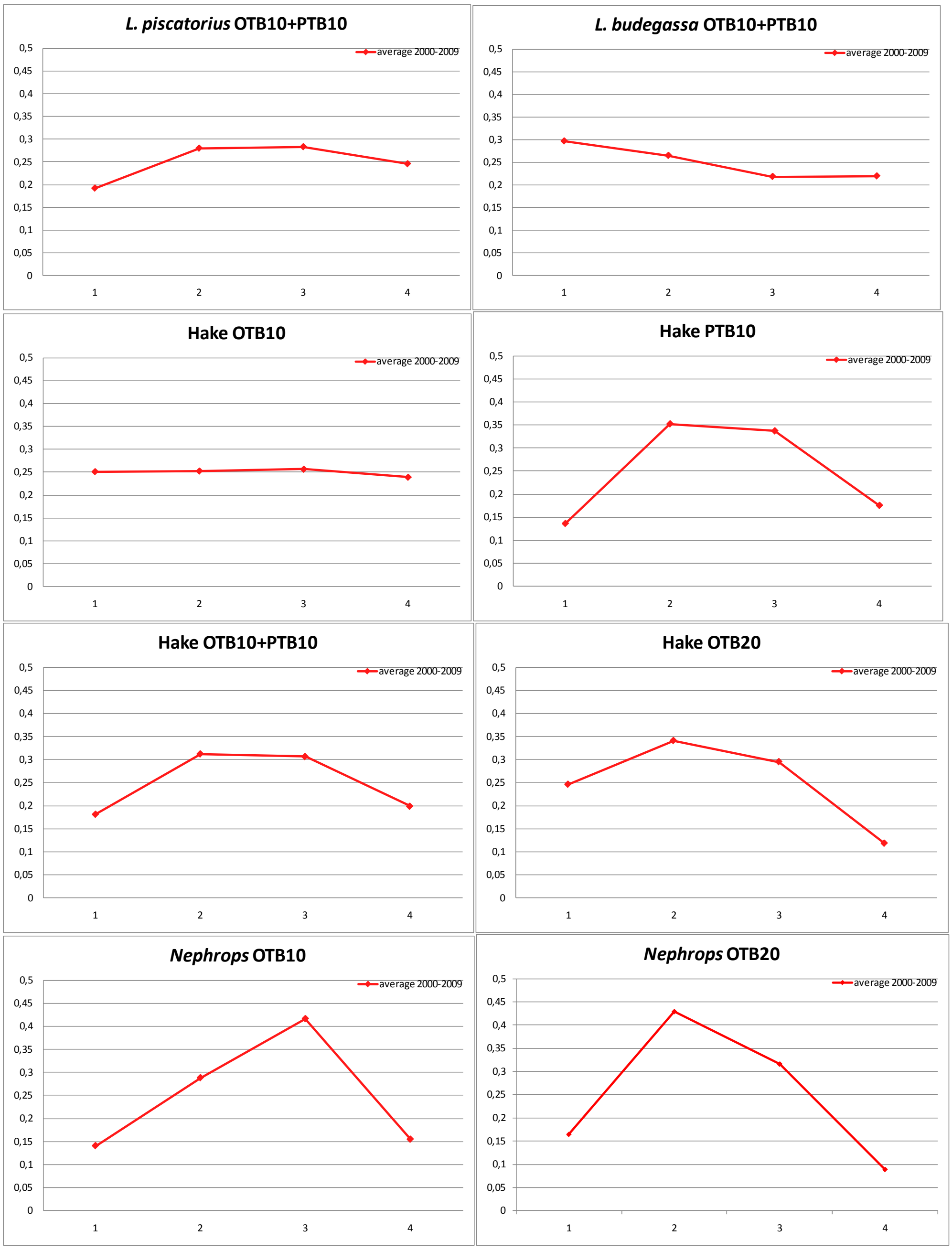


Figure 8.1.a. Quarterly percentages of annual landings (landings per quarter/total annual landings) of Spanish trawl fleets for the different species, averaged over years 2000-2009.

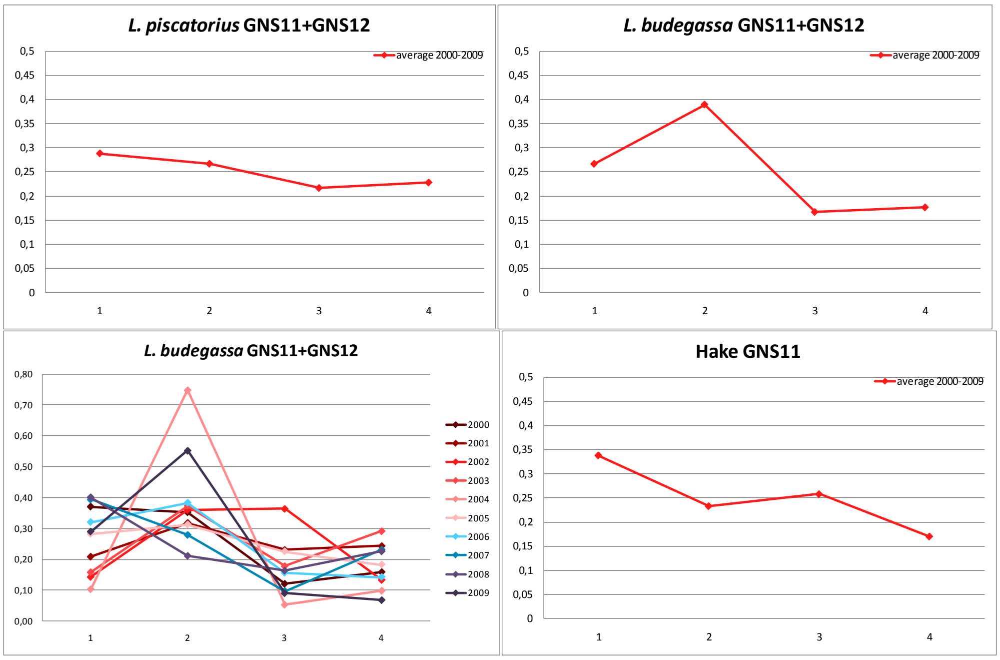


Figure 8.1.b. Quarterly percentages of annual landings (landings per quarter/total annual landings) of Spanish gillnet fleets for the different species, averaged over years 2000-2009. Bottom left panel displays all years separately.

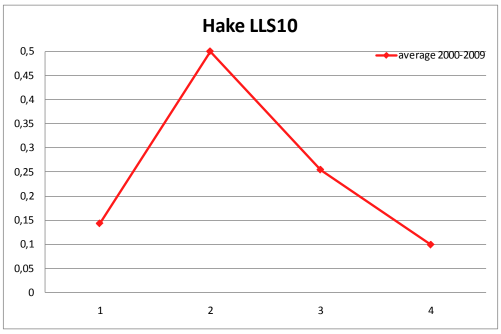


Figure 8.1.c. Quarterly percentages of annual landings (landings per quarter/total annual landings) of Spanish longline fleet for hake, averaged over years 2000-2009.

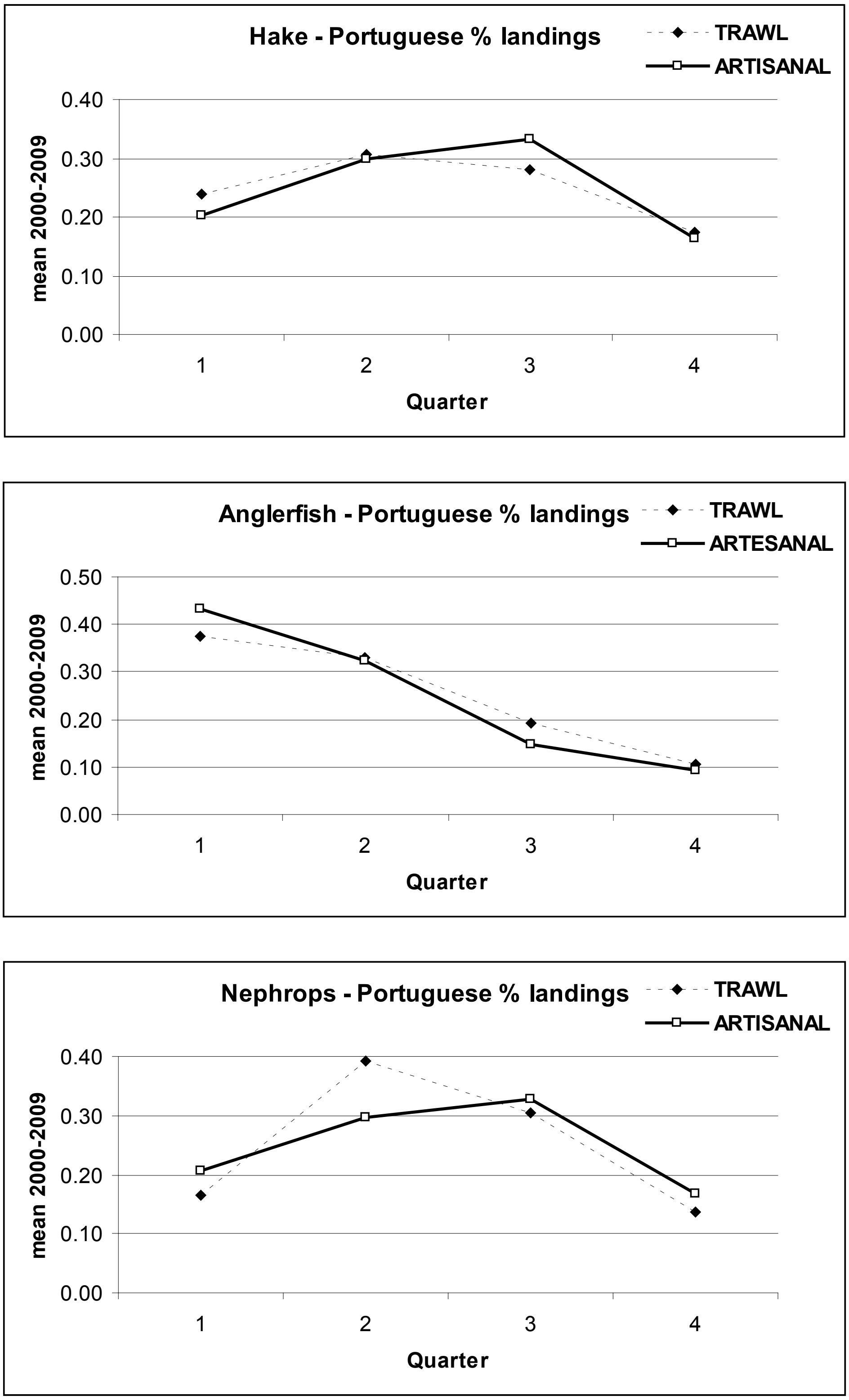


Figure 8.1.d. Quarterly percentages of landings of Portuguese fleets for hake, anglerfish and *Nephrops*.

8.2 Southern hake/anglerfish linkage

8.2.1 Methods

The Spanish gillnet fleet called "Rasco" targets anglerfish and does not catch hake, whereas the rest of the fleets that catch anglerfish also catch hake in a mixed fishery. Alternative scenarios were evaluated in a simulation framework that takes this aspect into account.

The mixed fishery analysis consisted in applying to anglerfish a combination of F reductions appropriate for hake and F reductions appropriate for anglerfish. The partial F corresponding to each fleet was estimated using the arithmetic mean of 2007-2009 landings, assuming a proportional relationship between landings and fishing mortality, 34% for "Rasco" fleet and 66% for the other fleets.

The following scenarios were considered for anglerfish:

- use the F multipliers obtained when HCR 2 is applied to hake (with hake TAC constraints of 15%, 25% and without TAC constraint), either including the "Rasco" fleet or leaving the "Rasco" fleet at F status quo.

- apply to the "Rasco" fleet the F multipliers obtained when HCR 2 with a 25% TAC constraint is applied to anglerfish and leave all other fleets at F status quo. HCR 2 with a 25% TAC constraint was selected for anglerfish based on the probability of achieving Fmsy in 2015 and a compromise between stock biomass at the end of the projection period and cumulated landings in 2015.

- apply the F multipliers corresponding to the selected HCR for anglerfish to the "Rasco" fleet and the F multipliers obtained when applying to hake HCR 2 with 15% TAC constraint to the other fleets.

8.2.2 Results

The same metrics used for anglerfish in Section 4 are calculated, with results presented in Table 8.2.2.1.

Table 8.2.2.1:

	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

The performance of each scenario has been graphically represented.

For each species:

- Plots of F/Fmsy
- Plots of B/Bmsy

For both species:

- Plots of combined landing
- Plots of Percentage of inter-annual variation in landings.

In all these plots the median with the 5th and 95th percentile were represented.

In this report it is only presented the scenarios *All Fleets: Hake HCR 2, TACc: 15%* (Fig. 8.2.2.1.) and *"Rasco": Anglerfish HCR 2, TACc: 25% & Other Fleets: Hake HCR2, TACc:15%* (Fig. 8.2.2.2.) as examples, the rest of the summary plots are included as a background document.

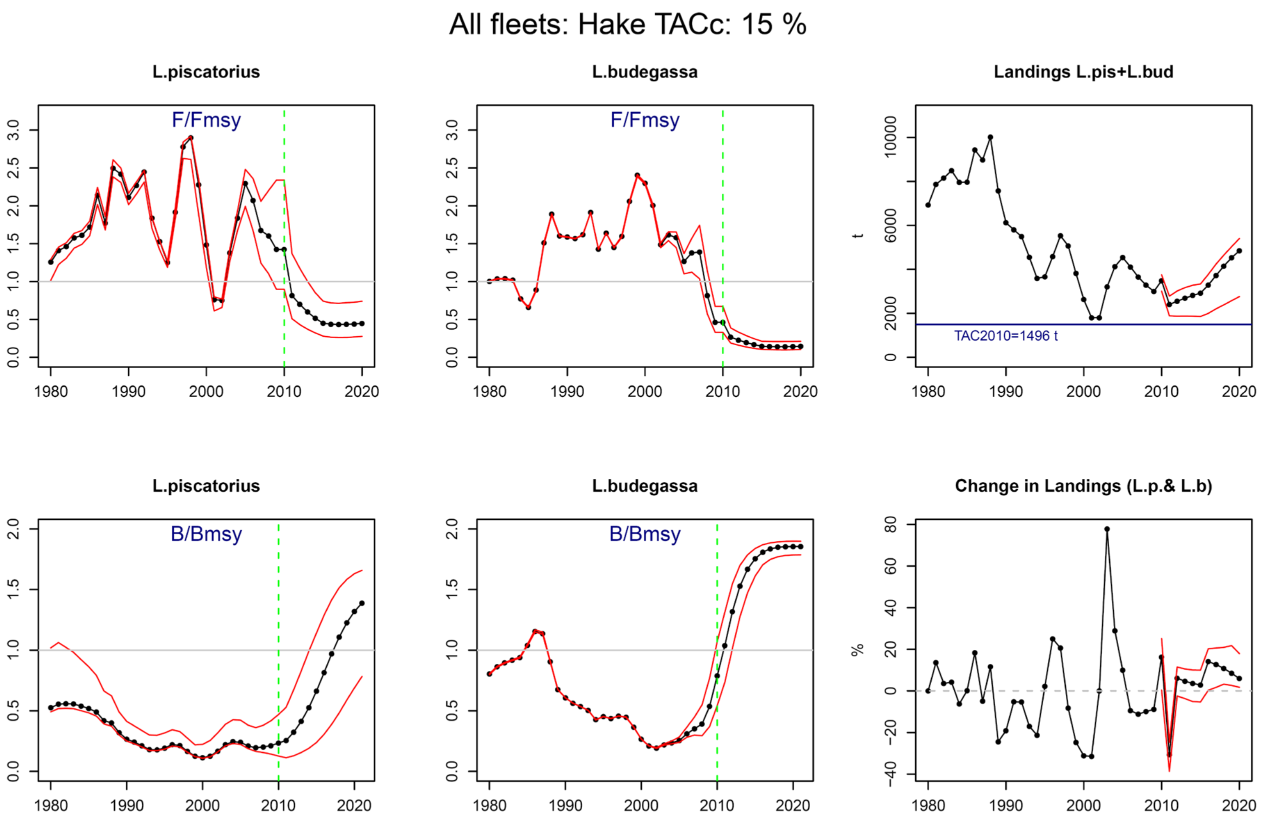


Figure 8.2.2.1. All Fleets: Hake HCR 2, TACc: 15% performance.

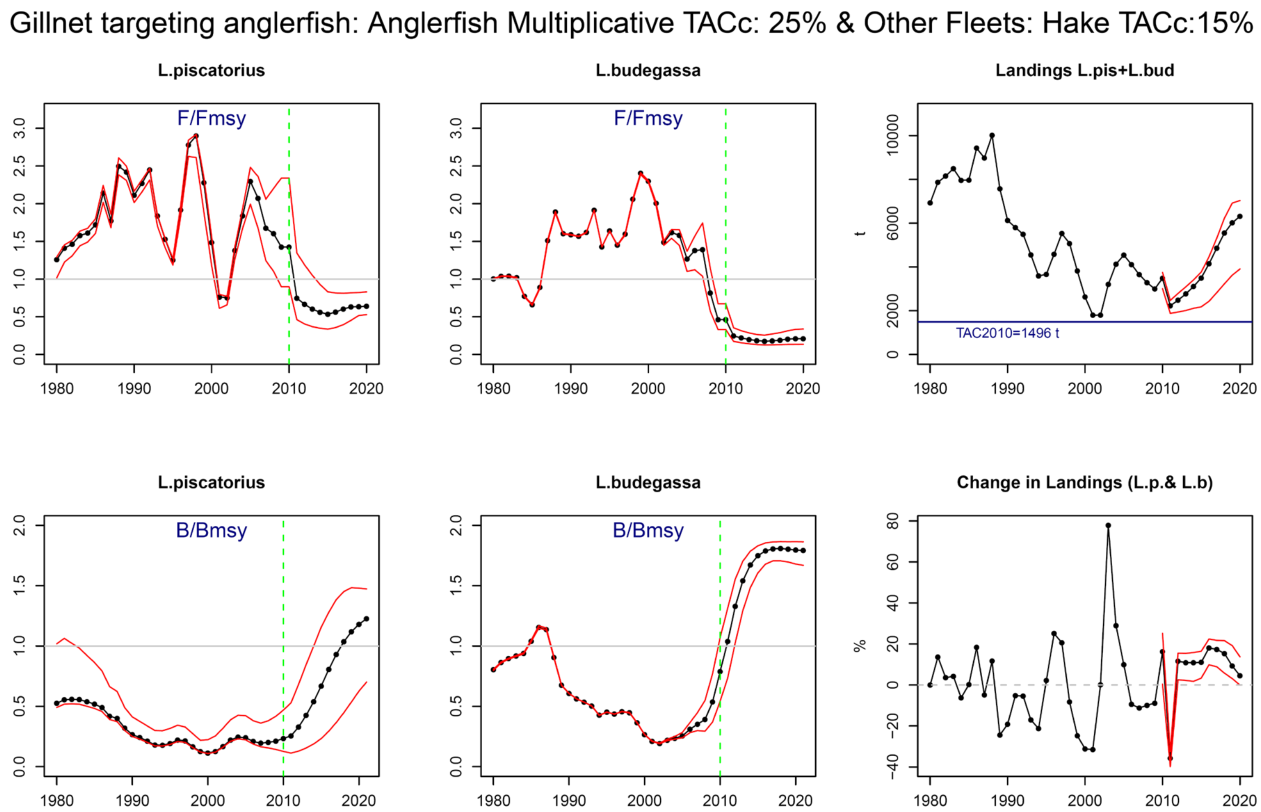


Figure 8.2.2.2. "Rasco": Anglerfish HCR 2, TACc: 25% & Other Fleets: Hake HCR2, TACc:15% performance.

8.2.3 Summary and conclusions

For *L. piscatorius*, the probability that F in 2015 is below or equal to Fmsy is at least 0.95 in scenarios where the hake HCRs are applied to all fleets and in the scenario that applies the anglerfish HCR 2 with 25% TAC constraint to the “Rasco” fleet and the hake HCR 2 with 15% TAC constraint to the other fleets.

When compared with the results obtained when applying HCR 2 with 25% TAC constraint to anglerfish (Section 4), all mixed fishery scenarios indicate an increase of *L. piscatorius* biomass, the anglerfish stock in poor condition, to larger long-term values (above B_{MSY}), at the expense of losses in combined yield. Main conclusions are: 1) Even though it does not catch hake, the “Rasco” fleet must also undergo a reduction in *F* in order to bring the *F* of *L. piscatorius* to F_{msy} in 2015 with high probability, but this reduction does not need to be as severe as for the other fleets (which also catch hake); 2) Conversely, if the fleets that catch hake and anglerfish do not follow the intended F reductions corresponding to the hake management, just reducing F on the “Rasco” fleet will not be enough for *L. piscatorius* to reach Fmsy by 2015; and 3) Joint management of hake and anglerfish would lead to a loss in yield for anglerfish. .

8.3 Spatial management of anglerfish

The two species of anglerfish (the white, *Lophius piscatorius,* and the black, *L. budegassa*) are North Eastern Atlantic species, but *L. budegassa* has a more southerly distribution. *L. piscatorius* is distributed from Norway (Barents Sea) to the Straits of Gibraltar (and including the Mediterranean and the Black Sea) and *L. budegassa* from the British Isles to Senegal (including the Mediterranean and the Black Sea). Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce and the stock structure remains unclear. This lack of information is due to their particular spawning behaviour. Anglerfish eggs and larvae are rarely caught in scientific surveys (ICES, 2010b - Annex H).

Nevertheless, the scientific sampling programmes 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 is almost null 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.

9 Discussion and conclusions

ToRs a) and b): The findings of the workshop may be summarised as follows.

Initially, evaluations were performed separately for each stock and the single stock outcomes of this workshop are summarised below.

Southern hake in Divisions VIIIc and IXa: The EC’s F policy with a 10% annual reduction does not achieve F_{MSY} in 2015. In addition, none of the HCRs considered in this workshop achieved F_{MSY} in 2015 in the presence of TAC overshoot. Conditioning an HCR to achieve F_{MSY} in 2015 with a multiplicative F reduction and either a ±15% or ±25% TAC constraint leads to similar probabilities of achieving F_{MSY} in 2015 but the ±15% TAC constraint produces slightly higher SSB in 2015.

Anglerfish in Divisions VIIIc and IXa (*Lophius piscatorius* and *Lophius budegassa*) : Due to the starting conditions of *L. budegassa*, with F_{2009} below F_{msy} (F_{2009}/F_{msy} =0.45), all scenarios tested keep *F* below F_{msy}. So the analysis of results within the report is mainly focused on *L. piscatorius* - when no TAC constraint is applied in the scenarios investigated, the *L. piscatorius* biomass increases slowly towards B_{msy}. TAC overshoot reduces the probability of *F* being equal to or below F_{msy} in 2015 to levels below 95% and slows down the recovery of the biomass. None of the HCRs considered in this workshop will achieve F_{msy} in 2015 if the TAC is overshot.

Nephrops (FUs 28 and 29): New CPUE standardization accepted as the basis of a stock assessment at this workshop. Recruitment has been at a low/median level with SSB presenting an increasing trend in recent years. Under-exploited at present with respect to F_{MSY} and with the potential for F to increase. An increase in F on *Nephrops* is to be expected if the future rose shrimp abundance decreases because *Nephrops* are caught in a crustacean fishery that targets rose shrimp.

Nephrops (FU 30): 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 that the bottom trawl fleet of the Gulf of Cadiz consists of only one, highly multi-specific *métier*, any F reduction measures applied to the fleet catching hake should also cause a reduction on the fishing pressure applied to *Nephrops*. The strong seasonality of the *Nephrops* fishery, with most of the landings between April and September, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

Nephrops (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, 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*. The strong seasonality of the *Nephrops* fishery, with most of the landings between May and August, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

The analytical evaluations above have all been undertaken on a stock by stock basis in the first instance. Subsequently, considerations of mixed fishery issues were investigated and discussed:

Southern hake/anglerfish linkage – Hake is the most over-exploited of these two stocks and hence, the management of anglerfish might exploit the fact that there is one fleet (Rasco) that does not catch hake. However, the "Rasco" fleet must also undergo a reduction in *F* in order to bring the *F* of *L. piscatorius* to F_{msy} in 2015 with a high probability. This reduction does not need to be as severe as for the other fleets which also catch hake. Conversely, if the fleets that catch both hake and anglerfish do not follow the intended F reductions corresponding to the hake management, just reducing F on the “Rasco” fleet will not be enough for *L. piscatorius* to reach Fmsy by 2015. Using hake as the key driver for the management of the mixed fisheries would lead to a loss in yield for anglerfish.

This workshop considered explicitly the biological implications of management options within HCRs and TAC overshoot scenarios and the participants note that an economic and social impact assessment of a long-term management plan has recently been undertaken by STECF (2010).

The paper by da Rocha *et al*. (2010) introduces social and economic behaviour explicitly into bio-economic models in order to evaluate recovery plans with an application to southern hake. The paper provides a starting point from which to begin the development of a full impact assessment.

ToR c): The additional findings of the workshop may be summarised as follows.

The description of the fisheries was updated from those presented in ICES (2010a) and considerations of mixed fishery issues discussed:

Description of the fisheries and seasonality of landings – There are differences between the seasonality of the Portuguese and Spanish catches which are further explained in the report. In general, however, the trawl fleets are concentrated in the second and third quarters, while gillnets show no clear seasonality in catches. For long-liners catches are concentrated in the second quarter. A possible way to improve the impact of static gears could be to enforce continuous closed periods so that fishermen will have to bring their gear ashore and stop fishing during certain periods.

Spatial management of anglerfish - Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce and the stock structure remains unclear. The scientific sampling programmes 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 is almost null where the percentage of *L. budegassa* is more than 90%. 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.

10 Working papers and documents presented to the workshop

10.1 Working papers and documents (W)

A number of documents were presented to the meeting as working papers and are listed in this Section 10.1 for ease of reference; together with their assigned code.

W1: POPULATION DYNAMICS ASSUMED IN THE GADGET ASSESSMENT OF THE SOUTHERN HAKE STOCK AND YIELD-PER-RECRUIT ANALYSIS. Carmen Fernández and Santiago Cerviño.

W2: HARVEST CONTROL RULES FOR THE SOUTHERN HAKE STOCK. Carmen Fernández and Santiago Cerviño.

W3: EFFECTS OF USING NEW STANDARDIZED CPUE SERIES IN THE ASSESSMENT OF FU 28-29 *NEPHROPS*. Cristina Silva and Fátima Cardador.

W4: CURRENT KNOWLEDGE ABOUT *NEPHROPS* STOCK FROM THE GULF OF CADIZ (FU 30). Vila, Y., Fernández, C., Abad, E., Silva, L.

W5: EXPLORING WHETHER IT IS POSSIBLE TO CONSIDER LANDINGS OF ANY OF THE *NEPHROPS* FUNCTIONAL UNITS 25, 31, 26-27 AS BYCATCH OF SOME FLEETS AND SPECIES. Esther Abad and Carmen Fernández.

W6: HARVEST CONTROL RULES FOR ANGLERFISH (*LOPHIUS PISCATORIUS* AND *LOPHIUS BUDEGASSA*). Paz Sampedro and Carmen Fernández.

W7: SPANISH LANDINGS SEASONALITY FOR SOUTHERN HAKE, WHITE ANGLERFISH, BLACK-BELLIED ANGLERFISH AND NORWAY LOBSTER BY MANAGEMENT UNIT. Esther Abad, Carmen Fernández, Santiago Cerviño and Paz Sampedro.

11 References

Throughout this report there have been a number of references cited and these references are collated.

Anon. (2003). Report of the subgroup on management objectives (SGMOS) of the Scientific, Technical and Economic Committee for Fisheries (STECF) for recovery plans of southern hake and Iberian Norway lobster stocks. 9 – 13 June 2003, IPIMAR, Lisbon, 107 pp.

ICES (2009). Report of the Working Group on Methods of Fish Stock Assessment (WGMG). ICES CM 2009/RMC:12.

ICES (2010a). Report on the evaluation of HCR for the establishment of a management plan for the Iberian mixed fisheries of hake, anglerfish and *Nephrops* aiming to achieve F_{MSY} by 2015. Jardim, E., C. Silva, R. Alpoim, F. Cardador and M. Azevedo. ICES CM 2010/ACOM:56.

ICES (2010b). Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim. ICES CM 2010/ACOM:11.

ICES (2010c). Report of the benchmark workshop on roundfish (WKROUND). ICES CM 2010/ACOM:36.

Jose Castro, Manuel Marín, Gersom Costas, Esther Abad, Antonio Punzón, Javier Pereiro and Armando Vázquez (in press). *ATLAS DE LAS FLOTAS DE PESCA ESPAÑOLAS DE AGUAS EUROPEAS ATLÁNTICAS*. Temas de Oceanografía. IEO. MCIN.

José-María Da Rocha, Santiago Cerviño, and María-José Gutiérrez (2010). *An endogenous bio-economic optimization algorithm to evaluate recovery plans: an application to southern hake*. ICES Journal of Marine Science, **67**: 1957–1962.

Jiménez, M. P. (2002). Aplicación de análisis multivariantes para la obtención y estandarización de esfuerzos pesqueros en pesquerías multiespecíficas. Las pesquerías demersales del Golfo de Cádiz. Tesis Doctoral. Universidad de Cádiz, 298 pp.

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Annex 2: Recommendations

Recommendation	For follow up by:
1. The report of WKSHAKE2 to be forwarded to the ICES' RG (working by correspondence) for its review scheduled for 30 November to 2 December 2010.	ICES Secretariat
2. A draft response to the EC request to be prepared by 2 December 2010 for the attention of the ICES' RG (working by correspondence).	ACOM Vice-chair and participants of WKSHAKE2
2. ICES' ADG (working by correspondence) during 3-8 December 2010 to be made aware of the report of WKSHAKE2 and the outcome of the ICES' RG.	ICES Secretariat
3. Section 5: Approach to the re-assessment of *Nephrops* (FUs 28 and 29) to be noted and reviewed.	WGHMM

Annex 3: Population dynamics model used for southern hake projections and yield-per-recruit analysis

The southern stock of hake is assessed by ICES using Gadget since 2010. The equations corresponding to the population dynamics model used in the Gadget assessment are presented below. These equations have been implemented in R and used to conduct a yield-per-recruit analysis and the projections presented in this document.

A3.1. Population dynamics equations corresponding to the hake assessment:

The population dynamics model developed in Gadget for southern hake works on a quarterly basis. The population at any given time is structured as a matrix of numbers at length and age. Let $N_t(l,a)$ denote the population numbers at length and age at time t, the start of a quarter. The lengths used in the hake assessment were {1.5, 2.5, 3.5,…, 129.5} cm, with all individuals larger than 129.5 cm assigned 129.5 cm of length, and the ages used were {0,1,2,…,15+}. The following processes act on the population during each quarter, in sequence:

- First, fishing, with selection purely length based. Catch numbers at length and age are given by the following equation (where the vector $F_t(l)$ is called "mortality" or "effective mortality" in Gadget output):

(A3.1) $$CN_t(l,a) = N_t(l,a) \{ 1 - \exp[- F_t(l)\ 0.25] \}$$

- Next, natural mortality, according to a rate M. Population numbers after fishing and natural mortality are given by:

(A3.2) $$N1_t(l,a) = N_t(l,a) \exp[- (F_t(l)+M)\ 0.25]$$

- Then growth. Individuals may grow a maximum of g_{max} cm during a quarter and all individuals that become larger than 129.5 cm are assigned length 129.5. The underlying idea is that an individual of length l grows according to the random variable:

(A3.3) $$\text{Growth}(l) \sim \text{Binomial}(g_{max}, p(l)), \text{ where } p(l) \sim \text{Beta}(\beta\,\alpha(l), \beta),$$

(A3.4) with $\alpha(l)$ chosen such that $E[\text{Growth}(l)] = g_{max}\,\alpha(l)/(\alpha(l)+1) = (L_\infty - l)\,\{1-\exp(-K\ 0.25)\}$.

In other words, expected growth follows a von-Bertalanffy model with parameters L_∞ and K. The parameter β controls the amount of variability in growth, with larger β values corresponding to lower variance of the variable Growth(l). In Gadget, growth is implemented in a deterministic (rather than stochastic) fashion. The proportion of individuals in $N1_t(l,a)$ that grow to length l′, denoted as g(l,l′), is given by the probability that the variable Growth(l) takes the value l′-l and can be explicitly written as a function of g_{max}, L_∞, K and β. If these parameters are constant, as is the case in the hake assessment model, $g(l,l')$ remains constant over time. The number of individuals of length l in the population after growth is given by

(A3.5) $$N2_t(l,a) = \sum_{l' \leq l} N1_t(l',a)\, g(l',l).$$

Then recruitment, which takes place in quarters 1 and 2. Annual recruitment values are estimated in the hake assessment without considering any stock-recruitment relationship. The proportion of annual recruitment allocated to quarter 1 is given by a parameter, rrat, assumed to stay constant over time. All recruits enter the population at age 0 and are distributed among lengths {1.5, 2.5,…, 19.5} cm with proportions given by the pdf of a Normal distribution with mean L_∞ {1 - exp(-K 0.25) } and standard deviation 2, evaluated at this set of lengths and normalised to sum to 1 over them. The distribution of recruitment among lengths stays constant over time. Hence, population numbers after recruitment are given by:

(A3.6) $$N3_t(l,a) = N2_t(l,a) + Rec_t(l,a),$$

where $Rec_t(l,a)$ is only positive when t corresponds to quarters 1 or 2, age a=0 and the length l is in the set {1.5, 2.5,…, 19.5}.

- Finally, all ages are incremented by 1 at the end of the year. Therefore, if t corresponds to the fourth quarter of a year, population numbers after age incrementation are:

(A3.7) $$N4_t(l,0)=0;\ N4_t(l,a)=N3_t(l,a-1), \text{ for } a=1,\ldots,14;\ N4_t(l,15+)=N3_t(l,14)+N3_t(l,15+).$$

Population numbers at the end of a quarter correspond to population numbers at the beginning of the following quarter: $N_{t+1}(l,a) = N4_t(l,a)$.

Even though fishing selectivity is length-based, Gadget can output a so-called fishing "mortality" at age. This is defined as follows: Summing over lengths on both sides of equation (A3.1), leads to

(A3.8) $$CN_t(a) = \sum_l N_t(l,a)\, \{ 1 - \exp[- F_t(l)\, 0.25] \} = N_t(a) \sum_l \{N_t(l,a)/N_t(a)\}\ \{ 1 - \exp[- F_t(l)\, 0.25] \},$$

where $CN_t(a)$ and $N_t(a)$ denote numbers at age in the catch and in the population, respectively. Now using the same idea underlying equation (A3.1) but just for ages leads to

(A3.9) $$CN_t(a) = N_t(a)\, \{ 1 - \exp[- F_t(a)\, 0.25] \}.$$

Equating the right hand sides of equations (A3.8) and (A3.9) and solving for $F_t(a)$ it is obtained that

(A3.10) $$F_t(a) = - 4 \log[1 - \sum_l \{N_t(l,a)/N_t(a)\}\ \{ 1 - \exp[- F_t(l)\, 0.25] \}].$$

$F_t(a)$ thus defined is related to fishing mortality at length, $F_t(l)$, but it also depends on the proportion of different lengths among individuals of age a in the population, which will change over time depending on the fishing pressure applied. Hence, the interpretation of $F_t(a)$ and its relationship with fishing effort and catchability is not straightforward.

The population dynamics equations described above were checked using the Gadget output from the assessment conducted by WGHMM 2010. The following outputs from the Gadget assessment were used: Population numbers at length and age, $N_t(l,a)$, at the start of each quarter t; Fishing mortality $F_t(l)$ for each quarter t; Annual recruitment; The parameters β (estimated to be 4.81), intervening in the growth model, and K (estimated to be 0.165), intervening in the growth model and length distribution recruits. All other parameters were fixed in the hake assessment (M=0.4, L_∞=130, g_{max}=15, rrat=0.5). Starting from the estimated numbers at the beginning of each quarter, $N_t(l,a)$, population dynamics equations (A3.2)-(A3.7) were applied and it was checked that the population numbers at the end of the quarter coincided with Gadget population estimates for the start of the following quarter.

Equations (A3.1), (A3.8)-(A3.10) were also checked using the Gadget output. Equation (A3.1) is not the usual Baranov catch equation. As this can cause confusion, the following clarifications are made:

1) For each length, age or length-age combination, Gadget output files give "population numbers", "number consumed" and "mortality". It has been checked that these 3 quantities are related as described in equation (A3.1). Defining fishing mortality through equation (A3.1) is consistent with what both WKROUND (ICES, 2010c) (where the hake benchmark assessment was conducted) and WGHMM 2010 have reported as "F" (average over ages 1-3, using equation (A3.10), which is consistent with equation (A3.1)). The multipliers of "F" used in the projections performed in this document are applied to the F-at-length vector defined via equation (A3.1). For coherence with the way assessment results have been presented for this stock, the resulting fishing mortality at age resulting from (A3.10), averaged over ages 1-3, will also be reported in each case.

2) A different definition of "F-at-length" could have been used, defining "F" as the value that fulfills Baranov catch equation instead of equation (A3.1), but this would have represented a departure from what has been reported as "F" previously for this stock. Moreover, the "F" that would be obtained by doing this would still not be the "usual" F, i.e. a fishing mortality rate. The reason is that, since fish are growing continuously, growth should also be dealt with concurrently with F and M and this is not achieved simply by replacing equation (A3.1) by the Baranov catch equation (involving only F and M and still ignoring growth). So the "F" that would be obtained by doing this would still have a somewhat unclear interpretation. A main issue in length-based models, such as the one used for hake, is to have an equation that provides a link between population abundance, some measure of fishing mortality and catch, and equation (A3.1) does that.

3) If "F" had been redefined to fulfill Baranov catch equation instead of equation (A3.1), the new redefined "F" would be 0.95 times the "F" value obtained from equation (A3.1), for the entire range of "F" values that might be reasonably considered in this work (from 0 to 1.4). So the results of the

analysis presented here are unaffected by which of the two options is taken as the definition of "F".

All checks were done using the R script “GADGET_Dynamics_Reproduce.R”, available on the WKSHAKE2 SharePoint.

By doing this check, it was found that recruitment had been wrongly reported in Table 7.6 of the WGHMM 2010 report, as the table only includes recruits larger than 4 cm, whereas all lengths (starting at 1.5 cm) should be included. This reporting error did not affect any subsequent calculations (in particular, projections) conducted by the WG.

A3.2. Yield-per-recruit analysis based on population dynamics of the hake assessment

To compute yield-per-recruit (YPR) based on the Gadget population dynamics, a fish population is started with a single recruit and simulated through time, applying repeatedly the dynamics described in equations (A3.2)-(A3.7), with fixed fishing mortality at length vector, until the individual is virtually extinguished. The single recruit is apportioned to quarters 1 and 2 according to (rrat,1-rrat), where rrat is the parameter that defines the proportion of annual recruits allocated to quarter 1, and to lengths {1.5,2.5,…,19.5} according to the values of a Normal pdf, as described in Section A3.1 of this annex.

The yield (where yield refers to landed weight, i.e. after subtracting discards from the total catch) generated by the single recruit throughout its lifetime is calculated for a range of multipliers of the fishing mortality at length vector. At each time step catch is computed from equation (A3.1) and the proportion of the catch landed for each length used in the yield computation.

The assumptions used in the YPR calculation presented in this document were as follows:

- The average of the estimated $F_t(l)$ by quarter for the final 3 assessment years was taken. The resulting $F_t(l)$ for each quarter was divided by its average value over lengths 15-80 cm to produce the relative exploitation pattern at length (by quarter).
- For Fbar (15-80 cm), by quarter, the final assessment year values were used as reference. This means that the relative values of Fbar in different quarters are as in the final assessment year.
- A range of multipliers was applied to this reference $F_t(l)$ (reference $F_t(l)$ depicted in Figure A3.1), thus obtaining the YPR curve.
- For each length, the proportions of the catch that are landed and discarded were computed from the Gadget estimates of the numbers landed and discarded for that length, averaged (by quarter) over the final 3 assessment years.
- Weight-at-length: length-weight relationship used in the hake assessment.
- Maturity-at-length: average over the final 3 assessment years.

In addition to computing the yield generated by the recruit throughout its lifetime (and hence finding F_{max} in terms of Fbar(15-80cm)), F-at-age was also calculated applying equation (A3.10) to the population generated by the recruit. Relating Fbar(ages

1-3) thus found with the corresponding YPR value permits also to express the reference point F_{max} in terms of Fbar(ages 1-3). This is done for consistency with the way Fbar has been previously reported for the hake stock (based on ages instead of lengths).

F_{max}=0.25 when expressed in terms of lengths 15-80 cm and F_{max}=0.24 when expressed in terms of ages 1-3 (see Figure A3.2).

The R function to compute biological reference points is in the R script named "BRP_QuarterlyF.R" and is more easily used by executing the R script named "Main_BRP.R". Both scripts are available on the WKSHAKE2 SharePoint.

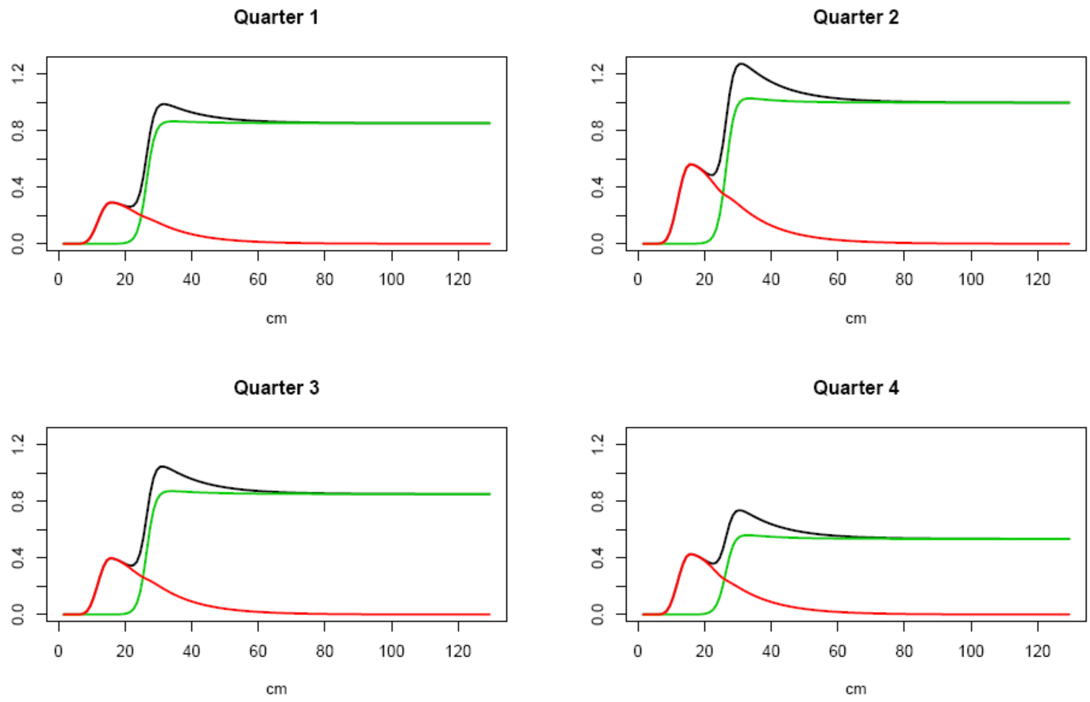

Figure A3.1: Reference F at length by quarter used in Yield-Per-Recruit analysis: average of final 3 assessment years scaled to Fbar(15-80 cm), by quarter, in the final year. Total catch (black), landings (green), discards (red).

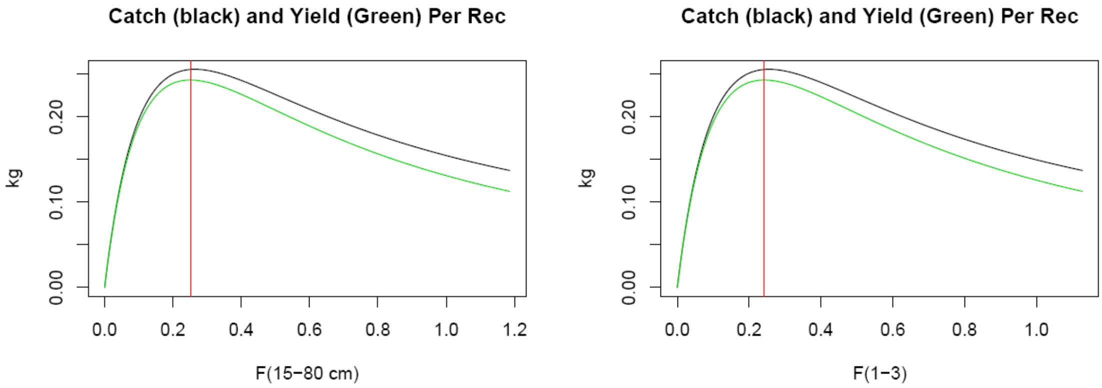

Figure A3.2: Results of Yield-Per-Recruit analysis. Vertical red line corresponds to F_{max}.

Annex 4: Revised quality handbook for *Nephrops* FUs 28–29

Quality Handbook **ANNEX: *Nephrops* FUs 28-29**

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Southwest and South Portugal (Division IXa, FUs 28-29)
Working Group:	WGHMM
Date:	26 November 2010 (updated at WKSHAKE2)
Revised by	Cristina Silva

A. General

A.1. Stock definition

The Norway lobster (*Nephrops norvegicus*) is distributed along the continental slope off the southwest and south Portuguese coast, at depths ranging from 200 to 800 m. Its distribution is limited to muddy sediments, and requires sediment with a silt and clay content of between 10–100% to excavate its burrows, and this means that the distribution of suitable sediment defines the species distribution. Although FUs 28 and 29 are different stocklets, landings records are not differentiated and they are assessed together.

A.2. Fishery

The fishery in FUs 28 and 29 is mainly conducted by Portugal. For the last 25 years, this species has been a very important resource for the demersal trawl fisheries operating in the region. With exception of the years when the abundance of pink shrimp (*Parapenaeus longirostris*) is extremely high, *Nephrops* constitutes the main target species of the majority of the crustacean trawl fleet, and is not generally caught as by-catch of other fleets.

The Portuguese trawl fleet comprises two components, namely the trawl fleet fishing for fish and the trawl fleet fishing for crustaceans. The trawl fleet fishing for fish operates off the entire coast while the trawl fleet directed to crustaceans operates mainly in the Southwest and South Portugal, in deep waters, where crustaceans are more abundant. The fish trawlers are licensed to use a mesh size >= 65 mm and the crustacean trawlers are licensed for two different mesh sizes, 55 mm for catching shrimp and >= 70 mm for Norway lobster. Demersal fish trawlers that regularly land *Nephrops*, do in fact target this resource, which in terms of overall profit, represents a significant additional income.

The number of trawlers targeting crustaceans has been fixed at 35 since the early 1990s. However, since the late 1990s, some vessels have been replaced by new ones, better equipped and with a more powerful engine. In 2008, the number of licensed fish trawlers was 69 with an average of 645 HP, 182 GRT and 26 m of overall length, whereas the number of crustacean trawlers was 30, with an average of 562 HP, 177 GRT and 25 m of overall length.

There are two main target species in the crustacean fishery, which are the Norway lobster and the deepwater rose shrimp. These two species have a different but overlapping depth distribution. Rose shrimp occurs from 100 to 350 meters of depth whereas Norway lobster is distributed from 200 to 800 meters. The number of fishing trips directed to one species or to the other depends on the abundance of these species each year. The number of fishing trips directed to *Nephrops* increased in 2004-2005, dropping again in 2006-2009.

The fishery takes place throughout the year, with the highest landings usually being made in the spring and summer.

A Recovery Plan for the southern hake and Iberian *Nephrops* stocks has been in force since the end of January 2006 (Council Regulation (EC) No. 2166/2005). The aim of the recovery plan is to rebuild the stocks within 10 years, with a reduction of 10% in F relative to the previous year and the TAC set accordingly. In order to reduce fishing mortality on *Nephrops* stocks in this area even further, the Recovery Plan introduced a seasonal ban in the trawl and creel fishery in a box, located in FU 28, for four months in the peak of the *Nephrops* fishing season (May – August).

Every year, the TAC and the number of fishing days per vessel is regulated.

A Portuguese national regulation (Portaria no. 1142/2004, 13th September 2004) enforced a complete closure of the deepwater crustacean trawl fishery in January–February 2005 and established a ban on *Nephrops* fishing from 15 September to 15 October. The ban in September–October was already implemented in 2004. This regulation was revoked in January 2006 after the implementation of the Recovery Plan, keeping only one month of closure of the crustacean fishery in January (Portaria no. 43/2006, 12th January 2006). Although these periods do not correspond to the main fishing season for *Nephrops*, these measures resulted in a reduction of effort.

The minimum landing size (MLS) for *Nephrops norvegicus* is 20 mm of carapace length (CL) or 70 mm of total length (TL). Discards are negligible and are mainly related to quality (broken or soft shells).

The main by-catch species are blue whiting, hake and anglerfish.

A.3. Ecosystem aspects

The Norway lobster (*Nephrops norvegicus*) is distributed along the southwest and south Portuguese coast, at depths ranging from 200 to 800 m. Its distribution along the continental slope is patchy and high abundance areas have been clearly identified.

Differences in the length composition of catches originating from FU28 (SW Portugal) and those originating from FU29 (S Portugal) were observed during the surveys. At present there is no scientific evidence to separate these stocks and consider them two sub-populations. Further work in this area is needed to improve our knowledge about this stock.

Another topic that should be further investigated, is the possible interaction between the stocks found in FU29 and FU30 (Cadiz). Exchanges between the two populations are likely to occur since there are no known physical/geographical constraints limiting this exchange. Aiming for a better understanding of the *Nephrops* population dynamics, tagging experiments and genetic studies would provide valuable information, which would help to support the issues dealt with during the assessment working groups.

Norway lobster is a benthic species that attains a maximum size of around 80mm (CL) corresponding to a weight of approximately 400g. Lobsters spawn from August through to November off the shelf edge in deep waters. After spawning, females carry the eggs for a 3 to 4 month period after which the larvae hatch and become pelagic free swimmers. Larvae move freely in the water column for a short time period before settling into the mud grounds. Females reach the first maturity at 30 mm and males around 28 mm of carapace length (CL) (ICES, 2006).

A comprehensive study into the role of Norway lobsters in the ecosystem has not yet been carried out. It would be particularly useful to have such information, as *Nephrops* is known to be part of an extended and dynamic community of highly valuable commercial species.

B. Data

B.1. Commercial catch

Up to 1992 the estimated landings from FUs 28 and 29 have fluctuated between 450 and 530 t, with a long-term average of about 480 t. Between 1990 and 1996, the landings fell drastically to 132 t. From 1997 to 2005 landings have increased to levels observed during the early 1990s but decreased again in recent years. The value of total landings in 2009 was 122 t, the lowest value of the series.

Males are the dominant component in all landings with exception of 1995 and 1996 when total female landings exceeded male landings (ICES, 2006a). For the last eight years male to female sex-ratio has been close to 1.5:1.

A discard sampling program onboard the Portuguese crustacean trawlers started in 2004. The weight of *Nephrops* discarded in 2006-2008 was very low with high CVs. No discards were recorded in 2009.

B.2. Biological

Length distributions for both males and females for the Portuguese trawl landings are obtained from samples taken weekly at the main auction port, Vila Real de Sto. António. The sampling data are raised to the total landings by market category, vessel and month. Information on discards is not taken into account in the estimation of the total catch length distributions due to the low level of discards and the lack of defined raising procedures. However, the length distribution of discards confirms the idea that *Nephrops* is not rejected because of its MLS (20 mm of CL) but mainly due to quality problems.

Mean weights-at-age for this stock are estimated from fixed weight-length.

A natural mortality rate of 0.3 was assumed for all age classes and years for males and immature females, with a value of 0.2 for mature females based in Morizur (1982). The lower value for mature females reflects the reduced burrow emergence while ovigerous and hence an assumed reduction in predation.

The size at maturity for females was recalculated at ICES-WKNEPH 2006 to be 30 mm being the same as used in assessments prior to 2008 (ICES, 2006). An asymmetrical log-log relationship was used to estimate the maturity ogive and L_{50}.

A segmented regression was used to estimate the size at maturity for males as the breakpoint in the growth relationship between the appendix masculina and the carapace length. The value estimated for FU 29 was 28.4 mm of CL (ICES, 2006).

Growth parameters were estimated using the Bhattacharya method and tagging experiments (Figueiredo, 1989).

Several factors were considered to potentially affect survival, including duration of the tow and season, and biological characteristics of the individuals (e.g. size, sex and ovigerous condition). Survival was only affected by season (increased mortality in warm months). A global estimate of survival of released lobsters, taking into consideration survival and proportion of the catches for each season, was 35% (Castro *et al.*, 2003)

Summary:

INPUT PARAMETERS		
Parameter	Value	Source
Discard Survival	0.35	
MALES		
Growth - K	0.200	Portuguese data (Bhattacharya method) ; tagging (ICES, 1990a)
Growth - L(inf)	70	"
Natural mortality - M	0.3	Figueiredo (1989)
Size at maturity (mm CL)	28.4	ICES (2006)
Length/weight - a	0.00028	Figueiredo (pers. comm., 1986)
Length/weight - b	3.2229	"
FEMALES		
Immature Growth		
Growth - K	0.200	Portuguese data (Bhattacharya method) ; tagging (ICES, 1990a)
Growth - L(inf)	70	"
Natural mortality - M	0.3	Figueiredo (1989)
Size at maturity (mm CL)	30	ICES (1994)
Mature Growth		
Growth - K	0.065	Portuguese data (Bhattacharya method) ; tagging (ICES, 1990a)
Growth - L(inf)	65	"
Natural mortality - M	0.2	Figueiredo (1989)
Length/weight - a	0.00056	Figueiredo (pers. comm., 1986)
Length/weight - b	3.0288	"

B.3. Surveys

The Portuguese crustacean surveys started in 1981. The surveys were carried out with the research vessels «Mestre Costeiro» and «Noruega» and the main areas covered were the southwest coast (Alentejo or FU 28) and the south coast (Algarve or FU 29). The main objectives were to estimate the abundance, to study the distribution and the biological characteristics of the main crustacean species, namely *Nephrops norvegicus* (Norway lobster), *Parapenaeus longirostris* (rose shrimp) and *Aristeus antennatus* (red shrimp).

In 1997, a stratified sampling design was adopted, based on the design for the demersal resources. The sectors and depth strata were the same used for the groundfish surveys, from 200 to 750 meters in the southwest coast and from 100 to 750 meters in the south coast. The number of hauls in each stratum was dependent on *Nephrops* and rose shrimp abundance variance, with a minimum of 2 stations per stratum. The average total number of stations in the period 1997-2004 was 60. These surveys were carried out in May-July and had a total duration of 20 days.

Since 2005, sampling was based on a regular grid superimposed on the area of *Nephrops* distribution. This sampling procedure allows a more powerful use of data, especially considering the use of geostatistical tools. The total duration of the survey was the same (20 days) and the haul duration had to be reduced from 60 to 30 minutes in order to cover all the rectangles (77) of the grid.

Sediment samples have been collected since 2005 with the aim to study the characteristics of the *Nephrops* fishing grounds.

In 2008, the crustacean trawl survey conducted in Functional Units 28 and 29, was combined with an experimental video sampling. The collection of images was limited to 10 stations in FU 28.

A SeaCorder, composed of an MD4000 high resolution colour camera, an MP4 video recorder and a 30 Gb hard drive, was hung at the central point of the headline, pointing forward onto the sea floor with an angle of 45 degrees, approximately (ICES, 2007). A 2-beam laser pointer is attached to the SeaCorder, for measuring purposes (estimation of the width of view and *Nephrops* and burrows sizes).

The collection of video footage was routinely carried out in each trawl station was routinely carried in 2009. This methodology is being evaluated to see if the data can be used for biomass estimation, length distribution and *Nephrops* catchability by the trawl gear (ICES, 2009).

B.4. Commercial CPUE

A first attempt to standardize the CPUE series was presented to WGHMM in 2008 (Silva, C. – WD 25) and reviewed in 2009, applying the generalized linear models (GLMs). The data used for this standardization were the crustacean logbooks for the period 1988-2008. The factors retained for the final model (year, month and vessel category) were those which contribute more than 1% to the overall variance. The model explains 17% to 19% of the variabilility, when using the CPUE in kg/day or kg/haul respectively. The CPUE series was standardised and the effort estimated correspondingly.

However some concerns related to the characteristics of the fishery remain. The main target species of this fleet are rose shrimp and Norway lobster. The vessels change their fishing objective according to the abundance of these species, which can affect the target CPUE estimation and consequently the derived effort.

A new standardization model was developed and presented to WKSHAKE2 (Silva and Cardador, 2010). Considering the behaviour of the fleet in periods of high abundance of rose shrimp, new variables related to the daily catches of this species and the proportion of *Nephrops* in the total daily catch were incorporated in the GLM model.

Two approaches were analysed:

1) The delta or two-step approach, i.e. to model the probability of obtaining a zero catch (Binomial with logit function) and the catch rate, given that the catch is non-zero, separately (Gamma distribution with log link function).

2) To model only the non-zero catches assuming that when the catch of *Nephrops* is zero, the fishery is not directed at this species. This assumption is based on the different depth distribution of rose shrimp and *Nephrops*, although some overlap occurs. This approach used a GLM model with Gamma distribution and log link function.

The explanatory variables included in the models were *year* and *month* as factors and *the daily log catch of rose shrimp* as a continuous variable, for the first approach, and also the *proportion of Nephrops in the total catch* for the second approach, categorized in two levels, <0.25 and ≥ 0.25.

The inclusion of catch rates of other species is a way of including the impact of fishers targeting species other than under consideration (Maunder and Punt, 2004). The categorization of the proportion of *Nephrops* in the total daily catch was set using external information from an independent analysis aiming the definition of metiers within the crustacean fishery. The trips were identified based on the value contribution of their target species and the corresponding proportion in weight was determined (C. Silva, *in prep.*).

The logistic model fitted to the presence/absence of *Nephrops* explains 31% of the total variability. The most influential explanatory variable was the daily catch rate of rose shrimp. The Gamma model fitted to the positive values of NEP_{CPUE} explains 45% of the total variability, with the proportion of *Nephrops* in the total daily catches as the most important factor.

Although the CPUE estimates differ in the scale, the year effects resulting from both approaches are similar. Taking into account the knowledge of the fishery, the more consistent results in the assessment and improved diagnostics (catchability residuals and retrospective patterns), the second model – with non-zero catches, Gamma distribution with log link function – was accepted for stock assessment.

B.5. Other relevant data

C. Historical Stock Development

In the past, LCA assessments were carried out for males and females separately over a 3-year reference period, in which the stock was considered to be in a steady state. The steady state assumption was questioned due to the decrease of the stock and this method was abandoned (ICES, 2002).

Software used: Lba99g.exe

Age structured XSA assessments have been carried out recently for *Nephrops*, males and females separately (ICES, 2008), with two tuning fleets: the crustacean fleet and the crustacean survey. The results were considered unreliable for several reasons most importantly, growth and natural mortality assumptions and the use of age-converted groups by slicing. However, the results have been taken as indicative of stock trends.

Software used:

- For conversion of the length compositions in ages with slicing: L2AGE4.exe
- XSA: Lowestoft VPA Suite (VPA95.exe), Retvpa02.exe, FLR package

Males	2006 – 2010 WGHMM	
Tuning Fleets used (First - Last year ; Ages used)	Period	Ages
P-TR: Crustacean Trawl Fleet	1988-2009	2 - 7
P-CTS: Crustacean Trawl Survey	1997-2009	2 - 7
First age for normal catchability independent	All ages independent	
First age at which q is considered independent of	6	
Taper time weight applied?	Tricube over 20 yrs	
F shrinkage (SE for mean F)	1.5	
F Shrinkage	Final 5	3 oldest
Minimum Log SE for terminal population estimates	0.3	
Fbar (age)	2 - 7	
Recruitment Age	2	

Females	2006 – 2010 WGHMM	
Tuning Fleets used (First - Last year ; Ages used)	Period	Ages
P-TR: Crustacean Trawl Fleet	1988-2009	2 – 12
P-CTS: Crustacean Trawl Survey	1997-2009	2 – 5
First age for normal catchability independent	All ages independent	
First age at which q is considered independent of age	11	
Taper time weight applied?	Tricube over 20 yrs	
F shrinkage (SE for mean F)	1.5	
F Shrinkage	Final 5 yrs	5 oldest
Minimum Log SE for terminal population estimates	0.3	
Fbar (age)	4 – 10	
Recruitment Age	2	

Other indicators, such as CPUE from the fleet, abundance index from crustacean trawl survey and mean sizes in landings and in surveys have also been used when analysing trends.

D. Short-Term Projection

To account for uncertainty around model fitting, residuals from the XSA fit were randomly re-sampled (bootstrapped, 1000 samples) generating new abundance indices and the XSA model was refitted by bootstrap sample. The projections were performed for each bootstrap line using:

- Model: Age forward projection
- Software: FLR (R 2.8.1, FLCore 2.2, FLAssess 2.0.1, FLXSA 2.0, FLBRP 0.7.1, FLash 0.7.0)
- Recruitment: At age 2. In the absence of a stock-recruitment relationship, recruitment values for the projected years of each bootstrap line were sampled from the recruitments of the same line for the period 1990-2009, which includes low and medium level recruitments
- Natural mortality: 0.3 for males, 0.2 for adult females

- F and M before spawning: NA
- Weight-at-age: arithmetic mean of last 3 years.
- Proportion mature-at-age: arithmetic mean of last 3 years.
- Exploitation pattern: average of last 3 years scaled to terminal year, due to observed declining trend.
- Intermediate year assumptions: F_{sq} (F = last assessment year F).

Males and females are caught together during the main fishing season (spring and summer) but the availability of females is reduced during the egg-bearing period (autumn and winter). As *Nephrops* males constitute the most exploited component of the stock, they will drive the strategies to be applied to females. Therefore, the F-multiplier, resulting from male stock projection, is applied to females.

The total Yield is the sum of the yields from males and females projections.

The bootstrap projections allow determining the 95% confidence limits of the estimates.

E. Medium-Term Projections

Not used

F. Long-Term Projections

Not used

G. Biological Reference Points

Biological reference points were estimated on the basis of the Yield per Recruit curve. Considering the retrospective pattern, WGHMM 2010 estimated the biological reference points based on the convergent part of the XSA, the selection pattern and weights-at-age being the average of the years 2002-2004.

However, since the extent to which the fishery targets *Nephrops* depends on rose shrimp abundance, and this might potentially impact on the relative exploitation pattern-at-age, a sensitivity analysis of the potential F_{MSY} proxies was conducted, with the average selection pattern of a three-year moving window since the beginning of the series. The $F_{0.1}$ shows some stability over the time series, either for males or females, and may be considered as a F_{MSY} proxy. At $F_{0.1}$ the %SPR are above 35% (table below). The Y/R curves for this species are flat-top and F_{MAX} is not well defined.

The following table summarizes the BRPs for males and females:

	Males		**Females**	
BRPs	**F**	**%SPR**	**F**	**%SPR**
$F_{0.1}$	0.21	40%	0.18	42%
$F_{35\%SPR}$	0.26	35%	0.24	35%

H. Other Issues

I. References

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Annex 5 Technical Minutes

Review of ICES WKSHAKE2 Report 2010 - 29 November to 2 December	
Reviewers:	Marcel Machiels (chair)
	Höskuldur Bjornsson
Chair WG:	Carl O'Brien
Secretariat:	Cristina Morgado

General

The Review Group considered the following ToRs of WKSHAKE2, to answer the request from European Commission about the development on a management plan for Iberian stocks of hake, *Nephrops* and anglerfish:

- Develop Harvest Control Rules for the Iberian mixed fishery of S. hake, *Nephrops* and anglerfish in order to achieve F_{MSY} by 2015.
- Calculate the probability P ($F_{2015} <= F_{MSY}$)
- Propose any other effort regime adaptation of the current one and evaluate its options, if appropriate.

The RG acknowledges the intense effort expended by the working group to produce the report

The core of the report deals with single stock evaluation of Harvest Control Rules (HCR) related to the EU management plan according to regulation no 2166/2005

Chapters on single stock evaluation seem to be written "stand alone". The result are presented in a wide variety of graphs and tables. The RG finds it difficult to grasp the messages of the WG concerning the requested ToRs and applied to the different stocks.

General comments

Section 2: Harvest control rules and TAC overshoot scenarios

In this chapter the HCR's evaluated are defined. Three HCR's are considered starting with a moderate annual decrease of the fishery mortality (F) by 10%. A linear decrease of F to and Fmsy in 2015 is considered and an immediate drop of F to Fmsy in 2011 is the third HCR

In additions the 3 HCR are modified with TAC constraints options and TAC overshoot scenarios. The RG considers the added modification as an integral part of a control rule and this results -for hake- in 50 HCR simulation (times 3 for some recruitment alternatives) to be evaluated.

The WG does not give clear motives for their selection of HCR's and its modifications. Specifically a clear definition and description of TAC overshoot is considered essential by the RG. Furthermore it seems that this will help to select and present the result of the more narrow range of relevant scenario's

Section 3: Southern Hake

This chapter describes the result of evaluating the HCR's for Hake to reduce the current F (estimated in 2010: 0.8) to 0.25 in 2015 using a projection based approach. The main conclusion -TAC overshoot- prevents achieving Fmsy in 2015. This should be elaborated with respect to ToR's a and c. In this respect it may be relevant to point at chapter III of Regulation number 2166/2005 dealing with fishing effort limitation.

Section 4: Anglerfish

This chapter describes the result of evaluating the HCR's for using a dynamic surplus production model. The starting conditions of L. budegassa are already below Fmsy so the HCR's concentrate on L. piscatorius. The main conclusion is similar as for Southern Hake

Section 5: *Nephrops* (FU28,29)

This chapter describes the result of a CpUE standardization based on a GLM procedure. And this time-series was used in a new assessment. The estimated F's for males and females are well below Fmsy=F(0.1). Projections were executed based un a HCR with a 50% increase of F until Fmsy is reached.

Section 6 and 7: *Nephrops* (FU30 and FU25,26-27,28)

The stocks described in these chapters lack a recent analytical assessment so it is not possible to generate projections allowing to compare options for HCR's. Fishing pressure on these stocks is linked to the activity of the fleets catching hake and anglerfish. Measures that will reduce fishery mortality of hake and anglerfish will probably reduce the fishing pressure on *Nephrops*.

Section 6 and 7: Mixed fishery considerations

This chapter summarizes the mixed demersal fisheries in the Atlantic Iberian Peninsula shelf and concentrates on a description of the (seasonal) interactions between fleets and stocks. A short catalogue is given of which fleets could be limited to achieve certain goals. Additionally some joint HCR-scenarios for Hake and Anglerfish were evaluated. It is concluded that joint management of hake and anglerfish would lead to a loss in yield for anglerfish since hake is the most over-exploited stock

Technical comments

The RG considers the TAC-constraints as used in the HCR-rules used in projections done by the WG as confusing. It seems to interact strongly with the overshooting problem. Without current and future overshooting a reductions in F from 0.8 to 0.25 is 4 years' time will probably result in reduced TAC's during the first years of the action and the probability that a will be larger than the previous year is very low. Given the most probable scenario that the TAC is lower the scenario with no TAC constraint will result in higher stock biomass and lower F's in the near future. Results presented by the WG show the opposite! Current TAC's are approximately 50% of the landings. Using any of the 3 HCR's evaluated a 15% constraint results in a reduction of actual landings of around 40% and this is a larger reduction in F then under scenario 1 or 2.

The RG realizes that following a MSE approach, as was suggested by the reviewers of the previous study takes too long in a situation where urgent measures are necessary to achieve management objectives urgently. What is missing in the projection done for hake is a CV on the state of the stock and an assessment error in the projections

For a period of 4 years it could be appropriate to run series of landing profiles. These require realistic CV estimates and a range of recruitment scenario's. Assumption about TAC overshoot are not necessary.

The RG didn't consent on the value of using GLM to improve the quality of CpUE time series used in assessment models but concludes that the CpUE time serie as it is presented in the report in inappropriate to be used in the assessment. It is unclear how the effect of months was incorporated in the time-series prediction. Moreover, a significant linear effect of rose shrimp CpUE values was found but for the estimations a fixed value of 19.4 kg/day was used.

The conclusion that joint management would lead to loss in the yield of anglerfish is only true for the short time. Yield (per recruit) curves are usually flat and the fishery mortality of L. piscatorius need to be reduced. An F close to but below Fmsy does not necessary mean loss of yield.

To evaluate mixed fisheries detailed knowledge about spatial distribution of stocks and fishing fleets is an advantage. Distributions can change if stock size increases. A quick look at the catch composition of different fleets like is done by the WG is a good step to start work, it might point to the solutions that need to be implemented. An attempt to quantify the contributions of the various fleets activities to the exploitation levels of the stocks under considerations would have been useful.

For future work more sophisticated simulations would be of value, perhaps some kind of MSE evaluation. What would be interesting to model is the discard process. Will the discard be reduced or increased with reduced TAC, or in other words do reduced landings lead to reduced F.

Conclusions

The RG concludes that the WG succeeded partially in the meeting the requests of ToR 1 to 3 to ICES. The main contributions deal with single stock evaluations. Results on probabilities for the most relevant stock, hake, of reaching Fmsy in 2015 are conservative estimates based on deterministic projections with added recruitment variability. References to effort regime adaptations are lacking.

Checklist for review process

General aspects

- Has the WG answered those TORs relevant to providing advice?
- Is the assessment according to the stock annex description?
- Is general ecosystem information provided and is it used in the individual stock sections.
- Has the group carried out evaluations of management plans?
- Has the group collected and analyzed mixed fisheries data?

For stocks where management plans or recovery plans have been agreed

- Has the management plan been evaluated in earlier reports?
- If the management plans has been evaluated during this WG:
    - Is the evaluation credible and understandable
    - Are the basic assumptions, the data and the methods (software) appropriate and available?

For update assessments

- Have the data been used as specified in the stock annex?
- Has the assessment, recruitment and forecast model been applied as specified in the stock annex?
- Is there any **major** reason to deviate from the standard procedure for this stock?

- Does the update assessment give a valid basis for advice? If not, suggested what other basis should be sought for the advice?

For overview sections

- Are the main conclusions in accordance with the WG report?
- Verify that tables and figures been updated and are correct (except for the advice table)