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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 Fmsy by 2015

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ACOM leadership request IPIMAR would carry out the analysis to address the EC request. The stocks of concern for the current request are the **southern hake**, *Merluccius merluccius*, the **6 Functional Units (FU) of Norway lobster**, *Nephrops norvegicus* (FU 31 - Cantabrian, VIIIc; FU 25 - North Galicia, VIIIc; FU 26 - West Galicia, IXa; FU 27 - North Portugal, IXa; FUs 28-29 - Southwestern and Southern Portugal, IXa and FU 30 - Gulf Cadiz, IXa) and the **two species of southern anglerfish**, *Lophius piscatorius* and *Lophius budegassa*.

Summary

ToR 1 and 2: The results from the simulations indicated that the Harvest Control Rule (HCR) with best performance (combination of high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decrease) on a stock-by-stock basis were:

- **Southern hake**: decreasing fishing mortality to 0.26 until 2015 with 20% constraint in landings;
- ***Nephrops* FU 28-29**: increase F to 0.21 (males) until 2015 with 15% yield constraint;
- **Anglerfish**: 10% F annual reduction to 0.35 (*L. piscatorius*) by 2015 with 15% yield constraint.

The approach used for the mixed fishery analysis consisted in applying to the anglerfish stocks the hake HCR that showed the best performance. The interaction between fleets and the stocks under analysis indicate that the fishery exploiting the *Nephrops* FU 28-29 have only a marginal impact on the southern hake and anglerfish stocks. The results of the mixed fishery approach indicate a faster recovery of *L. piscatorius*, the anglerfish stock in poor condition, though at the expense of greater losses of combined yield, in relation to the above indicated HCR for anglerfish.

ToR 3: The EC requested a proposal for any other effort regime adaptation of the current one and an evaluation of its options. Current effort regime sets an annual 10% reduction of number of fishing days for some selected gears. This can be considered an effective effort control for the fleet/segments using bottom trawl gears. A possible way to improve the impact of the effort management towards an effective reduction in fishing mortality 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.

1 Introduction

Request to ICES:

"*Council Regulation N° 2166/2005 established the rules for the recovery of the Southern hake and Nephrops stocks in the Cantabrian Sea and Western Iberian Peninsula. 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 statements rules.*

Given the mixed nature of this fishery both *Nephrops* and anglerfish are affected by the plan measures.

In view of the benchmark exercise to be carried out next February 2010, the recovery plan needs to be reviewed and a thorough management plan needs to be developed. ICES is requested to:

1) Develop Harvest Control Rules for the mixed fishery of S. hake, *Nephrops* and anglerfish in order to achieve F_{MSY} by 2015. Calculate P ($F_{2015} <= F_{MSY}$).
2) Provide advice on an F policy with a 10% annual reduction, until F_{MSY} is reached.
3) Propose any other effort regime adaptation of the current one and evaluate its options, if appropriate.

The latest assessment of southern hake stock (ICES, 2009) as well as the results from the assessment with Gadget adopted during the recent benchmark of this stock (ICES, 2010a) showed that the fishing mortality reduction targeted by the recovery plan has not been achieved. In fact, the implementation of the recovery plan has not been effective since the fishing mortality has been increasing in every year of the settlement of the recovery plan and is estimated to be 0.91 $year^{-1}$ in 2008 (ICES 2010) well above the target of the plan (0.27 $year^{-1}$). On the other hand, discards from the trawl fleets of undersized individuals (<27cm) are estimated to be between 20% and 40% of total landings in recent years (ICES, 2009a). The spawning stock biomass has increased in recent years, mainly due to above average recruitments during 2003-2007, but is estimated to be 12.5 th t in 2008 (ICES, 2010a), well below the 35 th t aimed by the recovery plan. In the case of the *Nephrops* FU 31, 25, 26 and 27 the available information indicates that the state of the stocks are poor (FU 31), are at a very low abundance level (FU 25) and at an extremely low level (FU 26-27) and ICES has therefore advised for a zero catch until there is evidence of stock improvement (ICES, 2008a). The *Nephrops* stocks in FU 28-29 appears to have recovered from its low level in 1996 and the last assessment indicates a reduction in the fishing mortality while for FU 30 the state of the stock is unknown but abundance has been stable in recent years (ICES, 2008a). ICES advice for the anglerfish stocks was for zero catch or the implementation of a management plan aiming at the recovery of *L. piscatorius* that is the stock in poor condition (ICES, 2009). The current analysis takes into account the different perception of the status of these stocks, the mixed fisheries aspects and the goal of achieving F_{msy} by 2015 as stated in the request.

In the current analysis the following assessments were used by stock: for southern hake the stock assessment adopted during WKROUND, performed with the Gadget model for the period 1982-2008 (ICES, 2010a); for the *Nephrops* FU 28-29 an update assessment from ICES (2008b) performed for males and females with 2008 data; for both anglerfish the last stock assessment performed with the Schaefer biomass dynamic model (ICES, 2009). It is noted that since *Nephrops* FU 31, FU 25, FU 26, FU 27 and FU 30 do not have assessments that allow to conduct stock projections (ICES, 2008b) these FUs are not addressed in the present evaluation.

The following HCR (Harvest Control Rule) was tested (where β is a multiplying factor related to the analysed tactics, see below, and α to the %TAC constraint):

if $F_{y-1} \neq F_{msy}$ then $F_{y+1} = \beta F_y$

if $F_{y-1} = F_{msy}$ then $F_{y+1} = F_{msy}$

if $TAC_{y+1} < (1-\alpha)TAC_y$ then $TAC_{y+1} = (1-\alpha)TAC_y$ and $F_{y+1} = F \sim TAC_{y+1}$

if $TAC_{y+1} > (1+\alpha)TAC_y$ then $TAC_{y+1} = (1+\alpha)TAC_y$ and $F_{y+1} = F \sim TAC_{y+1}$

where y is the last assessment year, y-1 is the last year with observations, y+1 is the year for which the advice is being provided and ~ means "set in accordance with".

It is noted, however, that since for southern hake and anglerfish stocks the TACs have been largely overshoot in recent years (during every year of the recovery plan for southern hake) and there isn´t a clear relationship between landings and TAC overshoot, the simulations were performed by imposing instead a constraint on landings (southern hake) and on yield (anglerfish). For *Nephrops* the TAC is set for the entire ICES Division IXa, thus applying for the combination of the several FUs in the area (FUs 26-30). Since a disproportionate amount of the TAC could be taken from one or the other of the FU units ICES has recommended the implementation of management of catches and/or effort at a geographic scale that corresponds to the distribution of the *Nephrops* (ICES, 2008a). The HCR for *Nephrops* FU 28-29 were, therefore, tested imposing also a yield constraint rather than a TAC constraint.

The HCR was tested for the following tactics, where | reads *conditional on*:

1) $\beta_y = x_y \mid F_{2015} = F_{msy}$ for all stocks

2) $\beta_y = 0.9 \mid F_{y-1} > F_{msy}$ for hake and anglerfish stocks

   $\beta_y = 1.1 \mid F_{y-1} < F_{msy}$ for Neps FU 28-29 (see section 3.2)

Option 1) addresses ToR 1 of the request. Since the aim is to achieve F_{msy} by 2015 the simulations were performed by first defining a fishing mortality trajectory with the following annual F decrease (southern hake and anglerfish) or F increase (*Nephrops* FU 28-29):

$$\frac{|F_{msy} - F_{2010}|}{2015 - 2010 + 1}$$

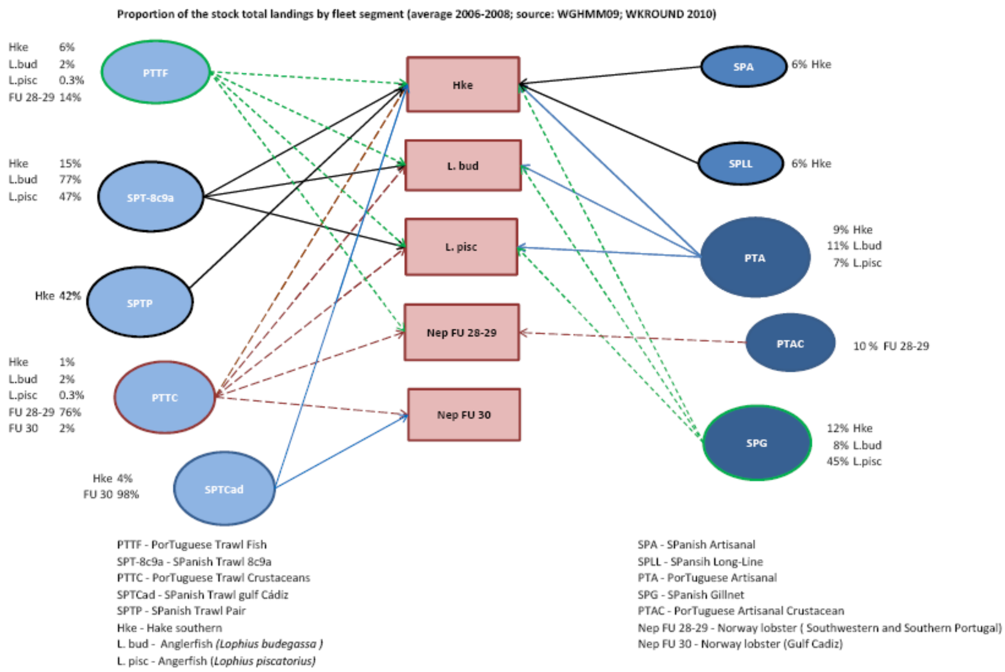
which was used to compute x in each year. For both options (1 and 2) the constraint were verified in every year and if landings (or yield) were outside the constraint boundary, the annual F was re-computed to produce the landings (or yield) constrained by the rule.

Following guidelines from WKFRAME (ICES, 2010b) and in the absence of evidence for a S-R relationship, the range of analyzed fishing mortality options for southern hake and *Nephrops* FU 28-29 included values encompassing proxies for F_{msy} ($F_{0.1}$, F_{max}, $F_{30\%SPR}$, $F_{35\%SPR}$) and also the option F=M. For the two stocks of anglerfish (*Lophius piscatorius* and *L. budegassa*) the F_{msy}, as estimated from the stock assessment with the Schaefer biomass dynamic model (ICES, 2009), was adopted as the target. The options considered for the interannual variation on landings (or yield) were ±15%, ±20% and ±25% (α=0.15, 0.20 and 0.25), following %TAC variation levels commonly adopted by the policy statement rules. Simulations were also performed without landings (or yield) constraint.

The Harvest Control Rule (HCR) was first tested by stock (southern hake, *Nephrops* FU 28-29 and the two anglerfish stocks, *L. piscatorius* and *L. budegassa*) using several combinations of target fishing mortality and interannual variation in landings (or yield) by performing stochastic projections (1000 iterations) of the stock abundance for a 20 years period (2009-2028) and assuming F_{sq} in 2009.

The metrics used to evaluate the HCR were: the year when $P[F=F_{msy}]>95\%$, the $P[F_{2015}<=F_{msy}]$, the cumulative yields in 2015 ($Y_{cum2015}$) and in 2028 ($Y_{cum2028}$), the spawning stock biomass in 2015 (SSB_{2015}) and in 2028 (SSB_{2028}) and the risk of SSB decreasing along the period, computed as the number of years corresponding to the $P[SSB_{y+1}<SSB_y]>5\%$. It is noted that for the anglerfish stocks, assessed with biomass dynamic model, total biomass was used instead of SSB.

For the mixed fishery approach it was taken into account the fleets' interaction between stocks, using the recent average proportion (2006-2008) of the stock total landings by fleet segment as shown in the following flowchart (further details given in sec 2.4):



The analysis consisted in applying to the anglerfish stocks the hake HCR that showed the best performance on a stock-by-stock basis analysis. The criteria to evaluate the performance of the HCR were based on the combination: high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decrease.

All analyses were implemented in R using FLR Libraries (Kell *et al.*, 2008). Details of the assessments, starting conditions and simulations are given below in each stock section.

2 Modelling approach and starting conditions by stock

2.1 Hake

<u>Assessment</u>

The assessment used for this analysis is the assessment approved by WKROUND (ICES, 2010a) using the model Gadget with a single recruitment event occurring at the end of the first quarter. The approved assessment considered two recruitment events, in the end of the first and second quarters, with ≈50% of recruitment occurring in each period. This change in the settings of the assessment model was introduced to facilitate the conversion of quarterly dynamics into annual.

<u>Conversion of gadget results (by length and quarters) into age and annual dynamics</u>

The conversion of length frequencies into ages is performed internally by Gadget considering the growth model provided. The population numbers in the start of each year and the recruitment in the end of the first quarter were used as the annual population, as well as the related weights at age. Catches, both landings and discards, in each quarter were summed to provide catches in numbers at age along the year. Weights at age in the catch, landings and discards were computed by the weighted mean of each quarter's weights and numbers at age. Fishing mortality was computed with the survivor's equation and adjusted to match the observed catches, once that due to the quarterly dynamics, fishing mortality is not applied all at the same instant and yearly catches are not based on a constant yearly population. Natural mortality was set at 0.4 for all ages (following WKROUND, ICES 2010a) with the exception of the recruits, for which M was set at 0.3 once that recruitment occurs in the end of the first quarter. Proportion mature-at-age was converted from yearly maturity ogives by length using the algorithm described by Parrack and Cummings (2003). All adjustments were made using the 15 age groups adopted by WKROUND (ICES, 2010a). Afterwards a plus group was set at age 8.

Figure 2.1.1 shows a comparison between WKROUND (ICES, 2010a) final run for southern hake and the approximation obtained in the current analysis. The similarities between both results were very high and the analysis was conducted based on the annual dynamics by age.

Uncertainty on the historical results and in the initial conditions

Gadget does not compute standard errors of the estimated parameters. However it was necessary to introduce variability in the results so that projections could take into account some degree of uncertainty. The method used introduces variability in population numbers at age, taking into account the historical (1989-2007) variability, and fixes fishing mortality so that population uncertainty is transmitted to catches in numbers at age. Population uncertainty is generated by a lognormal distribution with mean equals to the estimate and standard deviation estimated from the standard error of the historical mean (1989-2007) for each age (Table 2.1.1).

Figure 2.1.2 shows the stock and fishery trends over time with the uncertainty introduced by this study. Other methods will be explored in the future so that uncertainty in fishing mortality can also be taken into account.

Stochastic projections

Stochastic projections were performed with future recruitment generated by a lognormal distribution with mean equals to recruitments estimates for the period 1989-2007 and a CV of approximately 10%. The exploitation pattern was set as the average of 2006-2008 (scaled to 2008), split into landings exploitation pattern and discards exploitation pattern by the proportion of numbers at age landed and discarded over catch. It was also assumed that natural mortality (M of 0.4), weights-at-age and proportion mature-at-age averaged over 2006-2008 were time-invariant and without error.

Southern hake stock proxies for F_{msy} used in the analysis were: $F_{0.1}$, F_{max} and F=M (Table 2.1.2).

Due to the large and raising overshoot of the TACs in recent years the TAC constraint was simulated as landings constraint and set at 15%, 20% and 25%. In fact the TACs have increased in recent years due to a misinterpretation of the assessment provided by ICES. Extra scenarios without landings constraints were also carried out as well as scenarios for continuing fishing at 2008 levels, named as F_{sq}.

2.2 *Nephrops* FU 28-29 (Males and Females)

There are two main target species in the crustacean fishery, which are the deepwater rose shrimp (*Parapenaeus longirostris*) and the Norway lobster (*Nephrops norvegicus*). 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 fishing effort directed to *Nephrops* depends on the abundance of rose shrimp each year. The number of fishing trips targeting Norway lobster increased in 2004-2005, dropping again in 2006-2008 due to an increase in the abundance of rose shrimp (Figure 2.2.1).

As no assessment was carried out in 2009, an updated assessment was performed separately for males and females, using the data from the period 1984-2008. An age-based assessment with FLXSA was used with the same settings of the previous assessment (ICES, 2008b). 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. Biological reference points were estimated from the yield per recruit curves by sex using FLBRP.

Stochastic projections were performed for the period 2009-2028 on each of the 1000 samples, using the mean recruitment over the period 1984-2008, and scaling the average F-at-age of the last three years to 2008 F-value. 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 2006-2008) 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. For each scenario, the F-multipliers vector, resulting from the simulation of HCR combination on males stock, was applied to females.

2.3 Anglerfish (Lophius piscatorius and L. budegassa)

Two species of anglerfish, *L. piscatorius* and *L. budegassa*, are found in ICES Divisions VIIIc and IXa. Both species are caught together and are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the harbours landings statistics. Therefore, estimates of each species in Spanish landings from Divisions VIIIc and IXa and Portuguese landings from Division IXa are derived from their relative proportions in market samples (ICES, 2009a). Both stocks (*L. piscatorius* and *L. budegassa*) were assessed, during the 2009 ICES WGHMM (ICES, 2009a), with the Schaefer biomass dynamic model using the software ASPIC (Non-equilibrium stock production model incorporating covariates, Prager, 1994, 1995) with bootstrapping (1000 iterations). The current analysis used the outputs from this updated assessment for each stock.

Projections into the future were performed by stock using as input each of the 1000 estimates of (K, r, F_{msy}, B_{msy}, F_{2008}, B_{2009}) from the last assessment and computing the annual yield in year y, Y_y, and the total biomass at the start of the following year, B_{y+1}, as:

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

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

Projections were done using for *L. budegassa* the *F* multiplier that resulted from the application of the HCR for *L. piscatorius*, which is the species in poorer condition. Due to the nature of the species and fisheries it would be unrealistic to have different strategies for each stock and, therefore the strategy used for L. *budegassa* was the one adopted for *L. piscatorius.*

For each bootstrap iteration an estimate of F_{msy} is obtained and thus the HCR was tested taking into account the uncertainty around F_{msy}. Simulations were performed for the following scenarios: impose $F=F_{msy}$ in 2015 for *L. piscatorius* with yield constraints of 15%, 20% and 25%; 10% F reduction towards $F=F_{msy}$ for *L. piscatorius* with yield constraints of 15%, 20% and 25%. It is noted that the yield constraint was applied for both species combined. Finally, simulations were also performed for F_{sq} but without yield constraint.

2.4 Mixed fisheries and fisheries interactions

The demersal fisheries in Atlantic Iberian Peninsula Shelf are mixed fisheries, with many stocks exploited together in various combinations and in different fisheries. Accordingly to the IBERMIX project (Identification and segmentation of mixed-species fisheries operating in the Atlantic Iberian Peninsula waters (EU, Contract FISH/2004/03-33)) and reported in WGHMM 2007 (ICES, 2007) the Spanish and Portuguese fleets and the segments identified were the following ones:

Spanish fleets in ICES Div. VIIIc-IXa		
Current fleets in WGHMM	**Segments identified**	**Species**
Gillnet (MNZ)	SP-SGN-MNZ	targeting anglerfish
Gillnet (HKE)	**SP-SGN-HKE**	targeting hake
Small Gillnet (HKE)		targeting hake
Long line	SP-SLL	targeting hake
Trawl N	**SP-OTB-8c9aN-dem**	Otter trawl - Demersal species
	SP-OTB-8c9aN-pel	Otter trawl - Pelagic species
	SP-PTB-8c9aN	Pair trawl – 90% blue whiting and mackerel
Trawl S (Cádiz)	SP-OTB-9aS	Coastal and deeper waters
Artisanal N	SP-artisanal-8c9aN	Targeting demersal stocks
Artisanal S (Cádiz)	SP- artisanal-9aS	Targeting demersal stocks
Portuguese fleets in ICES Div. VIIIc-IXa		
Current fleets in WGHMM	**Segments identified**	
Artisanal	PT-GNS/GTR	targeting demersal stocks
	PT-LLS	targeting demersal stocks
Trawl	PT-OTB-crustaceans	targeting crustacen
	PT-OTB-fish	targeting fish

Landings in weight adopted in this report concern the fleets reported in the WGHMM in 2009 (ICES, 2009a). In the case of the Portuguese trawl was possible to split the landings into the two components or segments, Crustacean and Fish, for hake, anglerfish and Norway lobster. Trawl discards of hake and trawl Spanish data were split into pair and demersal trawl based on data provided by IEO (2010).

Hake and anglerfish are exploited by the Portuguese and Spanish fleets operating in ICES divisions VIIIc and IXa.

In the case of Norway lobster, FU 31, FU 25 and FU 26 are only exploited by the Spanish fleet, while FU 28-29 is since 1983 only exploited by the Portuguese fleet and FU 27 and FU 30 are exploited by both countries since 1996 and 2003, respectively.

The importance of the landings by stock and by fleet was analyzed. Table 2.4.1 shows the percentage of landings for fish stocks and Table 2.4.2 for Norway lobster functional units, by fleet and by country during 2004 – 2008.

The mean percentage for 2006-2008 is the basis of the flowchart fleet shown in the introduction section. In relation to the landings from the southern hake stock, 84% are reported from the Spanish fleet, where 42% is caught by its respective pair trawl fleet. For anglerfish, *L. budegassa*, 85% of the landings is reported from the Spanish fleet, being 77% and 8%, respectively from trawl and gillnets fleets. *L. piscatorius* is mainly landed by the Spanish fleet (92%), being 45% from gillnets and 47% from the trawl. In the case of Norway lobster, FU 27, the Spanish trawl has reported 63% of the landings, whereas in FU 30, the Spanish trawl fleet landed 98%. As it was mentioned FUs

31, 25 and 26 are only exploited by the Spanish fleet and FU 28-29 are only exploited by the Portuguese fleet.

The Portuguese crustacean trawl landed 76% of total landings of FU 28-29 and fish trawl 10%. The Portuguese artisanal fleet landing Norway lobster is not the same which is reporting landings for the fish stocks. This fleet comprises boats authorized to use several gears, where the traps and creel are those used to catch Norway lobster. During 2006-2008 this fleet had comprised 19, 16 and 27 boats (DGPA – Portuguese General Directorate for Fisheries and Aquaculture), respectively, authorized to catch with different gears, which include gillnets, trammel net, hooks and traps. This fleet is classified in two groups 4K1 and 4K2 which correspond, to fixed gears used in boats smaller and larger than 12 meters length, respectively. It is not possible to know what gear was used to catch this species, since they use different gears. However it is expected that according to the morphological and behaviour characteristics of this crustacean the main gear used is traps, therefore the catches of hake and anglerfish do not take place in the same fishing operations as for Norway lobster. The main characteristics of this fleet landing Norway lobster in 2006-2008 are in the following table:

Summary	2006		2007		2008	
	4K1	4K2	4K1	4K2	4K1	4K2
Number of boats	6	13	5	11	10	17
TAB (mean)	6.4	43.6	11.28	40.40	4.1	35.6
Length-over-all (mean) - m	8.7	18.6	9.16	18.21	7.1	17.0
% landings	6	94	10	90	9	91
Landings (tonnes)	1.7	29.1	2.7	24.5	4.0	40.1

The interaction between fleets and the stocks under analysis indicate that the fishery exploiting the *Nephrops* FU 28-29 has only a marginal impact on the southern hake and anglerfish stocks. Therefore, the mixed fishery analysis consisted in applying to the anglerfish stocks the HCR that showed the best performance for hake.

3 Results

3.1 Hake

Table 2.1.2 presents the levels of fishing mortality for each candidate to F_{MSY} proxy and the related percentage of virgin spawning stock biomass per recruit (%SPR). The levels of the fishing mortality candidates computed for this study are very similar to those computed by WKROUND (ICES, 2010a). The %SPR corresponding to $F_{0.1}$, F_{max} and F=M is 40%, 30% and 17%, respectively.

Figure 3.1.3 shows the scatter plot of SSB and recruitment and the replacement lines for target F (defined as the survivorship needed to replace the spawning stock in the future; the slope of the replacement line depends on the fishing mortality). Additionally a replacement line for F_{MSY} based on a Ricker curve was added. Note that the fit of a S/R model was considered inappropriate for this stock due to the cloudy behaviour of the observations (WKROUND, ICES 2010a). However, it was included on this analysis for comparison purposes. Clearly the fishery was never exploited at $F_{0.1}$ levels and even F_{max} levels were only observed 3 times in the historical series. F=M and F_{MSY} from the Ricker model are more in-line with the historical records, but considering the stock's history of over-exploitation, these levels seem too high to be a real option.

Table 3.1.1 presents the summary metrics for each scenario. The scenarios that achieve the objective of reaching F target in 2015 are shaded in light gray. Note that all scenarios considering 10% annual decrease failed to reach the objective, as well as all scenarios with a 15% constraint in landings.

Considering the objective of achieving F_{MSY} in 2015 with the least impact on the exploitation and lower risk to SSB, the scenario that showed better results is decreasing fishing mortality to F_{max} until 2015 with 20% constraint in landings (Figure 3.1.1). This scenario foresees cumulative catches until 2015 ≈70 000 t, the range of simulated values was between 67 000 and 77 000 t; SSB in 2015 of ≈22 000 t with a potential increase to ≈57 000 t in 2028; and a medium risk of SSB decreasing during the study period, 4 out of 7 years until 2015. During the recovery period the landings constraint was applied to ≈50% of the simulations. Having a 20% between years constraint gives higher stability to landings, although in the medium term a small loss is to be expected in relation to the scenario without constraint. In fact the scenario that drives fishing mortality to F_{max} without constraints performs marginally better but falls outside DGMARE's and CFP guidelines (usually a limit in the annual TAC variation is set).

Successful scenarios for $F_{0.1}$ and F=M show an opposite trade-off relative to F_{max}. In the first case loosing landings and gaining SSB, in the second case gaining landings and loosing SSB. Taking into account the values of %SPR at those F targets (Table 2.1.2) F_{max} shows acceptable reproductive potential levels and a better balance between the level of SSB and expected yield. Also the levels of SSB foreseen by the $F_{0.1}$ scenarios are about 2 times the maximum observed, which looks unrealistic.

An important feature of this analysis was to show that the constraint level of 15% is responsible for limiting the fishing mortality decrease, resulting in sharp increases in fishing mortality and low values of SSB. This is due to the combination of a decrease trend in SSB with the maintenance of high landings, which forces a raise in fishing mortality and an even higher decrease in SSB on the next year. Note that this scenario produced very low levels of SSB in 2015 (Table 3.1.1). In such conditions the constant recruitment assumptions are unrealistic and it is likely that the stock would collapse.

The scenarios of fishing at status quo F showed a high risk to the fishery and the stock. Although the cumulative landings are at the same levels as other scenarios, the SSB foreseen in 2015 is very low, <8 000 t for all scenarios, its risk of decrease is greater than 85% (6 out of 7 years until 2015, 19 out of 20 years until 2028) and the expected levels in 2028 are also very low. Figure 3.1.2 shows the stock trajectories at status quo F without constraints in landings.

3.2 *Nephrops* FU 28-29 (Males and Females)

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 three years. The effort decrease on *Nephrops* stocks is not only due to the Recovery Plan effort regulations but also to an effort shift to target rose shrimp.

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

- F in 2008 was below $F_{0.1}$
- The recruitment has been stable in the last period (2003-2008)
- SSB presents an increasing trend in recent years

The proxies used for F_{msy} were $F_{0.1}$ and $F_{35\%SPR}$, the latter being close to the value of M (Table 2.1.2). F_{max} is not well defined for these stocks (flat-top Y/R curves). The analysis was also carried out by performing stochastic projections for F_{sq}. Figures 3.2.1a-b show the replacement lines for $F_{0.1}$ ($\approx F_{40\%SPR}$), $F_{35\%SPR}$ and F_{sq} over the historical series of R and SSB. Recruitment is at age 2.

Tables 3.2.1a-c summarize the results from the simulation used to test the specified HCR for *Nephrops*, for males, females and both sexes combined (males+females). In all scenarios, females never reach F_{msy} ($F<<F_{msy}$).

The scenarios showing the best performance (combination of high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decreasing) for *Nephrops* FU 28-29 are those that have $F_{0.1}$ as the target F for males. Whatever the chosen F trajectory for $F_{0.1}$ (10% increase or smaller F steps until $F_{0.1}$ in 2015) and %Yield constraint, these scenarios produce very similar results (Figures 3.2.2a-b and 3.2.3a-b). Although the scenarios with $F_{35\%SPR}$ as the target F produce higher cumulative yields in the medium-term, the risk of SSB decrease (on average 2 years until 2015 and above 14 years until 2028) is much higher than at $F_{0.1}$.

Unlike the simulations tested for southern hake and anglerfishes, the scenarios here presented for *Nephrops* show the simulated results from an increase in F up to F_{msy}. A constraint of 15% on yield is considered more advisable as a precautionary measure, to limit the catches and a quick increase in F as a consequence of a reduction in the abundance of deepwater rose shrimp (see Sec 2.2). The simulations indicate that for the recommended HCR (F increase to $F_{0.1}$ until 2015 with 15%Yield constraint) the cumulative yield for combined sexes is around 1800 t in 2015, increasing to around 5600 t in 2028.

3.3 Anglerfish

Table 3.3.1 present the summary of the metrics from the simulations performed for anglerfish and used to test the HCR.

At F_{sq} the probability of the biomass decreasing for *L. piscatorius* along the projected period is very high.

The results from the simulations indicate that for the HCR with 10% annual decrease in F the 15% yield constraint was applied very few times and the 20% and 25% yield constraint gave the same results. The HCR with 10% F annual reduction (Figure 3.3.1) has a high probability of achieving F_{msy} by 2015 for *L. piscatorius* (≈0.8) though only in 2018 is the probability higher than 95%. The risk of total biomass decreasing for *L. piscatorius* is low (only three years and in the period 2010-2015) and the cumulative yield in 2015 and 2028 are estimated to be around 19 th t and 82 th t, respectively. The commitment of the application of this HCR to both anglerfish stocks is harvesting the *L. budegassa* well below its sustainable levels at high long-term yield ($F<<F_{msy}$) with cumulative yield in 2015 and 2028 estimated to be 11 th t and 32 th t, respectively.

It is noted, however, that although for *L. piscatorius* F_{msy} is achieved by 2018 with high probability, the biomass only reaches B_{msy} beyond 2028.

3.4 Mixed fisheries

The results from the simulations applying to anglerfish (Table 3.4.1 and Figure 3.4.1) the F-multiplier corresponding to the HCR showing the best performance for southern hake (annual F decrease to $F_{msy}=F_{max}$ in 2015 and 20% Landings constraint) indicate a faster recovery of *L. piscatorius* to F_{msy} (high probability of $F=F_{msy}$ in 2015), a recover to B_{msy} before 2028 but results in greater losses in anglerfish yield when compared to the HCR selected for anglerfish on a single stock basis (Table 3.3.1). The mixed fishery results indicate cumulative yield for combined species of 24 th t in 2015 and of 74 th t in 2028 while the single stock analysis indicate 29 th t in 2015 but 115 th t in 2028.

4 Discussion and Conclusions

Hake: The present perception of the stock status and dynamics sustain that the best proxy for F_{MSY} is F_{max}. The impact on landings of the distinct candidates is similar and an F_{max} strategy guarantees a fairly high yield when compared to the stock's historical performance.

It is important to bear in mind that the TAC is not controlling the fishery and in that sense it is not promoting the recovery of the stock as expected. It must be noted that the decrease in fishing mortality to bring landings in-line with the TAC should be above 50%.

The simulations were performed with landings constraint instead of TAC constraint due to the absence of a relationship between landings and TAC overshoot. However, this approach gives a good perspective of the relative effect of each constraint level on the stock development and take into account the landings stability required by the stakeholders, implicit in the TAC constraint.

Discard practices were kept constant during the projection period. However, reducing mortality of small fish will substantially improve SSB and yield, as stated by ICES (2009b) and showed by Jardim, *et.al* (2010). The mortality of small fish is mainly deployed by the trawl fleets (ICES, 2009a).

Although it was foreseen the development of a MSE (Management Strategy Evaluation) approach, such modelling was not possible due to the difficulties in converting Gadget results by length/quarter to age/annual and introduce uncertainty on the stock estimates that Gadget does not provide. However, Jardim *et.al* (2010), in a MSE analysis for this stock, conclude that the best strategy is to drive the stock to F_{max} until 2015. These authors also test distinct S/R models and showed that management using a Ricker model (F_{MSY} higher than F_{max}) results in instability of the landings and the stock size. In the current analysis F_{MSY} is also higher than F_{max} and corresponds to very low %SPR (< 10%). The conclusions from Jardim *et.al* (2010) are in agreement with those of the present study.

Nephrops: Last assessment was performed in WGHMM in 2008. The results of the assessment were only used as indicative of stock trends. Since 2008 the commercial CPUE series was reviewed and in the current update assessment only daily records targeting *Nephrops* were used. The results of the assessment indicate a retrospective pattern for the F and SSB (lower F and higher SSB) in the last years and a high coefficient of variation. The assessment performed with 1000 bootstrap samples, adding uncertainty in the historical series, correct this pattern since the starting conditions for the projections have a higher F and a lower SSB.

As it was referred in Section 2.2, *Nephrops* is one of the target species in the crustacean trawl fishery, the volume of its catches depending on the abundance of rose shrimp. Rose shrimp has a higher market value and the fishing grounds are less deep. In periods of high abundance of rose shrimp, the vessels spend less effort on *Nephrops*, not because of low catches of this species but because they get higher revenue targeting rose shrimp with lower production costs.

The last period of high catches of rose shrimp was in 1998-2003. In 2006, the abundance of this species increase again and in 2008 the catches were still growing. At present, the catches of *Nephrops* are at a very low level. It is expected that when the shrimp abundance decreases, there is a shift in the target species, increasing the fishing pressure on *Nephrops*.

Nephrops stocks can bear a higher fishing effort than it is exerted now, but it is important to have in mind that this increase can happen anytime.

Anglerfish: Although the HCR with 10% F reduction brings the *L piscatorius* F to levels of F_{msy} with high probability in 2015 and there is a low risk of biomass decrease along the period, the biomass recovery to B_{msy} is slow. To recover the *L piscatorius* biomass to B_{msy} before 2028 a higher F annual reduction would be required. However, since *L. budegassa* is already exploited below its F_{msy}, the adopted HCR can be seen as a trade-off between recovery of B to B_{msy} for *L. piscatorius* and losses in yield from *L. budegassa*. It is noted that to reduce the combined yield of these stocks to levels of the actual TAC (set for both species combined) it would be necessary to reduce largely the fishing mortality (more than 60%).

Mixed fisheries: The approach used for the mixed fishery analysis assumes that the southern hake is the driving species for the management plan and that no major changes to the fishing activity, in terms of spatial distribution, gear choice and target species occur in the future. The HCR that showed best performance for southern hake was applied to the anglerfish stocks. The results indicate a faster recovery of *L. piscatorius*, the anglerfish stock in poor condition, though at the expense of greater losses of combined yield, in relation to the HCR that showed best performance on a single stock basis.

Although the development of a thorough management plan for southern hake and anglerfish stocks, within the context of the mixed fisheries in the Iberian Peninsula, may require more complex models, the approaches available for this type of analysis are still under development and are not yet available to implement in a routine basis (e.g. Hamon *et al*., 2007; Andersen *et al*., 2010). Nevertheless, it is considered that the results from the simulations carried out in this analysis provide valuable information on species and fleets interactions, upon which a management plan can be based.

In the context of the interactions between stocks and fishing fleets/segments (flowchart; sec 1) and, assuming that the stock of hake is the stock that will control the management (strategy) of the other stocks, the following conclusions can be drawn:

i) Portuguese fleets:

- The Portuguese artisanal fleets (PTA) will be affected by the reduction of fishing mortality in the hake stock, but the impact on the hake, *L. budegassa* and *L. piscatorius* stocks' biomass will be limited due to the low contribution of these fleets to total landings, 9%, 10% and 8%, respectively;
- The Portuguese fish trawl (PTTF) will be affected by the reduction of fishing mortality in the hake stock, but the impact on *Nephrops*, *L. budegassa* and *L. piscatorius* stocks' biomass will be limited due to the low contribution of this fleet to total landings, 14%, 2% and 6%, respectively. The impact on hake´s biomass may be considerable due to the expected reduction of hake discards of small fish, although the contribution of this fleet to the total landings is small, of 9%;

- The reduction of fishing mortality to be applied to the hake stock should not be applied to the fishery of Nephrops on FU 28-29 because the landings of hake from the Portuguese crustacean trawl (PTTC) are negligible (1%) and the *Nephrops* stocks are being exploited below the fishing mortality target;
- The increase of fishing mortality to be applied to *Nephrops* FU 28-29 will have a marginal effect in the stocks of hake, *L. piscatorius and L. budegassa,* because landings of the Portuguese crustacean trawl (PTTC) only represent 1%, 0.3% ,and 2%, respectively;
- The Portuguese artisanal fleet catching *Nephrops* (PTAC) only occasionally is able to catch hake.

ii) Spanish fleets:

- The Spanish gillnet fleets (SPG) will be affected by the reduction of the fishing mortality in the hake stock with (i) low impact on the biomass of hake and *L. budegassa* due to the low landings of these stocks, 12% and 8%, respectively but (ii) with a considerable impact on *L. piscatorius* biomass due to the high landings, 45%;
- The Spanish trawl fleets (SPT8c9a) will be affected by the reduction of the fishing mortality in the hake stock with a major impact on the hake, *L. budegassa* and *L. piscatorius* stocks' biomass due to the high landings of these stocks, 15%, 77% and 47%.
- The Spanish pair trawl fleet (SPPT) will be affected by the reduction of the fishing mortality in the hake stock with a major impact on the hake biomass due to the high landings of this stock, 42%.
- The trawls fleets discard a large volume of small hake, and reducing mortality is expected to improve hake's biomass;
- Regarding the stocks under consideration in the present analysis, the Spanish pair trawl, artisanal and longlines fleets land mainly hake and have no interactions with the stocks of anglerfish and *Nephrops*;
- *L. piscatorius* (the anglerfish species in poor condition) should benefit from the reduction of the fishing mortality in the hake stock since the contribution of the Spanish demersal trawl to the anglerfish catches are high (77% for *L. budegassa* and 47% for *L. piscatorius*) as well as from the gillnets for *L. piscatorius* (45%). However, greater losses on the yield of *L. budegassa* are expected;

The EC requested a proposal for any other effort regime adaptation of the current one and an evaluation of its options (ToR 3). Current effort regime sets an annual 10% reduction of number of fishing days for some selected gears. This can be considered an effective effort control for the fleet/segments using bottom trawl gears. However, as highlighted in SGMOS (2004) report, for static gears (mainly gillnets and trammel nets) the effort control set as number of fishing days may not be effective once the fishing gears can be left fishing while the vessels are in the port.

Additionally, the STECF-SGRST (2008) also emphasized that the use of fishing days (or kW*days) to manage effort of static gears such as gillnets and longlines is a very poor approximation of the effective effort and thus may put at risk the management goals. A possible way to improve the impact of the effort management towards an effective reduction in fishing mortality 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.

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Table 2.1.1 Southern hake: Initial population (mean) and variability (cv) and fishing mortality at age in the start of 2009.

age	0	1	2	3	4	5	6	7	8
nPop	76199	100760	19093	5901	1304	329	114	39	34
cvPop	0.078	0.073	0.073	0.081	0.098	0.133	0.175	0.192	0.274
F	0.107	0.720	1.087	1.032	1.006	0.995	0.990	0.987	0.984

Table 2.1.2 ***a)*** **Natural mortality coefficient and reference points by stock and** ***b)*** **%SPR and %B at the target F.**

a)

Stock	Source	M	F_{2008}	$F_{0.1}$	F_{max}	$F_{35\%SPR}$	F_{msy}
Hake	WGHMM09	0.2	0.52	0.10	0.18		
	WKROUND	0.4	0.91	0.20	0.26		
	this analysis	0.4	0.95	0.18	0.26		
L.pisc	WGHMM09 (1)		0.55				0.35
L.bud	WGHMM09 (1)		0.27				0.44
Nep FU 28-29 M	this analysis	0.3	0.15	0.21	**	0.28	
Nep FU 28-29 F	this analysis	0.2	0.12	0.19	**	0.28	

(1) assessment with Schaefer biomass dynamic model

** F_{max} not well defined (flat-top Y/R curve)

b)

hake

	$F_{0.1}$	F_{max}	M
target F	0.18	0.26	0.40
%SPR	40	29	17

L.pisc

	F_{msy}
target F	0.35
%B(1)	50

Nep FU 28-29 M

	$F_{0.1}$	$F_{35\%SPR}$	M
target F	0.21	0.28	0.30
%SPR	40	35	35

Table 2.4.1 Proportion of landings by fish species, country and fishing gear, 2004-2008.

% Landings by stock and country/gear

species	country	gear	2004	2005	2006	2007	2008	Av 06-08
bud	pt	artisanal	27.5	23.9	10.5	8.6	12.5	10.5
	pt	crust_trawl	2.4	1.4	1.6	2.6	2.2	2.1
	pt	fish_trawl	2.8	2.1	1.9	2.4	2.0	2.1
	pt Total		**32.6**	**27.3**	**13.9**	**13.6**	**16.7**	14.8
	sp	gilnet	12.3	10.8	10.8	5.2	7.4	7.8
	sp	trawl	55.1	61.9	75.3	81.2	75.9	77.5
	sp Total		**67.4**	**72.7**	**86.1**	**86.4**	**83.3**	85.2
bud Total			100.0	100.0	100.0	100.0	100.0	100.0
hke	pt	artisanal	18.8	13.5	10.6	9.6	7.7	9.3
	pt	crust_trawl	1.1	1.2	1.3	0.5	0.6	0.8
	pt	fish_trawl	10.4	10.4	7.2	4.4	5.0	5.5
	pt Total		**30.3**	**25.1**	**19.1**	**14.5**	**13.3**	**15.6**
	sp	artisanal	6.4	8.6	4.5	5.5	6.6	5.5
	sp	gilnet	6.0	7.6	6.6	12.0	15.7	11.5
	sp	LL	1.9	1.1	3.2	5.9	9.0	6.1
	sp	Pair trawl	23.8	33.2	43.8	44.8	37.6	42.1
	sp	Trawl North	16.3	13.7	16.9	13.8	14.5	15.1
	sp	Trawl Cadiz	15.3	10.6	5.9	3.4	3.1	4.1
	sp Total		**69.7**	**74.9**	**80.9**	**85.5**	**86.7**	**84.4**
hke Total			100.0	100.0	100.0	100.0	100.0	100.0
pis	pt	artisanal	10.6	6.7	8.8	8.2	5.4	7.5
	pt	crust_trawl	0.39	0.32	0.44	0.28	0.24	0.3
	pt	fish_trawl	0.46	0.47	0.53	0.26	0.22	0.3
	pt Total		**11.5**	**7.5**	**9.8**	**8.7**	**5.9**	**8.1**
	sp	gilnet	40.2	44.5	42.1	42.9	50.0	45.0
	sp	trawl	48.3	48.0	48.1	48.4	44.1	46.9
	sp Total		**88.5**	**92.5**	**90.2**	**91.3**	**94.1**	**91.9**
pis Total			100.0	100.0	100.0	100.0	100.0	100.0

Table 2.4.2 Proportion of landings by functional unit, by country and gear.

Norway lobster - % landings by FU

FU	division	country	gear	2004	2005	2006	2007	2008	Av 06-08
25	8c	sp	trawl	100	100	100	100	100	100.0
26	9a	sp	trawl	100	100	100	100	100	100.0
27	9a	pt	artisanal	25	38	41	33	36	36.5
	9a	pt	trawl	0	1	0	0	1	0.6
	9a	sp	trawl	75	61	59	66	63	62.9
27 Total				100	100	100	100	100	100.0
28+29	9a	pt	artisanal	7	7	7	8	17	10.3
	9a	pt	crust_trawl	85	85	83	75	70	75.9
	9a	pt	fish_trawl	9	7	10	17	14	13.8
28+29 Total				100	100	100	100	100	100.0
30	9a	pt	crust_trawl	3	1	2	2	4	2.3
	9a	sp	trawl	97	99	98	98	96	97.7
30 Total				100	100	100	100	100	100.0
31	8c	sp	creel	2	3	0	0	0	0.0
	8c	sp	trawl	98	97	100	100	100	100.0
31 Total				100	100	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*

Table 3.1.1 Summary of metrics for hake scenarios (F_{2008} = 0.95 year^{-1}, $Land_{2008}$ =17 th t, SSB_{2008} =12.5 th t). Scenario showing best performance (combination of high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decreasing) is dark shaded.

Scenario	HCR			FtrgYear	P[F2015<Ftrgt]	cumLnd2015	cumLnd2028	ssb2015	ssb2028	f2015	f2028	SSBRiskDec2015	SSBRiskDec2028	P[LndConstr2015]
	Strategy	Target	LndContr											
hke28s.15f0100	Ftrg in 2015	F0.1	None	2015	1.00	68	239	27	81	0.18	0.18	2	8	
hke28s.15f0115			15%	2019	0.00	70		3*		0.97		6		1.00
hke28s.15f0120			20%	2016	0.66	67	235	24	81	0.18	0.18	4	11	0.61
hke28s.15f0125			25%	2015	0.98	68	239	27	81	0.18	0.18	3	9	0.17
hke28s.15f0400		F=M	None	2015	1.00	75	254	18	34	0.40	0.40	3	12	
hke28s.15f0415			15%	2018	0.19	70		3*		0.97		6		0.95
hke28s.15f0420			20%	2015	1.00	73	252	18	34	0.40	0.40	4	13	0.40
hke28s.15f0425			25%	2015	1.00	75	254	18	34	0.40	0.40	3	12	0.07
hke28s.15fmax00		Fmax	None	2015	1.00	71	256	23	57	0.26	0.26	3	10	
hke28s.15fmax15			15%	2019	0.06	70		3*		0.97		6		0.98
hke28s.15fmax20			20%	2015	0.99	70	254	22	57	0.26	0.26	4	12	0.49
hke28s.15fmax25			25%	2015	1.00	71	256	23	57	0.26	0.26	3	10	0.12
hke28s.10df0100	10% red to Ftrg	F0.1	None	2025	0.00	77	229	17	74	0.50	0.18	3	3	
hke28s.10df0115			15%	NA	0.00	72		2*		1.62		6		0.73
hke28s.10df0120			20%	NA	0.00	76	223	14	70	0.56	0.18	4	4	0.28
hke28s.10df0125			25%	2026	0.00	77	229	16	74	0.50	0.18	3	3	0.07
hke28s.10df0400		F=M	None	2018	0.00	77	250	17	34	0.50	0.40	3	10	
hke28s.10df0415			15%	NA	0.00	72		2*		1.62		6		0.73
hke28s.10df0420			20%	2021	0.00	76	244	14	34	0.56	0.40	4	10	0.28
hke28s.10df0425			25%	2018	0.00	77	250	16	34	0.50	0.40	3	10	0.07
hke28s.10dfmax00		Fmax	None	2022	0.00	77	243	17	57	0.50	0.26	3	6	
hke28s.10dfmax15			15%	NA	0.00	72		2*		1.62		6		0.73
hke28s.10dfmax20			20%	2025	0.00	76	236	14	56	0.56	0.26	4	6	0.28
hke28s.10dfmax25			25%	2022	0.00	77	243	16	57	0.50	0.26	3	6	0.07
hke28s.fsq00	Status quo	F2008	None	NA	0.00	77	194	8	8	0.95	0.95	6	19	
hke28s.fsq15			15%	NA	0.00	72		2*		2.00		6		0.63
hke28s.fsq20			20%	NA	0.00	77	193	8	8	0.95	0.95	6	19	0.09
hke28s.fsq25			25%	NA	0.00	77	194	8	8	0.95	0.95	6	19	0.00

* - These scenarios are not realistic. At these levels of SSB the simulated recruitments are unlikely to occur and the stock should have collapsed.

Table 3.2.1a Summary of metrics for *Nephrops* males scenarios (F_{2008} = 0.18 year^{-1}, Y_{2008} =101 t, SSB_{2009} =742 t). Scenarios showing best performance (combination of high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decreasing) are shaded.

Scenario	HCR			Year|F=F_{msy}	P[F_{2015}=F_{msy}]	$Ycum_{2015}$	$Ycum_{2028}$	SSB_{2015}	SSB_{2028}	F_{2015}	F_{2028}	Risk SSB_{2015}	Risk SSB_{2028}	Risk SSB_{2015} (*)	Risk SSB_{2028} (*)
	F target	Tactic	Yield constr.												
15f0115	F0.1	F target in 2015	15%	2017	0.88	1092	3499	1020	1021	0.21	0.21	3	16	0	1
15f0120	F0.1	F target in 2015	20%	2015	0.97	1103	3507	1012	1020	0.21	0.21	3	16	0	0
15f0125	F0.1	F target in 2015	25%	2015	0.99	1108	3510	1009	1020	0.21	0.21	3	16	0	0
15f3515	F35%SPR	F target in 2015	15%	2018	0.74	1196	3799	929	820	0.28	0.28	4	17	2	15
15f3520	F35%SPR	F target in 2015	20%	2016	0.94	1226	3812	902	818	0.28	0.28	4	17	2	15
15f3525	F35%SPR	F target in 2015	25%	2015	0.98	1235	3817	897	818	0.28	0.28	4	17	2	15
10if01	F0.1	10% increase	NA	2015	0.97	1111	3510	1033	1022	0.21	0.21	3	16	0	4
10if0115	F0.1	10% increase	15%	2018	0.82	1092	3499	1015	1022	0.21	0.21	3	16	0	1
10if0120	F0.1	10% increase	20%	2016	0.93	1106	3508	1002	1020	0.21	0.21	3	16	0	0
10if0125	F0.1	10% increase	25%	2015	0.95	1111	3510	994	1020	0.21	0.21	3	16	0	0
10if35	F35%SPR	10% increase	NA	2018	0.73	1222	3811	886	818	0.28	0.28	4	17	2	15
10if3515	F35%SPR	10% increase	15%	2021	0.45	1174	3790	944	821	0.27	0.28	4	17	1	14
10if3520	F35%SPR	10% increase	20%	2019	0.61	1207	3806	909	819	0.28	0.28	4	17	2	15
10if3525	F35%SPR	10% increase	25%	2018	0.69	1218	3809	893	818	0.28	0.28	4	17	2	15
fsq	Fsq	NA	NA	NA	NA	1042	3304	1056	1103	0.18	0.18	3	16	0	0
fsq15	Fsq	NA	15%	NA	NA	1029	3262	1069	1134	0.17	0.17	3	16	0	0
fsq20	Fsq	NA	20%	NA	NA	1040	3294	1059	1108	0.18	0.18	3	16	0	0
fsq25	Fsq	NA	25%	NA	NA	1041	3302	1056	1105	0.18	0.18	3	16	0	0

(*) SSB risk decrease was calculated with a tolerance of 10% to disregard small fluctuations.

Table 3.2.1b Summary of metrics for *Nephrops* females scenarios (F_{2008} = 0.13 year^{-1}, Y_{2008} =66 t, SSB_{2009} =844 t). Scenarios showing best performance for males (Table 3.2.1.a) are shaded.

Scenario	HCR			Year|F=F_{msy}	P[F_{2015}=F_{msy}]	$Ycum_{2015}$	$Ycum_{2028}$	SSB_{2015}	SSB_{2028}	F_{2015}	F_{2028}	Risk SSB_{2015}	Risk SSB_{2028}	Risk SSB_{2015} (*)	Risk SSB_{2028} (*)
	F target	Tactic	Yield constr.												
15f0115	F0.1	F target in 2015	15%	NA	0.07	695	2136	961	961	0.15	0.15	1	9	0	0
15f0120	F0.1	F target in 2015	20%	NA	0.07	695	2136	961	961	0.15	0.15	1	9	0	0
15f0125	F0.1	F target in 2015	25%	NA	0.07	695	2136	961	961	0.15	0.15	1	9	0	0
15f3515	F35%SPR	F target in 2015	15%	NA	0.03	788	2418	898	815	0.20	0.20	4	17	0	0
15f3520	F35%SPR	F target in 2015	20%	NA	0.03	795	2422	892	815	0.20	0.20	4	17	0	0
15f3525	F35%SPR	F target in 2015	25%	NA	0.03	795	2422	892	815	0.20	0.20	4	17	0	0
10if01	F0.1	10% increase	NA	NA	0.07	714	2148	944	960	0.15	0.15	1	6	0	0
10if0115	F0.1	10% increase	15%	NA	0.07	703	2140	953	961	0.15	0.15	1	8	0	0
10if0120	F0.1	10% increase	20%	NA	0.07	710	2145	948	960	0.15	0.15	1	6	0	0
10if0125	F0.1	10% increase	25%	NA	0.07	712	2146	946	960	0.15	0.15	1	6	0	0
10if35	F35%SPR	10% increase	NA	NA	0.03	811	2429	874	816	0.20	0.20	4	17	0	0
10if3515	F35%SPR	10% increase	15%	NA	0.02	765	2407	918	815	0.19	0.20	3	16	0	0
10if3520	F35%SPR	10% increase	20%	NA	0.03	793	2421	893	815	0.20	0.20	4	17	0	0
10if3525	F35%SPR	10% increase	25%	NA	0.03	806	2427	879	815	0.20	0.20	4	17	0	0
fsq	Fsq	NA	NA	NA	NA	658	2012	987	1025	0.13	0.13	1	1	0	0
fsq15	Fsq	NA	15%	NA	NA	658	2012	987	1025	0.13	0.13	1	1	0	0
fsq20	Fsq	NA	20%	NA	NA	658	2012	987	1025	0.13	0.13	1	1	0	0
fsq25	Fsq	NA	25%	NA	NA	658	2012	987	1025	0.13	0.13	1	1	0	0

(*) SSB risk decrease was calculated with a tolerance of 10% to disregard small fluctuations.

Table 3.2.1c Summary of metrics for *Nephrops* scenarios for Males+Females (Y_{2008} =167 t, SSB_{2009} =1586 t). Scenarios showing best performance for males (Table 3.2.1.a) are shaded.

Scenario	HCR			$Ycum_{2015}$	$Ycum_{2028}$	SSB_{2015}	SSB_{2028}
	F target	Tactic	Yield constr.				
15f0115	F0.1	F target in 2015	15%	1787	5635	1981	1982
15f0120	F0.1	F target in 2015	20%	1799	5643	1973	1981
15f0125	F0.1	F target in 2015	25%	1803	5647	1970	1981
15f3515	F35%SPR	F target in 2015	15%	1984	6217	1828	1635
15f3520	F35%SPR	F target in 2015	20%	2021	6235	1794	1633
15f3525	F35%SPR	F target in 2015	25%	2030	6240	1789	1633
10if01	F0.1	10% increase	NA	1825	5659	1978	1982
10if0115	F0.1	10% increase	15%	1795	5639	1968	1982
10if0120	F0.1	10% increase	20%	1816	5653	1950	1981
10if0125	F0.1	10% increase	25%	1823	5657	1939	1981
10if35	F35%SPR	10% increase	NA	2034	6239	1760	1634
10if3515	F35%SPR	10% increase	15%	1940	6198	1862	1636
10if3520	F35%SPR	10% increase	20%	2001	6227	1802	1634
10if3525	F35%SPR	10% increase	25%	2024	6236	1772	1633
fsq	Fsq	NA	NA	1700	5316	2043	2128
fsq15	Fsq	NA	15%	1687	5274	2056	2159
fsq20	Fsq	NA	20%	1698	5306	2046	2133
fsq25	Fsq	NA	25%	1699	5314	2043	2130

Table 3.3.1 Summary of metrics for *L. piscatorius* scenarios (F_{2008} = 0.55 year^{-1}, B_{2009} = 4410 t, Y_{2008} = 2337 t) and for *L. budegassa* scenarios (F_{2008} = 0.27year^{-1}, B_{2009} = 4187 t, Y_{2008} = 951 t). Scenario showing best performance (combination of high probability of achieving F_{msy} by 2015, high cumulative yield and low risk of SSB decreasing) is shaded.

Scenario	Species	HCR			Year|F=F_{msy}	P[F_{2015}=F_{msy}]	$Ycum_{2015}$	$Ycum_{2028}$	B_{2015}	B_{2028}	F_{2015}	F_{2028}	Risk B_{2015}	Risk B_{2028}
		F target	Tactic	Yield constr.										
15fmsy15	*L. piscatorius*	Fmsy	F target in 2015	15%	2015	1.00	19189	81194	9489	16031	0.34	0.34	3	3
	L. budegassa				2009	0.98	10908	32981	8560	9129	0.19	0.19	0	0
	total						30097	114175						
10dfmsy15	*L. piscatorius*	Fmsy	10% decrease	15%	2018	0.80	19175	82035	10477	16041	0.35	0.34	3	3
	L. budegassa				2009	0.98	10700	32790	8674	9129	0.19	0.19	0	0
	total						29875	114826						
status quo	*L. piscatorius*	Fmsy	status quo	0%	NA	0.07	20080	67228	6831	8206	0.48	0.48	6	19
	L. budegassa				2009	0.94	12791	40981	7784	7983	0.27	0.27	0	0
	total						32872	108209						

L. piscatorius: F_{msy} = 0.35, B_{msy} 16330 t.

L. budegassa: F_{msy} = 0.44, B_{msy} 5813 t.

Table 3.4.1 Summary of metrics for anglerfish from the mixed fishery approach.

Scenario	Species	HCR			Year|F=F_{msy}	P[F_{2015}=F_{msy}]	$Ycum_{2015}$	$Ycum_{2028}$	B_{2015}	B_{2028}	F_{2015}	F_{2028}	Risk B_{2015}	Risk B_{2028}
		F target	Tactic	Yield constr.										
Hake -15fmax20	*L. piscatorius*		Hake		2015	1.00	15568	55125	12176	25616	0.13	0.13	4	4
	L. budegassa				2009	1.00	8713	18670	9504	10613	0.07	0.07	0	9
	total						24210	74090						

Figure 2.1.1 - Hake comparison between WKROUND and this analysis

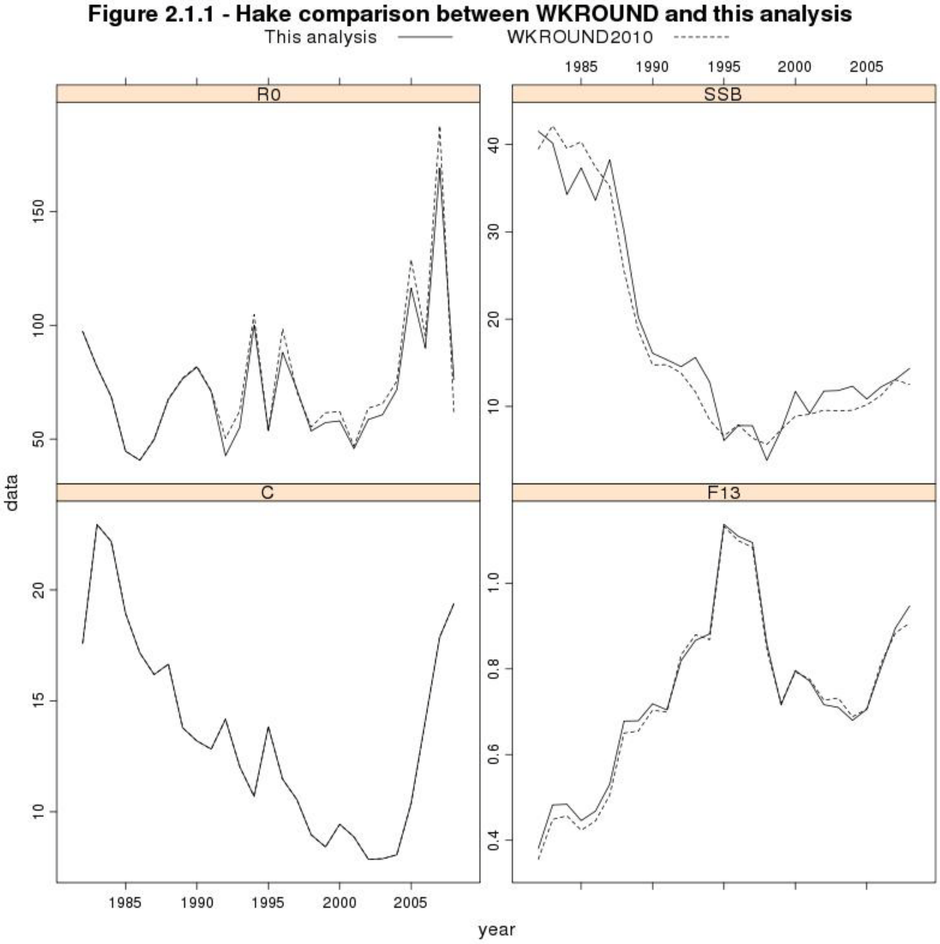
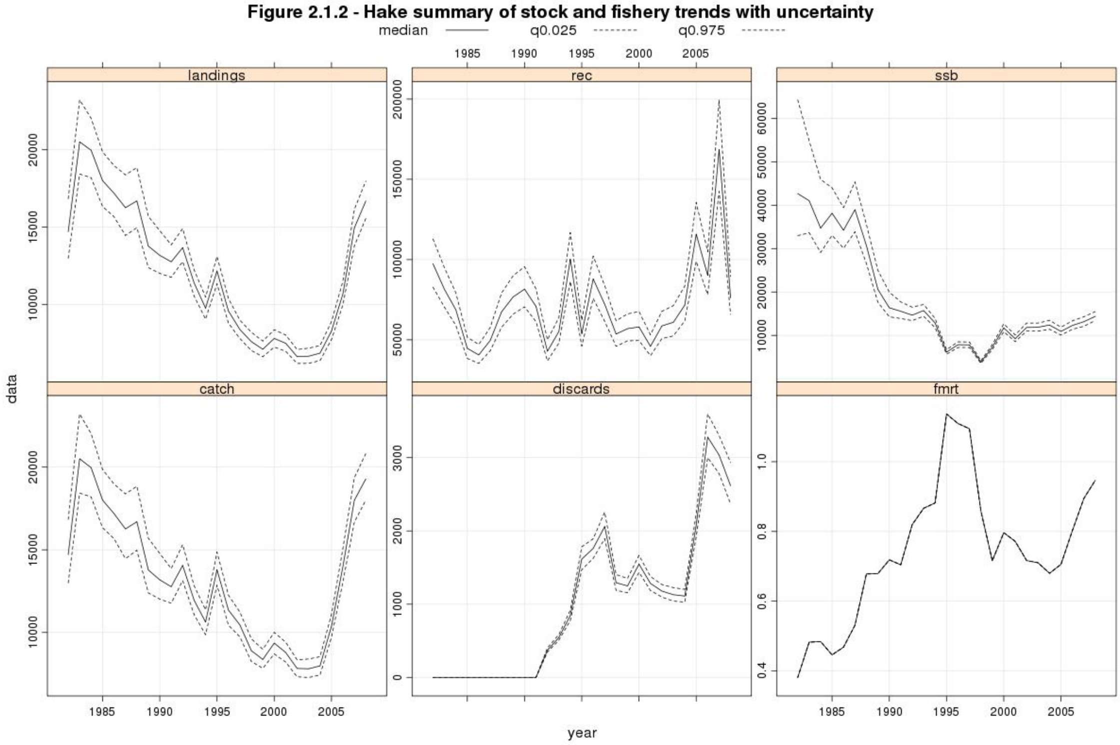


Figure 2.1.2 - Hake summary of stock and fishery trends with uncertainty



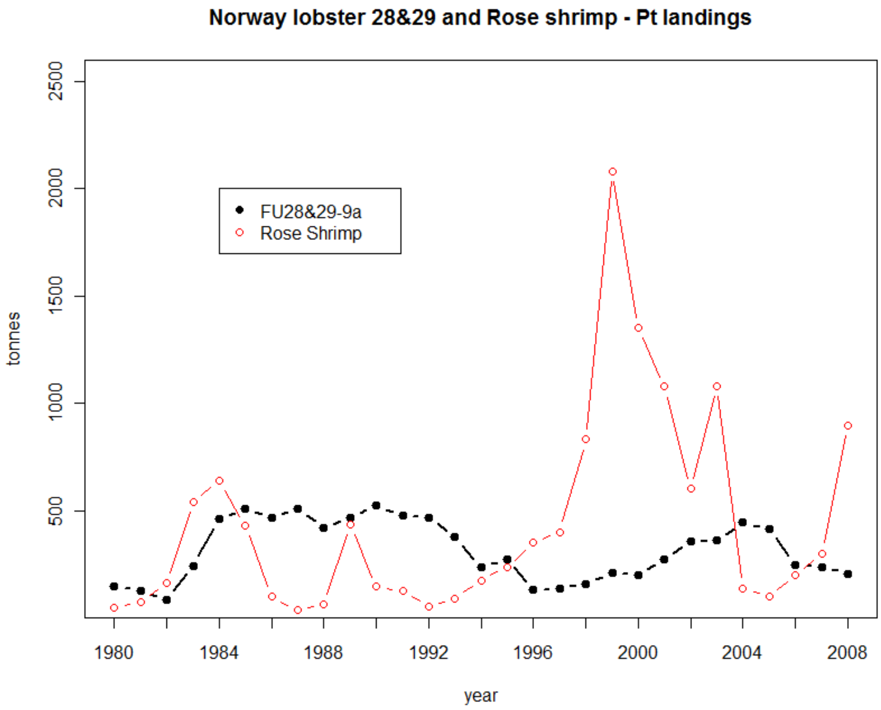


Figure 2.2.1 Portuguese landings of *Nephrops* and rose shrimp in FU 28-29 for the period 1980 to 2008.

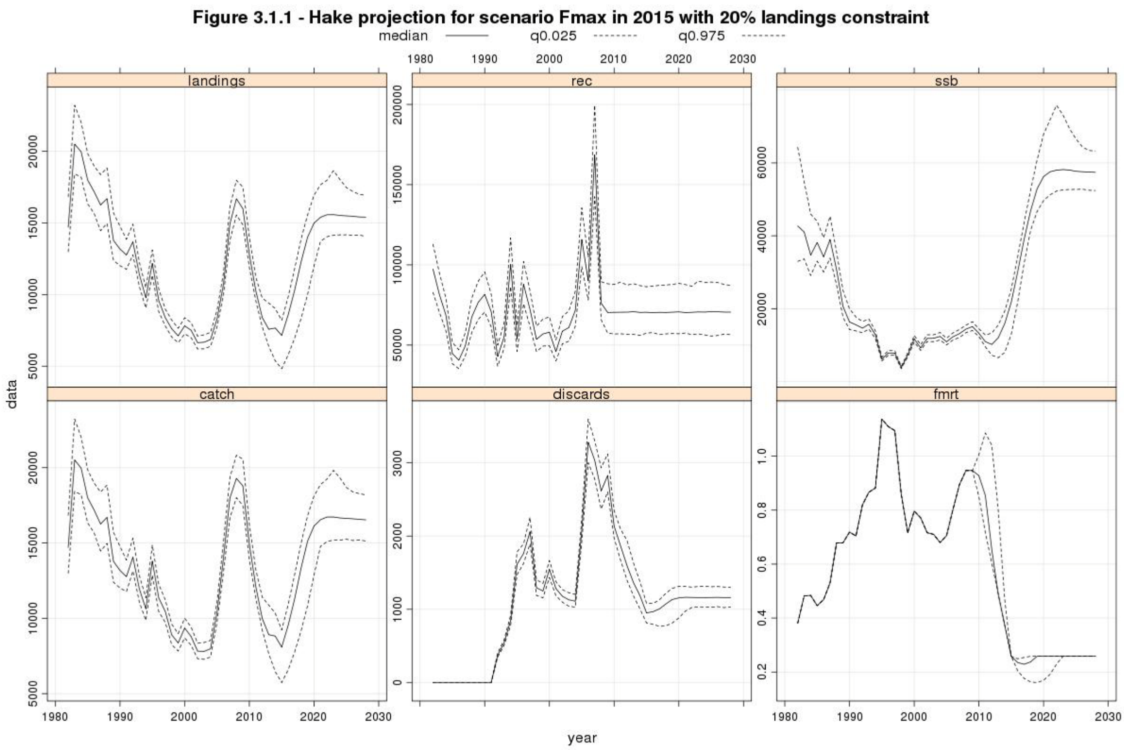
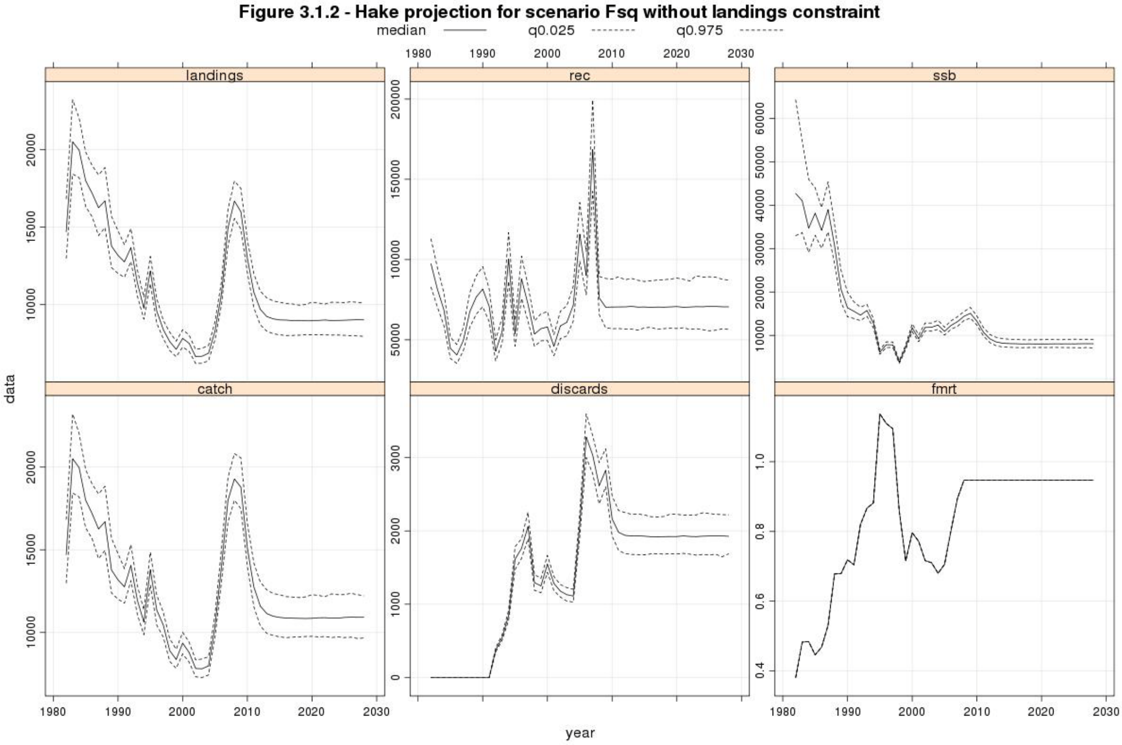


Figure 3.1.2 - Hake projection for scenario Fsq without landings constraint



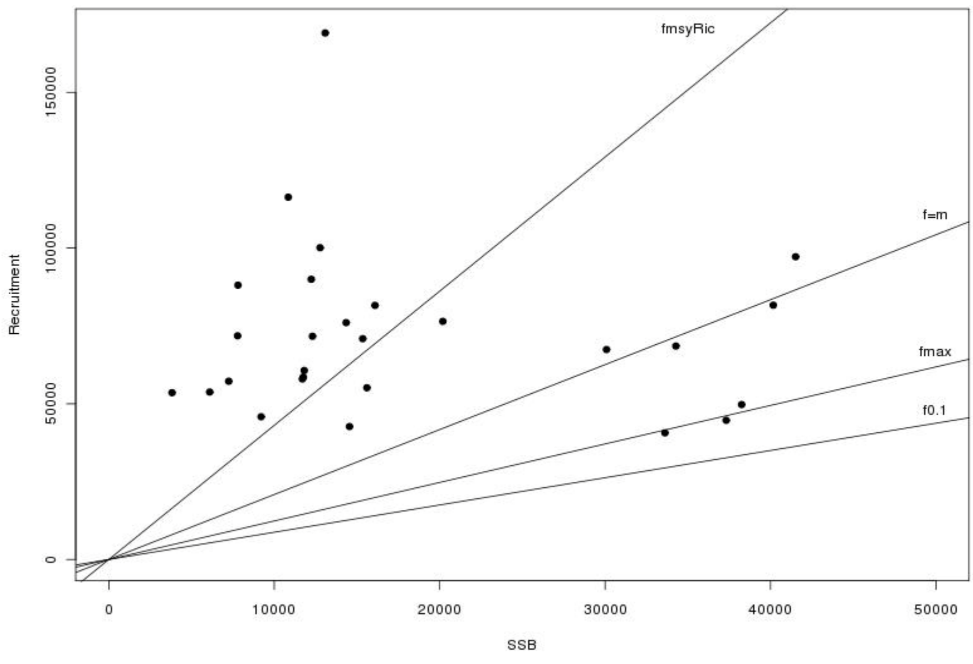


Figure 3.1.3 Hake S-R plot and replacement lines for target F. The replacement line for F_{msy} based on a Ricker model is additionally plotted.

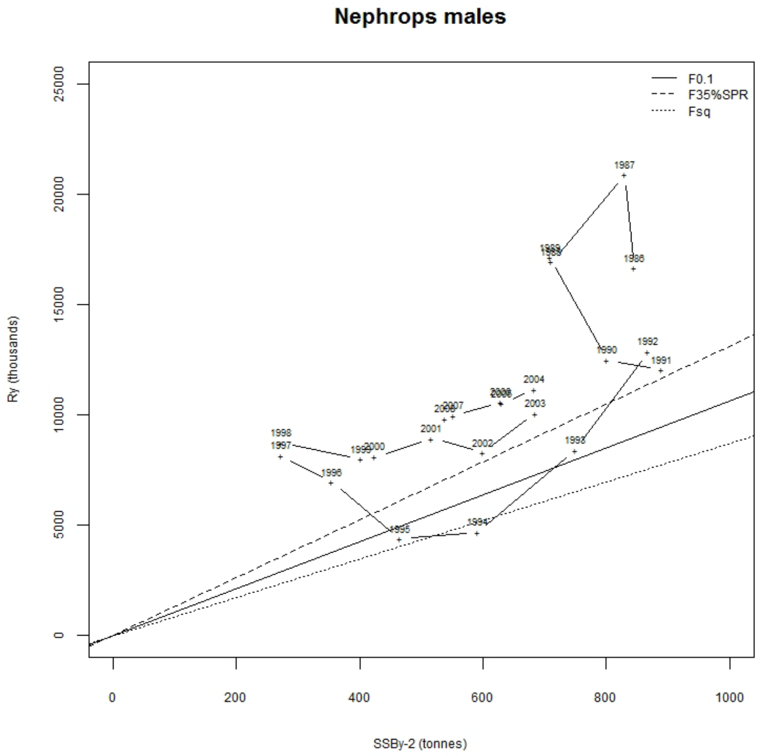


Figure 3.2.1a S-R plot and replacement lines for target F of *Nephrops* males.

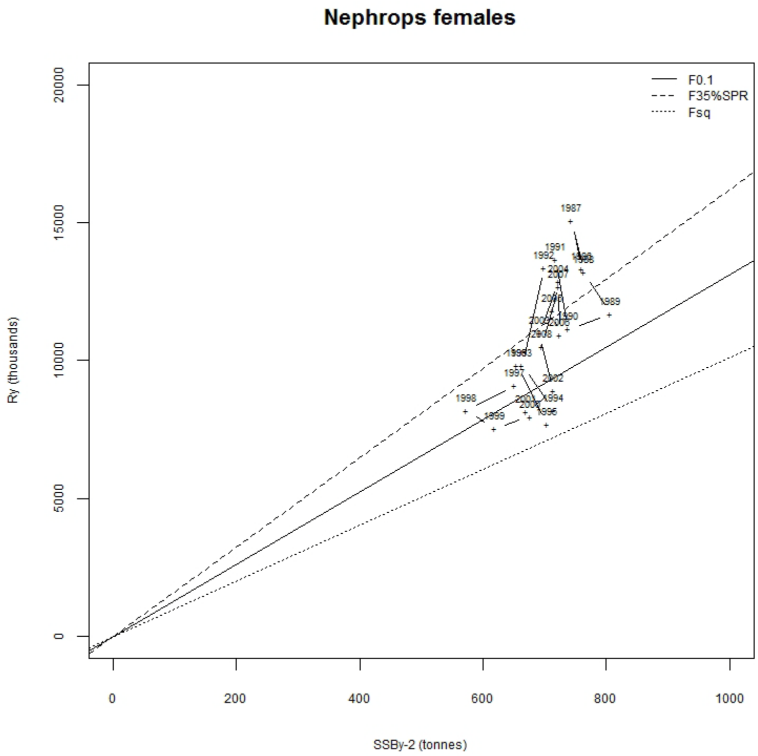


Figure 3.2.1b S-R plot and replacement lines for target F of *Nephrops* females.

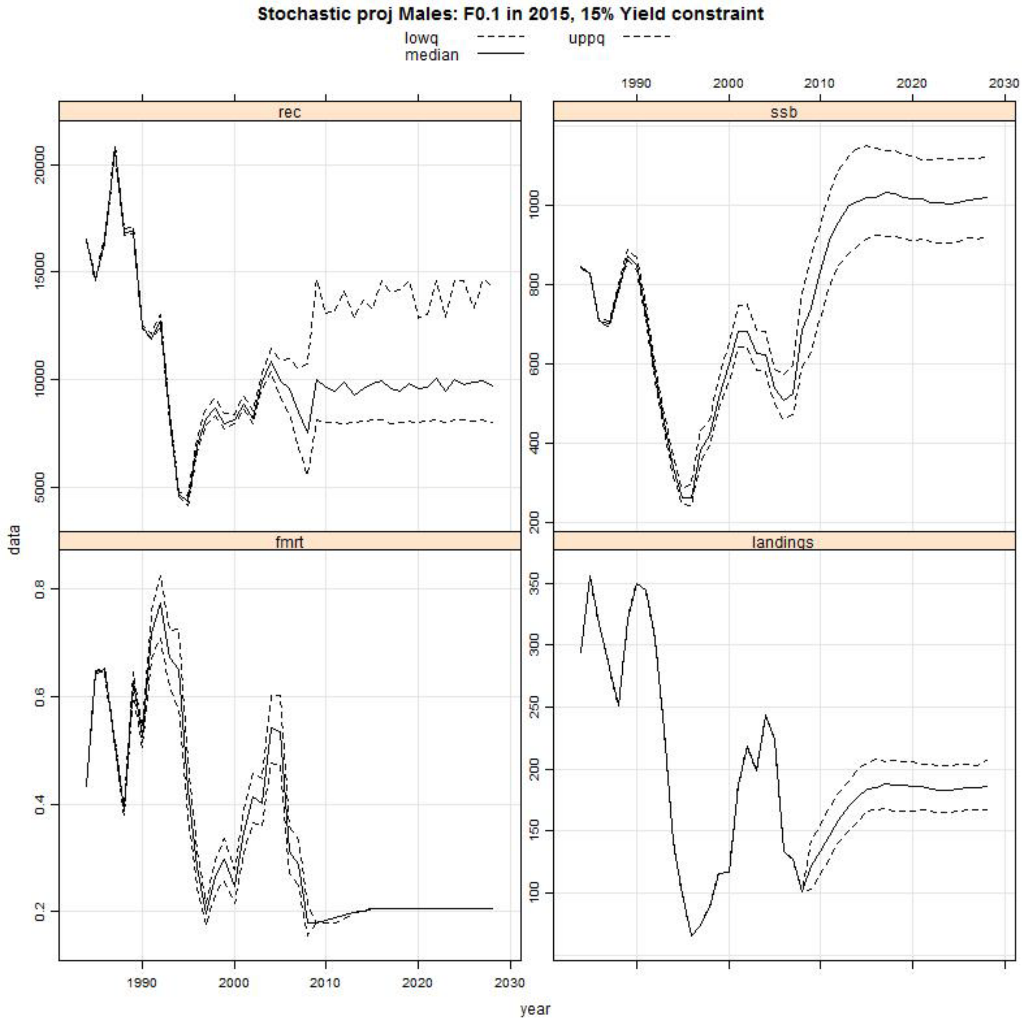


Figure 3.2.2a *Nephrops* FU 28-29, Males. HCR: F_{2015}=F_{msy} ($F_{0.1}$), 15% Yield constraint.

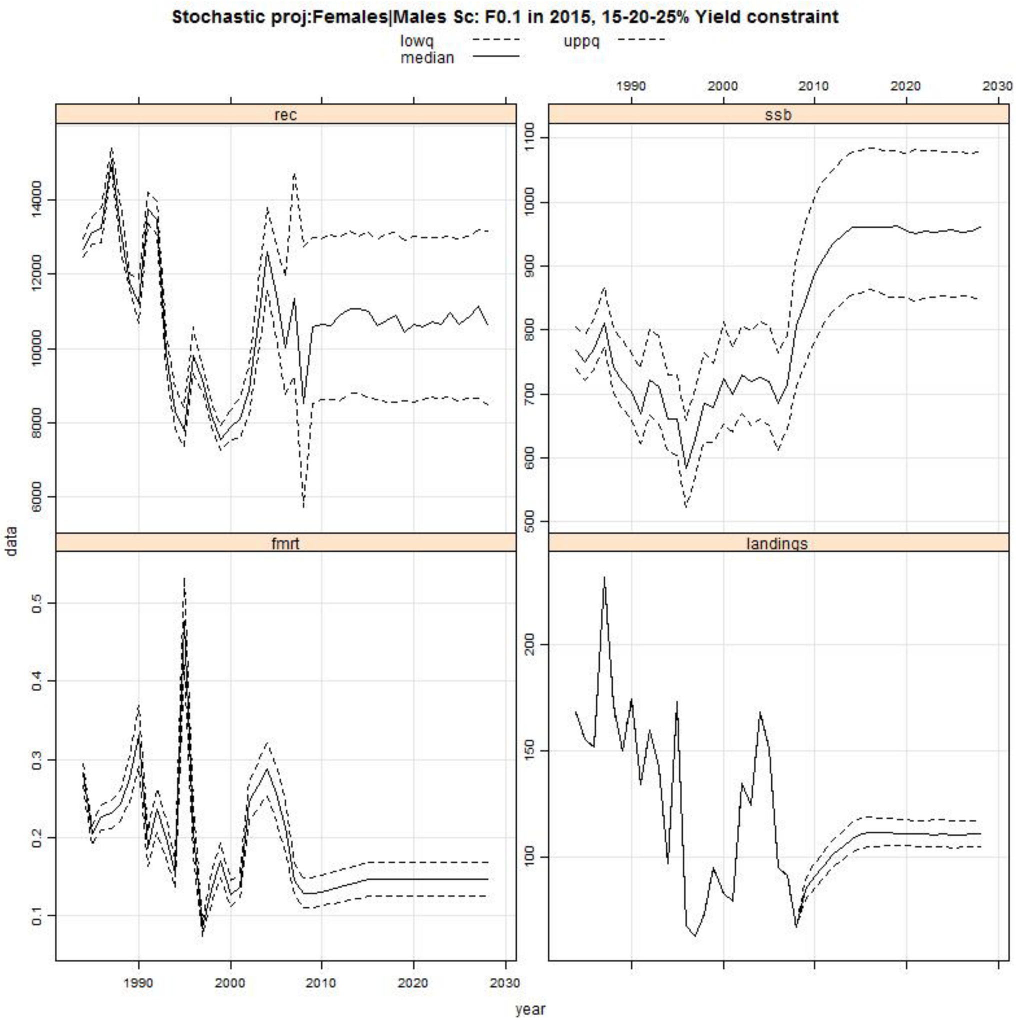


Figure 3.2.2b ***Nephrops*** **FU 28-29, Females, conditional on Males HCR: F_{2015}=F_{msy} ($F_{0.1}$), 15% Yield constraint.**

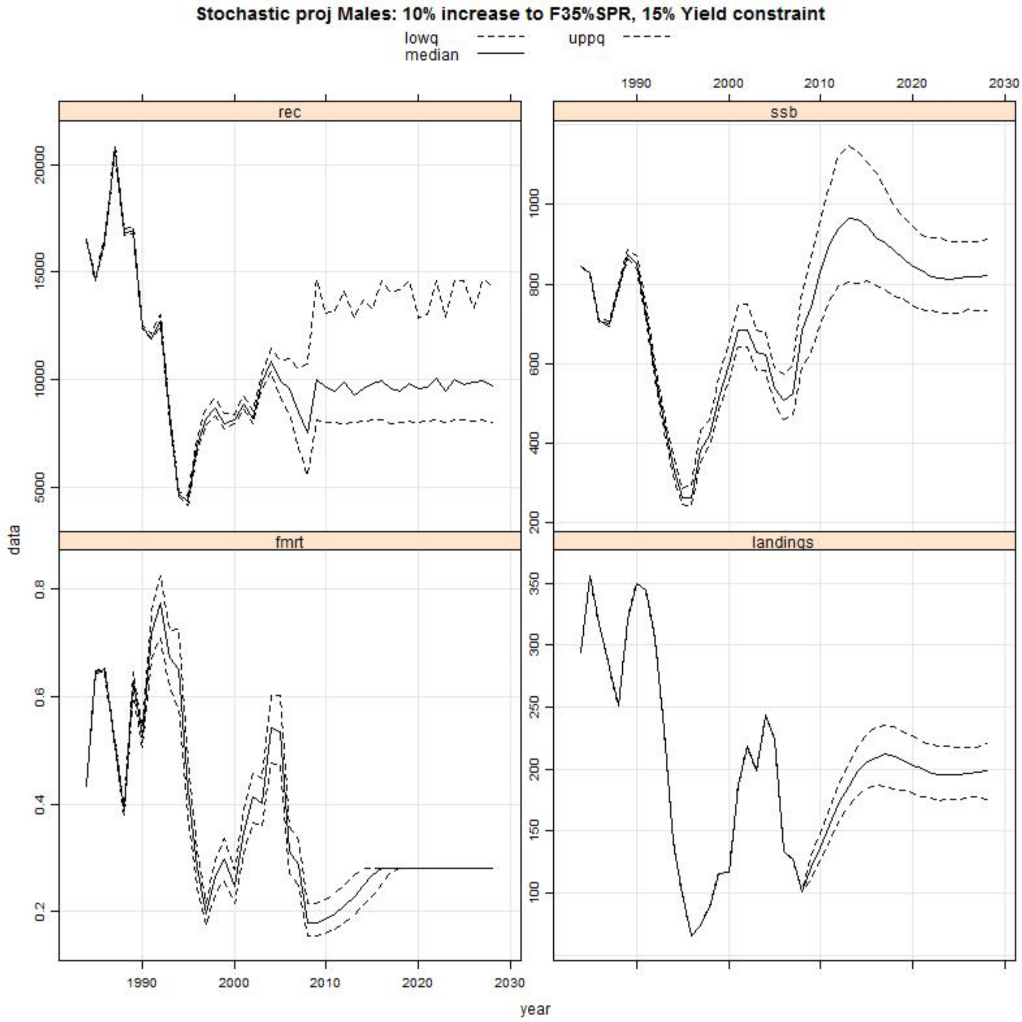


Figure 3.2.3a ***Nephrops*** **FU 28-29, Males, HCR: 10% increase in F to F_{msy} ($F_{0.1}$), 15%Yield constraint.**

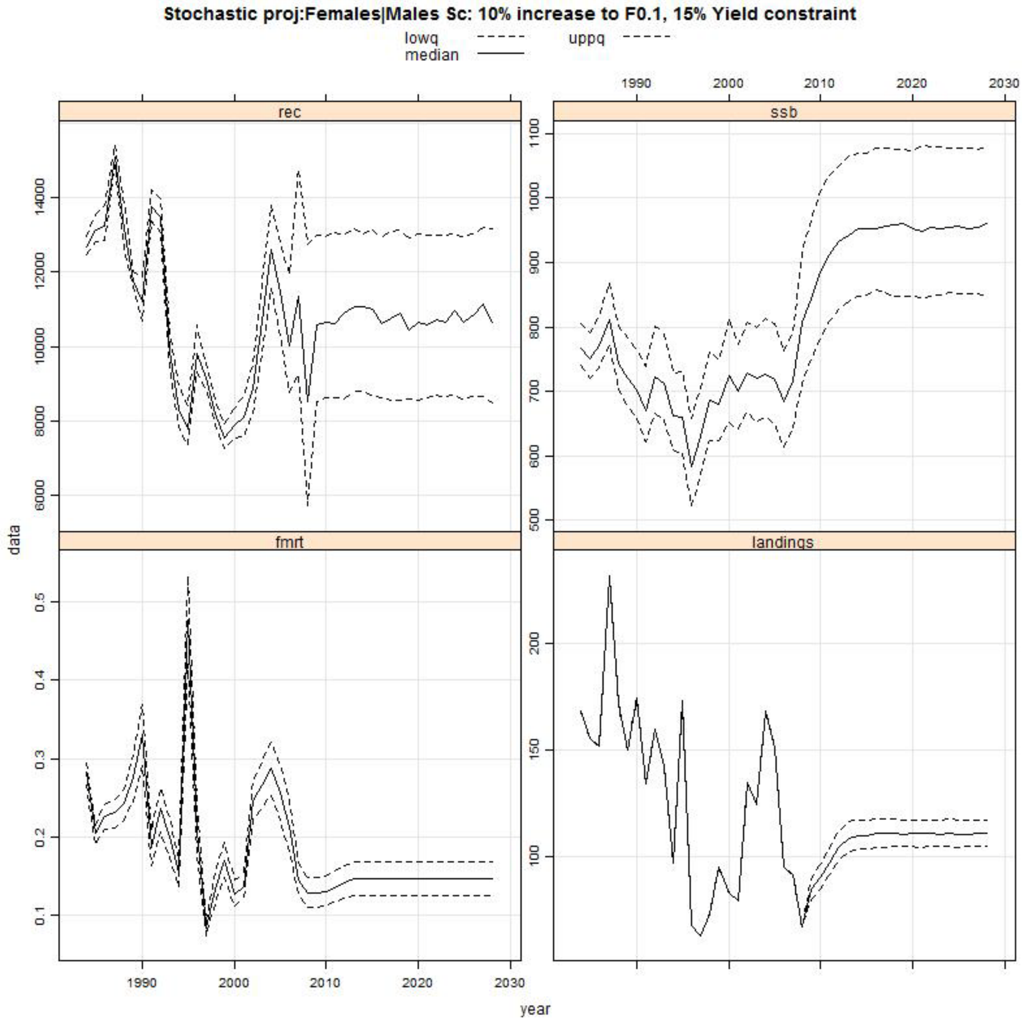


Figure 3.2.3b ***Nephrops*** **FU 28-29, Females, conditional on Males HCR: 10% increase in F to $F_{msy}(F_{0.1})$, 15%Yield constraint.**

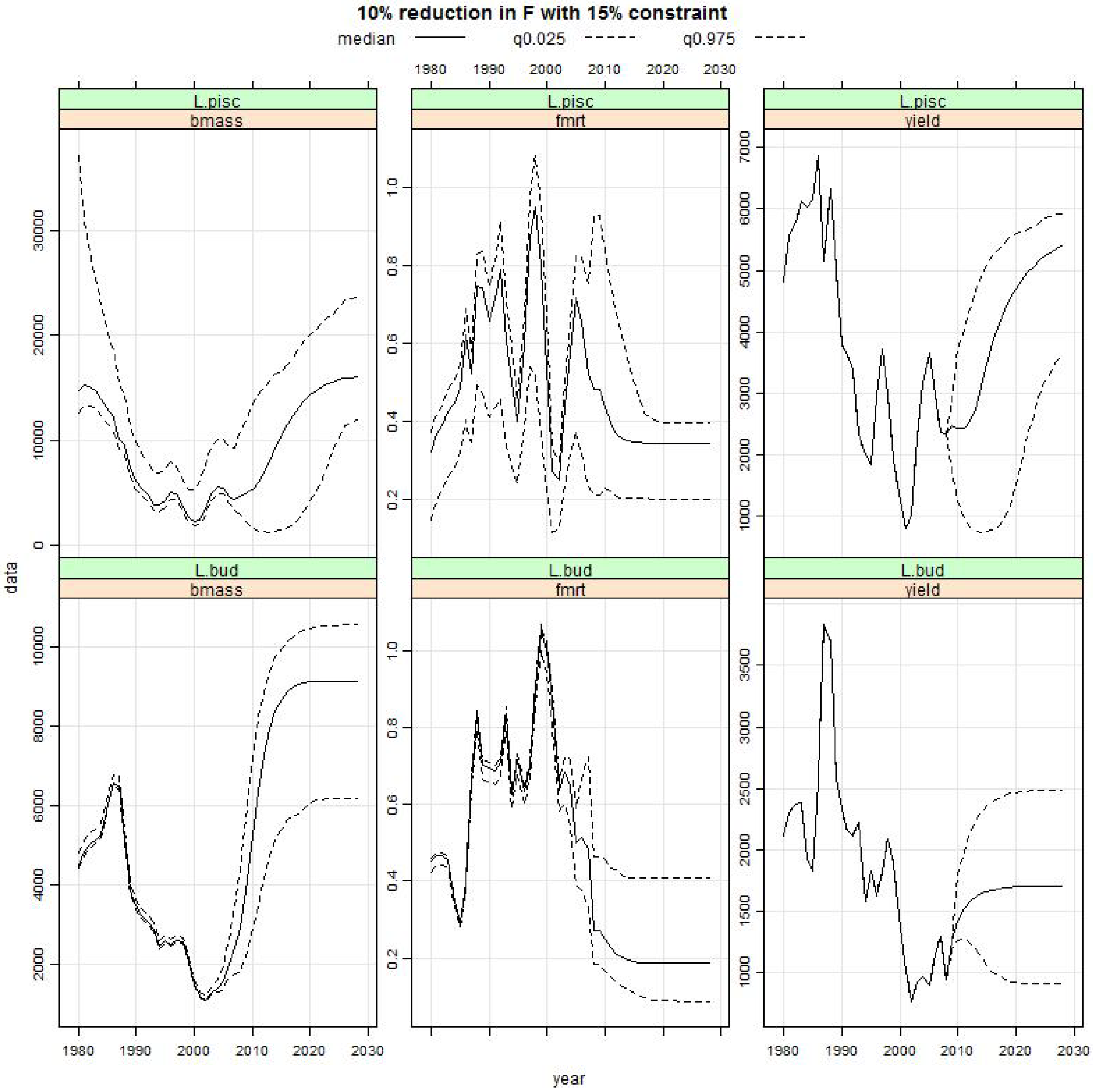


Figure 3.3.1 Projections (2009-2028) for anglerfish with HCR: 10% decrease in F till $F=F_{msy}$ with 15% yield constraint (assessment period: 1980-2008).

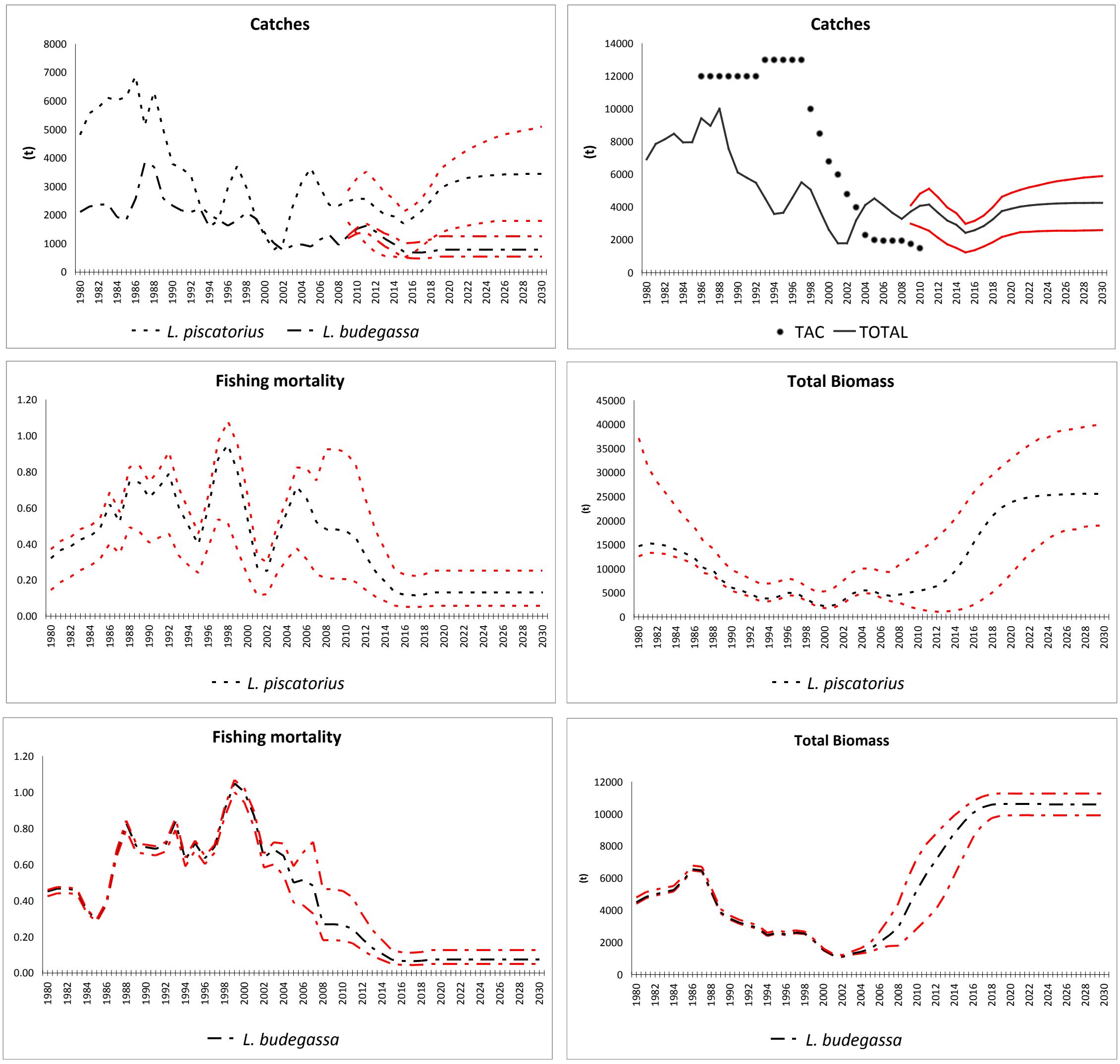


Figure 3.4.1 Results for anglerfish from the mixed fishery approach (assessment period: 1980-2008).

5 Review of ICES INRB-IPIMAR Report / Bay of Biscay Advice 2010

Review Group Technical Minutes

Review of ICES INRB-IPIMAR Report 2010 *25-31 May 2010*

Reviewers:	Mark Dickey-Collas	Netherlands (chair)
	Cecilie Kvamme	Norway
	David Miller	Netherlands
Secretariat:	Cristina Morgado	ICES

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

The report presents an attempt to test for the most suitable HCR rule to be applied in the Iberian mixed fishery for hake, anglerfish and *Nephrops* to achieve Fmsy goals by 2015. The approach taken tries to cut through the complexity of the issue with some simplifying assumptions and single species projections instead of a full feedback, multispecies management strategy evaluation (MSE).

The simulations are essentially long term projections of the currently accepted assessments for the stocks of interest, assuming constant recruitment. Mixed fishery interactions, selectivity of the fleets and weights at age are all assumed to remain equal to the 2006-2008 mean values. While uncertainty in initial starting numbers of the stock is considered (hake: based on past variability in numbers at age; *Nephrops*: bootstrapping index residuals, anglerfish: ASPIC bootstrap runs), no alternative hypotheses on stock status or dynamics are evaluated and consideration of future process error (biological and fishery) is limited. A small CV (10%) on future recruitment of hake is used, but this likely underestimates potential future variation in recruitment. It is not clear if any future variability in recruitment is considered for the other two stocks. In the case of *Nephrops*, only 1 functional unit was considered to have an adequate assessment on which to project the stock (and even this assessment was considered by the working group to be indicative of trends only). All this brings into question how robust this analysis can be considered to be.

However, despite the concerns over the robustness of the evaluation, taken as a 'projection-analysis' of the current perceptions of the stocks, the evaluation has been clearly and methodically preformed. The authors have attempted to evaluate the mixed fishery concerns by simply seeing the effect of the proposed 'best' HCR for hake on the most vulnerable of the other stocks given assumptions on the interaction between fleets and stocks under analysis. This is a significant simplification but does in theory effectively assess what the 'maximum harm' caused by the proposed HCR would be. There has been a good examination of possible Fmsy proxies and the impact of different levels of TAC constraint. i.e. the HCR part and the target part is well evaluated, but the underlying stock and fishery dynamics on which these are tested are over-simplifications of the likely uncertainty in the system.

The methods, results and conclusions are generally well presented, clearly explained and transparent. Some of the performance results could have been presented in figure form to allow easier comparison between runs. The main concerns with this evaluation is whether the simplifications are justified (especially with regards to the *Nephrops*) and whether the level of uncertainty in stock dynamics, biological and fishery process error and mixed fishery dynamics still allow the results to be considered robust to likely uncertainty in this system. In addition, by not considering potential TAC overshoots (which appear common in these fisheries), conclusions on the probability of achieving Fmsy by 2015 or about absolute levels of SSB or yield cannot be drawn. Applying just a landings constraint only allows for a relative comparison of potential HCRs.

Given the lack of consideration for future uncertainty, variability (in recruitment and growth) and alternative stock/fishery dynamics scenarios, these results may be inadequate to confidently address TORs 1 and 2 of the request to ICES. A proposal has been made to improve the current effort management regime in response to TOR 3.

Annotations to the report of the evaluations are available.