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# ANALYSIS OF THE POTENTIAL IMPACT OF SEVERAL MANAGEMENT MEASURES FOR EASTERN ATLANTIC BLUEFIN TUNA ON THE BASIS OF YIELD PER RECRUIT*

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*SUMMARY*

*A standard yield per recruit (YPR) analysis is used to analyse the effects of minimum size regulations and time area closures on bluefin tuna from the eastern stock (east Atlantic and Mediterranean). Analyses were based on a fishing mortality vector computed over the period 1990-1994 for which data were more reliable and VPA (performed during the 2002 stock assessment) showed a relatively good convergence. This fishing mortality vector was modified according to some combinations of minimum size regulations and time area closures. It is concluded that: (i) PSmed is the main contributor to catch at age in the range of ages 1-13; (ii) The minimum size regulations considered would increase the YPR more than the time area closures, but these would enhance SPR more than minimum size regulations; (iii) Closing the Mediterranean has a bigger impact on both YPR and SPR than closing the east Atlantic, given that the majority of the catch occurs there; (iv) under some scenarios, some fleets could increase their long term YPR over 100%. On the other hand, some fleets would reduce their short term yield to near 30% with respect their equilibrium yield before implementing the measures discussed in this document.*

*RÉSUMÉ*

*Une analyse de la production par recrue (YPR) standard a été utilisée afin d'analyser les effets des réglementations de taille minimale et des fermetures spatio-temporelles sur le thon rouge du stock de l'Est (Atlantique Est et Méditerranée). Les analyses se basaient sur un vecteur de mortalité par pêche calculé sur la période 1990-1994, période pour laquelle les données étaient plus fiables et pour laquelle la VPA (réalisée durant l'évaluation du stock de 2002) présentait une convergence relativement satisfaisante. Ce vecteur de mortalité par pêche a été modifié selon certaines combinaisons de réglementations de taille minimale et de fermetures spatio-temporelles. Les conclusions sont les suivantes: (i) PSmed est l'engin ayant contribué le plus à la prise par âge dans la gamme des âges 1-13; (ii) les réglementations de taille minimale considérées accroîtraient plus la YPR que les fermetures spatio-temporelles mais ces dernières amélioreraient plus le SPR que les réglementations de taille minimale; (iii) la fermeture de la Méditerranée aurait un plus grand impact sur la YPR et le SPR que la fermeture de l'Atlantique Est, étant donné que la majorité des prises y sont réalisées; (iv) dans le cadre de certains scénarios, certaines flottilles pourraient accroître leur YPR à long terme de plus de 100%. Par ailleurs, certaines flottilles réduiraient leur production à court terme de près de 30% par rapport à leur production en conditions d'équilibre avant la mise en œuvre des mesures discutées dans le présent document.*

*RESUMEN*

*Se utiliza un análisis estándar de rendimiento por recluta (YPR) para analizar los efectos de las regulaciones de talla mínima y de las vedas espacio-temporales sobre el atún rojo del stock*

* *Following the initial submission of this document, the 2006 Bluefin Tuna Species Group carried out computations based on the approach presented here, but using improved datasets. Thus, the conclusions derived from the assessment may differ somewhat from those presented here. Nevertheless, the authors decided to publish this paper in order to make a detailed description of the method used permanently available.

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*oriental (Atlántico este y Mediterráneo). Los análisis se basaron en un vector de mortalidad por pesca calculado para el periodo 1990-1994, para el que los datos eran más fiables y el VPA (realizado durante la evaluación de stock de 2002) mostraba una convergencia relativamente buena. Este vector de mortalidad por pesca fue modificado de acuerdo con algunas combinaciones de regulaciones de talla mínima y vedas espacio-temporales. Se concluyó que: (i) PSmed es el principal contribuyente a la captura por edad en el rango de edades 1-13; (ii) las regulaciones de talla mínima consideradas aumentarían el YPR más que las vedas espacio-temporales, pero estas mejorarían el SPR más que las regulaciones de talla mínima; (iii) establecer vedas en el Mediterráneo tiene un mayor impacto tanto en el YPR como en el SPR que establecerlas en el Atlántico este, dado que la mayoría de las capturas se producen en el Mediterráneo; (iv) bajo algunos escenarios, algunas flotas podrían aumentar su YPR a largo plazo por encima del 100%. Por otra parte, algunas flotas reducirían sus rendimientos a corto plazo hasta cerca del 30% con respecto a su rendimiento en equilibrio antes de implementar las medidas debatidas en este documento.*

*KEYWORDS*

*Yield/recruit, yield predictions, size limit regulations, time-area closures, bluefin tuna*

## 1. Introduction

Following the recommendations of the 3rd Meeting for Bluefin Tuna Research (Madrid, June 2005) (ICCAT, 2006), some preliminary analyses on the effects of minimum size regulations on Yield-per-Recruit (YPR) and Spawner-per-Recruit (SPR) were conducted in 2005 (Restrepo *et al.*, 2006), and it was suggested that the approach could be extended to test additional combinations of minimum size and time area closure scenarios. This document presents preliminary results of analyses on the effects of some combinations of minimum size regulations and time area closures for the East Atlantic bluefin tuna (East Atlantic and Mediterranean), for consideration of the BFT species group.

## 2. Materials and methods

Participants at the June 2005 planning meeting agreed that the selectivity pattern should be computed over a period for which SCRS has more confidence and more detailed Task II data. The meeting agreed that the early 1990s would be a reasonable baseline because this time period was just prior to the first quota implementation and the beginning of farming, and it is also a time period with relatively good convergence of the VPA. Following Restrepo *et al.* (2006) we used the period 1990-1994 as a reference, where a single minimum size regulation [Rec. 94-11] was in place.

The YPR and SPR analyses presented here are based on the fishing mortality pattern as inferred from the last stock assessment of the Eastern Atlantic and Mediterranean bluefin tuna stock (ICCAT, 2003). Nine fishing mortality patterns were considered, as explained below. Case 1 corresponds to the fishing mortality pattern realized in 1990-1994, a period when size limit regulations were not as restrictive as nowadays. Other scenarios were considered with different minimum size regulations and time area closures, assuming perfect implementation of the different management measures and that fishing effort is not redistributed to other areas outside the time area closure, as follows:

| *Case* | *Management Measure* |
|---|---|
| 1 | Base Case |
| 2 | Protect age 1 |
| 3 | Protect age 2 |
| 4 | Close the Mediterranean in June-July |
| 5 | Close the East Atlantic and Mediterranean in June-July |
| 6 | Protect age 1 and close the Mediterranean in June-July |
| 7 | Protect age 1 and close the East Atlantic and Mediterranean in June-July |
| 8 | Protect age 2 and close the Mediterranean in June-July |
| 9 | Protect age 2 and close the East Atlantic and Mediterranean in June-July |

Additionally, the short and medium term effects of the different management measures on the yield per recruit where analysed. Fleet specific effects where computed using the new fleet, area and time specific catch ratios, following the new substitution rules adopted in (ICCAT, 2005). The following main groups of gears were considered (the acronyms used and the average catch over the last 10 years, as an indicator of their importance, are given within brackets): purse seine Mediterranean (PSmed, 17017 MT), longline Mediterranean (LLmed, 3627 MT), others Mediterranean (OTmed, 3549 MT), longline east (LLeast, 3237 MT), baitboat east (BBeast, 2224 MT), others east (OTeast, 3175 MT).

### *2.1 Formulations*

The following equations provide details about the computations, where *a* is the age, *y* the year, *g* the gear and *c* the Case selection pattern examined:

$$\overline{F}_a = \frac{\sum_{1990}^{1994} F_{y,a}}{6}$$ Average fishing mortality vector for the 1990-1994 period.

${}^{c}T_a$ Selectivity multiplier for each case (*c*) being examined (see Section 2.2).

$${}^{g}R_{a,y} = \frac{{}^{g}C_{a,y}}{\sum_g C_{a,y,g}}$$ Ratio of gear-specific catch to total catch

$${}^{g}\overline{R}_a = \frac{\sum_{1990}^{1994} {}^{g}R_{a,y}}{5}$$ Average catch ratio for each gear.

$${}^{c}F_a = \overline{F}_a \cdot {}^{c}T_a$$ Fishing mortality vector for case *c*

Per-recruit calculations are based on standard methodology. The overall yield per recruit was calculated with the ${}^{c}F_a$ vector for each case. The gear-specific yield per recruit values were calculated by multiplying the overall *YPR* values times the catch ratios:

$${}^{g}YPR = \sum_a Y_a \cdot {}^{g}\overline{R}_a \ ,$$

where $Y_a$ are the equilibrium yield per recruit values for each age over the 1990-1994 period.

### *2.2 Fishing mortality multipliers*

The computation of ${}^{c}T_a$ for each Case and its rationale are as follows:

*Case 1*. Base Case.

${}^{c}T_a = 1$ for all ages. The $\overline{F}_a$ vector resulting from the VPA is applied.

*Case 2*. Protect Age 1.

${}^{c}T_1 = 0$

${}^{c}T_a = 1$ for *a*>1

*Case 3*. Protect Age 2.

${}^{c}T_1 = 0$

$${}^{c}T_2 = 0$$

$${}^{c}T_a = 1 \text{ for } a>2$$

*Case 4*. Close the Mediterranean in June-July.

$${}^{c}T_a = p_A + p_M * (1 - r_M)$$

Where $p_A$ and $p_M$ are the catch proportions at age for the Atlantic and Mediterranean, respectively, in the period 1990-1994: $p_{A(1\text{-}10+)}$ =(0.41; 0.21; 0.11; 0.16; 0.16; 0.19; 0.25; 0.28; 0.30; 0.25) ; $p_{M(1\text{-}10+)}$ =( 0.59; 0.79; 0.89; 0.84; 0.84; 0.81; 0.75; 0.72; 0.70; 0.75); and $r_M$ is the proportion of catch at age reduced by the closure in the Mediterranean.

*Case 5*. Close the East Atlantic and Mediterranean in June-July.

$${}^{c}T_a = (p_A + p_M) * (1 - r)$$

Where $r$ is the proportion of catch at age reduced by the closure in the East Atlantic and Mediterranean.

*Case 6*. Protect age 1 and close the Mediterranean in June-July.
Same as case 4 with ${}^{c}T_1 = 0$

*Case 7*. Protect age 1 and close the East Atlantic and Mediterranean in June-July.
Same as case 5 with ${}^{c}T_1 = 0$

*Case 8*. Protect age 2 and close the Mediterranean in June-July.
Same as case 4 with ${}^{c}T_1 = 0$ and ${}^{c}T_2 = 0$

*Case 9*. Protect age 2 and close the East Atlantic and Mediterranean in June-July.
Same as case 5 with ${}^{c}T_1 = 0$ and ${}^{c}T_2 = 0$

## 3. Results and Discussion

**Figure 1** shows the mean catch ratios for main gear groups during the reference period, indicating their relative contribution to the total catch at age. Purse seine in the Mediterranean is the mayor contributor to catch in all ages but 13-15. Baitboat East is the next most important contributor to juvenile catches, although the magnitude of their contribution is significantly lower. The contribution of other fisheries in the East Atlantic and Mediterranean is mainly for age 1. In the adult fraction, longlines and other fisheries (including traps) both in the East Atlantic and in the Mediterranean have important contributions to the catch at age.

Overall YPR and SPR, as well as gear specific YPR are shown in **Table 1**. For the various Cases, SPR varies between 67.74 kg and 186.51 kg and YPR between 10.92 kg and 13.89 kg. The minimum size regulations considered would increase the YPR more than the time area closures, but these would enhance SPR more than minimum size regulations. For instance, protecting age 1 would increase YPR and SPR in 8.1% and 13.3% respectively, and the increase due to closing the Mediterranean in June-July would be 4.8% and 92% respectively. Closing the Mediterranean has a bigger impact on both YPR and SPR than closing the East Atlantic, given that the majority of the catch occurs there. Moreover, when combined with minimum size regulations, closing the East and Mediterranean did not improve the YPR with respect to closing only the Mediterranean, although the increase in SPR was evident.

Gear specific outputs show that LLeast, LLmed and OTmed would increase their YPR in all scenarios, sometimes well above 100%. For the three gears, the long term YPR increases more under time area closure scenarios than under minimum size regulations. PSmed would increase their YPR if ages 1 and 2 were protected (8.6% and 13.9% respectively), and would decrease their YPR in between 33.2% and 39.7% in the rest of scenarios (time area closures or time area closures combined with minimum size regulations). BBeast would only increase their long term YPR if the Mediterranean was closed (20.6 % increase, and 12.3 % increase if also age 1 is protected). However, long term YPR would decrease between 6.6% and 40.9% in the rest of the scenarios. OTmed would most benefit if age 2 fish were protected (50% increase in YPR), but would reduce their YPR if age 2 is not protected and area closures are imposed.

**Figure 2** shows overall yield per recruit curves for each scenario. Associated reference points are further given in **Table 2**. Results indicate that Fmax would be over 1 for scenarios 3 to 9.

The short term effects of the management measures considered have a different impact on each gear **(Figure 3)**. If age 2 was protected, most of the gears would decrease their yield the first year, and specially for BBeast for which YPR would decrease to about 40% of the original yield in the first year, to be stabilized around 70% in about 6 years, when some gears would start to increase their yield. Under proposed time area closures in the Mediterranean or in the East and Mediterranean, the YPR of PSmed and OTmed would decrease to around 45% in the first year. Maximum yield reductions in the first year (to about 30%) are expected under cases 8 and 9 for OTmed and PSmed. Under these scenarios, the YPR increase for LLeast after 10 years would be 148% and 164%, respectively.

These results are based on the assumption that reported catch is real, the measures are implemented perfectly and no redistribution of fishing effort outside the area closure. In this document no scenario has been defined to test alternative assumptions. However, the group may want to discuss or test some of those alternatives. For instance, fishing effort is likely to be redistributed unless boats are forced to be in port. In the case of minimum size regulations, it may be that fish of the age that is meant to be protected could be caught because they grow bigger than the minimum size established, that older fish can not be caught because they do not reach the legal size, or that, at the same time, some fish of a given school can be caught and some others of the same age can not, given variability in growth. As an example, **Figure 4** shows the cumulative length distribution of ages 1, 2 and 3 from January to December, according to mean lengths at age predicted by Cort's growth equation (1991) and standard deviations of length around mean lengths at age computed by Rodriguez Marín *et al.* (2001) with Multifan. Vertical lines indicate minimum size regulations of 70 cm (approximately 6.4 kg, the current regulation), 75 cm (approximately 8 kg in order to protect age 1) and 96 cm (approximately 16 kg in order to protect age 2). The figure suggests that implementation errors are more likely to occur in some months than others, because minimum sizes do not lay between modes. This suggests the need to consider the seasonality of fisheries to evaluate the likelihood of implementation errors of minimum size regulations.


**Aknowledgements**

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**Table 1**. YPR analysis results: spawning stock biomass, overall yield and yield by gear (LL = Long line, PS = Purse seine, BB = Baitboat and OT = Others) and area (East and Mediterranean). Upper panel: biomass and yield in Kg. Lower panel: results expressed relative to Case 1.

| | | SSB | Yield Total | Yield LLeast | Yield BBeast | Yield OTeast | Yield LLmed | Yield PSmed | Yield OTmed |
|---|---|---|---|---|---|---|---|---|---|
| Base Case | Case1 | 67,74 | 10,92 | 1,20 | 0,75 | 1,06 | 0,88 | 5,58 | 1,45 |
| age 1 | Case2 | 76,77 | 11,80 | 1,36 | 0,70 | 1,12 | 0,99 | 6,06 | 1,58 |
| age 2 | Case3 | 110,15 | 13,89 | 1,94 | 0,52 | 1,51 | 1,38 | 6,35 | 2,18 |
| JJMed | Case4 | 130,04 | 11,45 | 2,47 | 0,90 | 2,06 | 1,40 | 3,42 | 1,20 |
| JJE+Med | Case5 | 145,33 | 11,63 | 2,35 | 0,63 | 2,14 | 1,57 | 3,60 | 1,34 |
| age1 JJMed | Case6 | 142,54 | 12,14 | 2,71 | 0,84 | 2,18 | 1,53 | 3,58 | 1,29 |
| age1 JJE+M | Case7 | 156,67 | 12,20 | 2,53 | 0,56 | 2,28 | 1,69 | 3,73 | 1,42 |
| age2 JJMed | Case8 | 177,18 | 13,39 | 3,36 | 0,58 | 2,62 | 1,90 | 3,37 | 1,56 |
| age2 JJE+M | Case9 | 186,51 | 13,19 | 3,01 | 0,44 | 2,67 | 2,01 | 3,42 | 1,64 |

| | % | SPR | Yield YPR | Yield LLeast | Yield BBeast | Yield OTeast | Yield LLmed | Yield PSmed | Yield OTmed |
|---|---|---|---|---|---|---|---|---|---|
| Base Case | Case1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| age 1 | Case2 | 13,3 | 8,1 | 13,3 | -6,6 | 5,4 | 12,0 | 8,6 | 8,9 |
| age 2 | Case3 | 62,6 | 27,2 | 62,5 | -29,8 | 41,9 | 56,5 | 13,9 | 50,0 |
| JJMed | Case4 | 92,0 | 4,8 | 106,5 | 20,6 | 94,0 | 58,7 | -38,7 | -17,4 |
| JJE+Med | Case5 | 114,6 | 6,5 | 96,2 | -15,7 | 101,7 | 77,6 | -35,4 | -7,8 |
| age1 JJMed | Case6 | 110,4 | 11,1 | 126,3 | 12,3 | 105,3 | 73,9 | -35,8 | -11,1 |
| age1 JJE+M | Case7 | 131,3 | 11,7 | 111,5 | -25,4 | 114,4 | 91,4 | -33,2 | -2,4 |
| age2 JJMed | Case8 | 161,6 | 22,6 | 181,3 | -22,3 | 146,3 | 115,9 | -39,7 | 7,0 |
| age2 JJE+M | Case9 | 175,3 | 20,8 | 151,8 | -40,9 | 151,3 | 127,6 | -38,7 | 13,1 |

**Table 2**. Reference points for each scenario. The F multiplier needed to reach $F_{max}$, $F_{01}$, $F_{30\%}$ and $F_{40\%}$ in each Case is indicated. Also shown is the yield per recruit (kg) corresponding to each F value under each Case.

| | Case1 | Case2 | Case3 | Case4 | Case5 | Case6 | Case7 | Case8 | Case9 |
|---|---|---|---|---|---|---|---|---|---|
| Fmult=1 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| YPRfmult1 | 10,920 | 11,802 | 13,889 | 11,449 | 11,628 | 12,136 | 12,199 | 13,388 | 13,194 |
| Fmax | 0,694 | 0,773 | 1,064 | 1,047 | 1,167 | 1,186 | 1,312 | 1,622 | 1,736 |
| YPRmax | 11,325 | 11,998 | 13,899 | 11,455 | 11,702 | 12,224 | 12,421 | 14,036 | 14,035 |
| F01 | 0,444 | 0,478 | 0,589 | 0,658 | 0,726 | 0,715 | 0,784 | 0,868 | 0,930 |
| YPR01 | 10,716 | 11,303 | 12,906 | 10,808 | 11,026 | 11,469 | 11,639 | 12,962 | 12,962 |
| F30% | 0,555 | 0,595 | 0,760 | 0,893 | 0,992 | 0,973 | 1,072 | 1,249 | 1,334 |
| YPR30% | 11,170 | 11,789 | 13,577 | 11,377 | 11,619 | 12,105 | 12,298 | 13,848 | 13,844 |
| F40% | 0,407 | 0,435 | 0,543 | 0,649 | 0,719 | 0,702 | 0,772 | 0,879 | 0,939 |
| YPR40% | 10,473 | 11,015 | 12,621 | 10,773 | 10,997 | 11,417 | 11,595 | 13,004 | 12,996 |

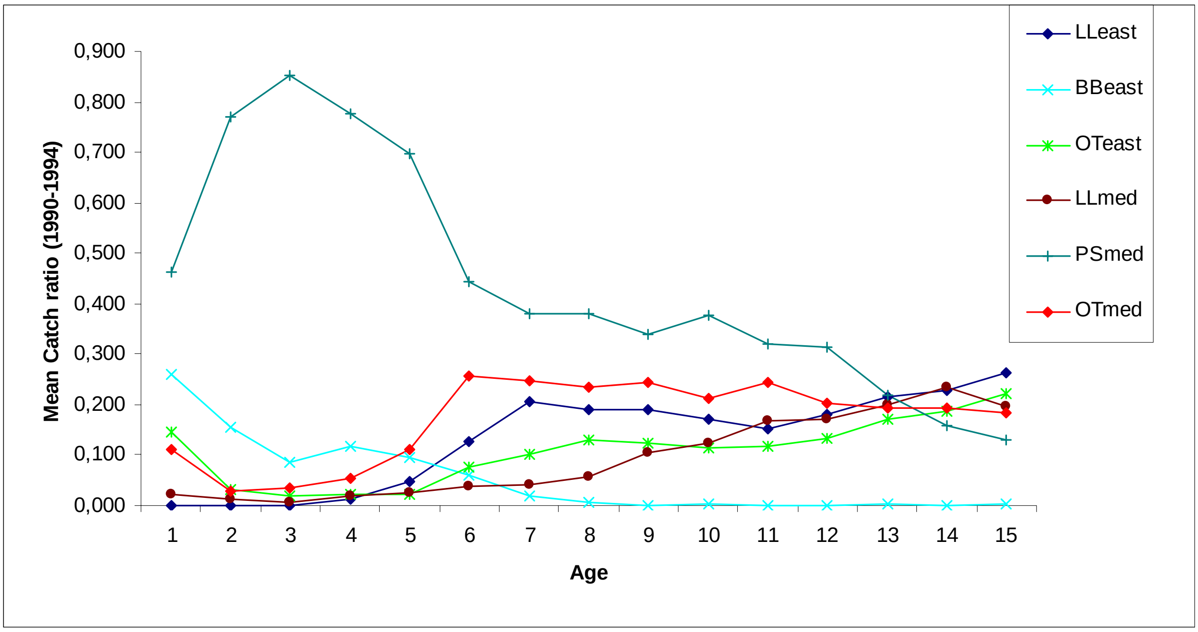


**Figure 1**. Mean catch ratios for main gears in the East Atlantic and the Mediterranean during the reference period 1990-1994.

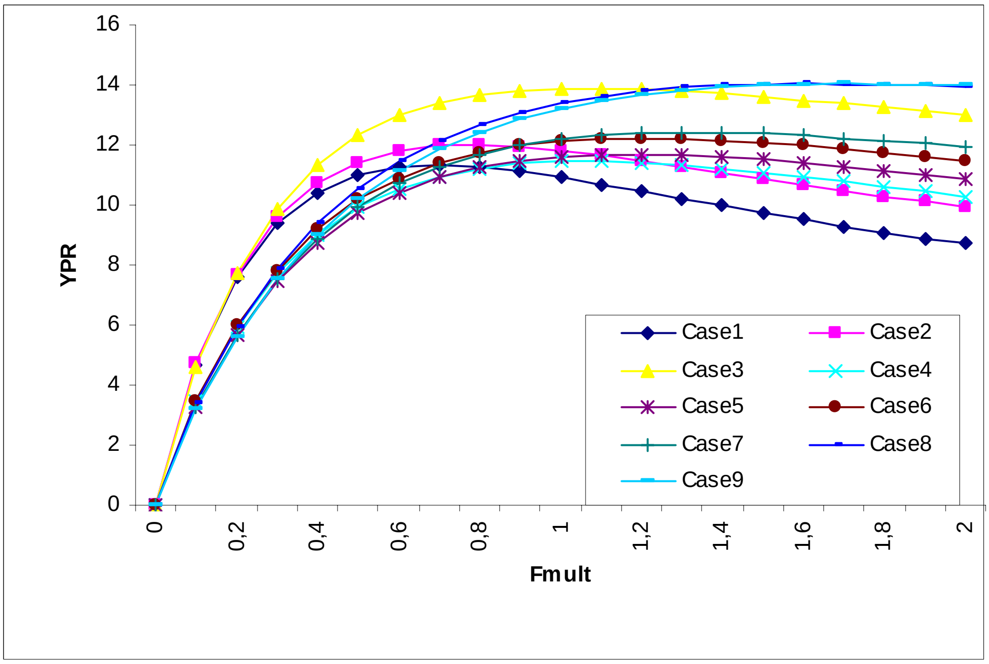


**Figure 2**. Yield per recruit curves for cases 1 to 9.

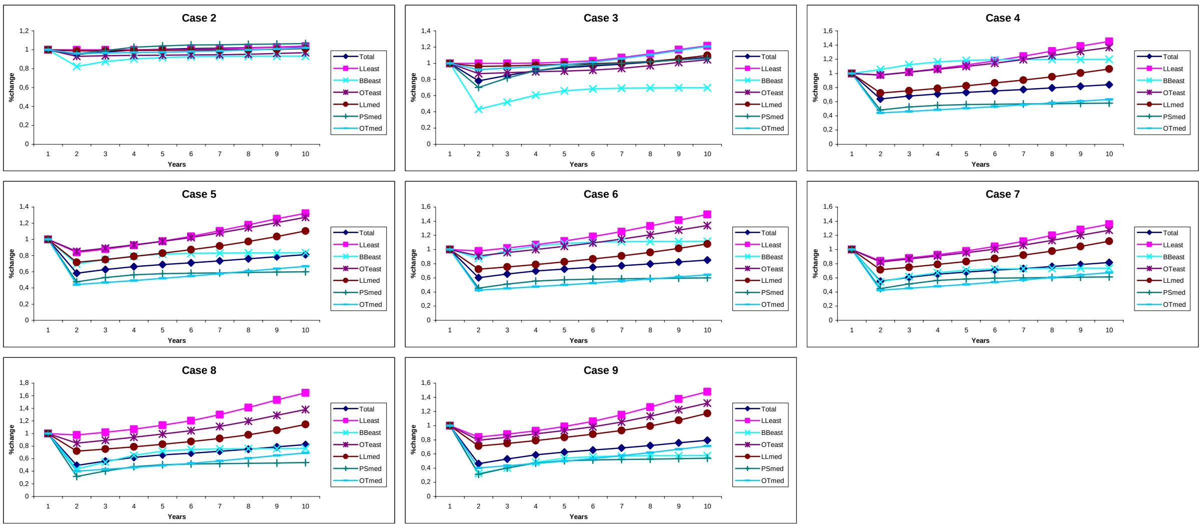


**Figure 3**. Short term projections of total and gear specific yield per recruit. The starting point is the equilibrium situation under Case 1, and the relative change is measured with respect to the yield of each fishery in that equilibrium.

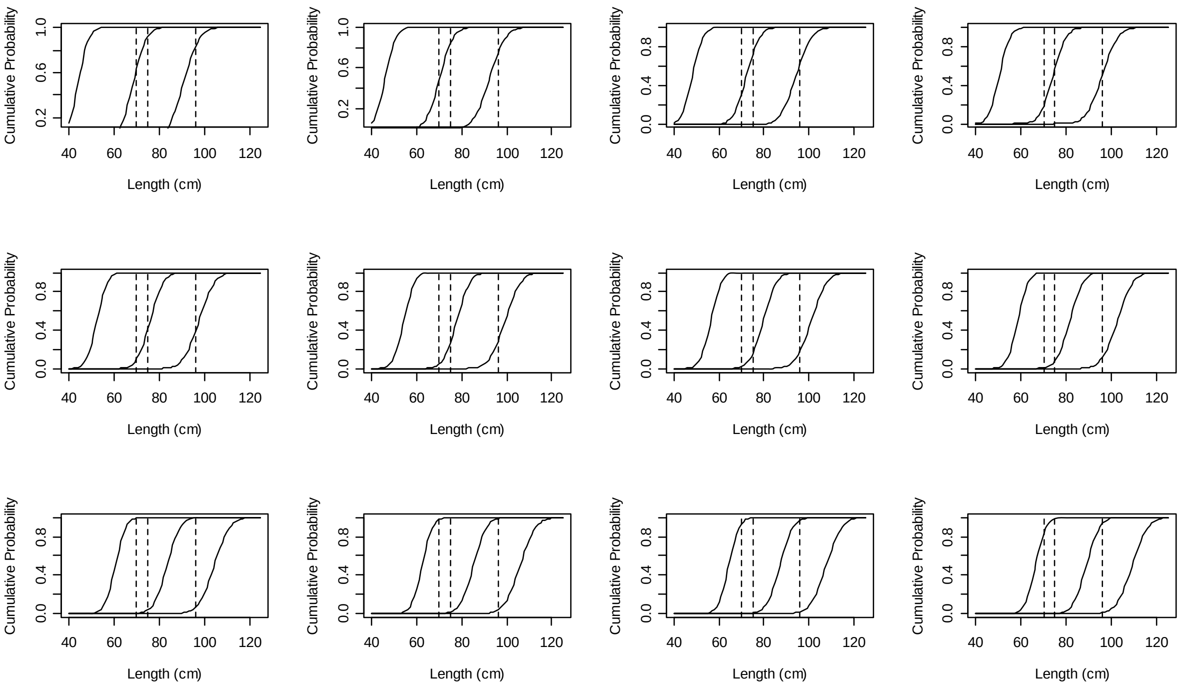


**Figure 4**: Cumulative length distributions for ages 1, 2 and 3, for January through December (left to right, top down), based on Cort (1991) and Rodriguez Marín *et al.* (2001). Vertical lines at 70, 75 and 96cm indicate approximate size limits at 6.4, 8 and 16 kg, respectively.