SCRS/2006/073 Col. Vol. Sci. Pap. ICCAT, 60(3): 937-948 (2007)

ESTIMATES OF SELECTIVITY FOR EASTERN ATLANTIC BLUEFIN TUNA FROM CATCH CURVES

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SUMMARY

Knowledge of gear-specific selectivity patterns can be useful in age-structured analyses. In recent assessments of eastern Atlantic bluefin tuna, Thunnus thynnus*, the SCRS has derived selectivity estimates from the results of virtual population analyses. This document proposes an alternative approach, based on equilibrium catch curves, that is simple to apply and that relies on a smaller set of assumptions. The study uses the catch-at-age data from the last assessment conducted in 2002, and estimates recent and historical selectivity patterns for the total stock as well as some of the major gears (trap, baitboat, purse seine and longline). The resulting estimates seem reasonable for the various gears, given prior knowledge. The document also presents selectivity estimates for Spanish traps based on trap CPUE-at-size data for 1992-2004.*

RÉSUMÉ

Les connaissances des schémas de sélectivité spécifiques des engins peuvent s'avérer utiles dans les analyses structurées par âge. Dans les récentes évaluations du thon rouge de l'Atlantique Est, Thunnus thynnus*, le SCRS a calculé les estimations de sélectivité d'après les résultats des analyses de populations virtuelles. Le présent document propose une approche alternative, basée sur les courbes de capture en conditions d'équilibre, laquelle est simple à appliquer et qui repose sur un jeu de postulats plus petit. L'étude utilise les données de prise par âge de la dernière évaluation réalisée en 2002 et estime les schémas de sélectivité récents et historiques pour l'ensemble du stock ainsi que pour certains des principaux engins (madrague, canne, senne et palangre). Les estimations en résultant semblent raisonnables pour les divers engins, compte tenu des connaissances préalables. Le document présente aussi les estimations de sélectivité des madragues espagnoles sur la base des données de la CPUE par taille des madragues pour 1992-2004.*

RESUMEN

Los conocimientos sobre los patrones de selectividad específicos del arte pueden ser útiles en los análisis estructurados por edad. En evaluaciones recientes de atún rojo del Atlántico oriental, Thunnus thynnus*, el SCRS ha derivado estimaciones de selectividad a partir de los resultados de análisis de población virtual. Este documento propone un enfoque alternativo basado en curvas de captura en equilibrio, que es sencillo de aplicar y que depende de un conjunto de supuestos menor. El estudio utiliza los datos de captura por edad de la última evaluación llevada a cabo en 2002, y estima patrones de selectividad recientes e históricos para el stock total, así como para algunos de los artes principales (almadraba, cebo vivo, cerco y palangre). Las estimaciones resultantes parecen razonables para los diferentes artes dados los conocimientos previos. El documento presenta también estimaciones de selectividad para las almadrabas españolas basadas en los datos de CPUE por talla de las almadrabas para 1992-2004.*

KEY WORDS

Gear selectivity, stock assessment, bluefin tuna

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1. Introduction

Estimating the selectivity of a stock to one or more fishing gears can be a useful exercise in stock assessment. For example, knowledge of gear-specific selectivity patterns is needed in age-structured projections aimed at investigating minimum size regulations, fleet-specific catch limitations, etc.

There are few direct methods for estimating selectivity (e.g., Millar 1992). More commonly, selectivities are estimated during the fitting of age-structured population analyses. In forward analyses that make a separability assumption (i.e., that fishing mortality is made up of a year component and an age component), such as CAGEAN (Deriso *et al.* 1985) or CATCHEM (Porch 1996), the selectivity-at-age patterns are estimated as parameters. In contrast, in backwards (VPA) analyses, such as the ADAPT (Gavaris 1988; Powers and Restrepo, 1992) method used for eastern Atlantic bluefin tuna in recent assessments, the selectivity patterns are obtained indirectly, as inferred from the estimates of fishing mortality at age (e.g. ICCAT 2003; Restrepo *et al.* 2006).

At the last assessment in 2002, the bluefin tuna Species Group obtained the "recent" selectivity pattern from the mean estimated fishing mortalities from ADAPT for a three-year time period excluding the most recent three years. The choice of ignoring the estimates in the three most recent years was made because, like in all VPAs, the ADAPT estimates are most uncertain at the end of the time series. Thus, the "recent" selectivity pattern used by the group in 2002 was based on estimates of fishing mortality that took place five to seven years earlier (1995-1997). The fishing mortalities estimated through ADAPT (and thus the selectivity pattern) further depend on various assumptions about the choice and the weighting of the tuning indices, the choice of M, terminal year selectivities and F-ratios or the minimization algorithm.

The objective of this paper is to propose an alternative approach, based on catch curve analyses, for estimating selection patterns. We use the same catch-at-age matrix as in the 2002 assessment for illustrative purposes.

2. Methods

Catch curve analyses (Ssentongo and Larkin 1973; Jensen 1985) can be fit to relative abundance data from a cohort in successive years (which is known as year-class curve analyses; see Fromentin *et al.*, SCRS/2006/072). Alternatively, they can be fit to a "synthetic" cohort by using data from a single year (or a few years) over the full range of ages.

Let p_a denote the fraction of the total catch corresponding to age a. Then, a linear regression on p_a over a range of ages [α to β],

$$\ln(p_a) = b_1 + b_2 \cdot a ,$$

can be used to estimate the total mortality as $\hat{Z} = -\hat{b}_2$. This approach makes several strong assumptions, such as equilibrium (constant recruitment; constant exploitation rate), and the age range [α to β] should correspond to fully-recruited ages (although in practice, the age range is usually chosen in an *ad hoc* manner by examining a plot of $\ln(p_a)$ against a).

While the catch curve analyses are usually applied for estimating Z, we apply it for estimating selectivity. In theory, the ages that are not fully selected do not follow a linear relationship, as shown in **Figure 1**.

The selectivities can be estimated from the ratio of observed to predicted catch proportions:

$$\hat{p}_a = \exp(\hat{b}_1 + \hat{b}_2 \cdot a) ,$$

$$\hat{S}_a = \frac{p_a}{\hat{p}_a}$$, and then re-scaled so that the maximum is 1.

In other words, the selectivity is maximal (equal to 1) when there is no difference between the observed (points of Fig. 1) and expected (dotted line of Fig. 1) curves, such as the ages 8+ in Figure 1, and it becomes smaller as the difference between both curves increases, such as the age 1 in Figure 1.

For a given gear, the ratio of the gear's catch to the total catch is proportional to the ratio of the gear's fishing mortality to the total fishing mortality. Thus, the approach can be extended to gear-specific estimates using the catch ratios and multiplying by total selectivity:

$$R_{a,g} = \frac{C_{a,g}}{\sum_g C_{a,g}} \,,$$

$s_{a,g} = S_a R_{a,g}$, and then re-scaled so that the maximum is 1.

We used the 1960-2000 catch at age matrix for ages 1 to 15+ from the 2002 assessment. The age range in the linear regressions was [α to β]=[10 to 14], to reflect the same assumption made in the assessment that ages 10+ are equally vulnerable and to avoid the plus-group (here 15+).

Estimates for the "recent" time period were made with data for 1996-2000, 1997-2000, and 1998-2000. Historical estimates were obtained with data from the first two decades (1961-1970 and 1971-1980) and for subsequent five-year time periods.

Gear-specific selectivities were computed for the following: Trap (eastern Atlantic and Mediterranean separately), longline (eastern Atlantic and Mediterranean separately), baitboat (eastern Atlantic only), purse seine (Mediterranean only) and "Other gears" (representing the remainder of the catches for eastern Atlantic and Mediterranean combined).

3. Results

3.1 Recent patterns

Figure 2 shows the fitted regression and estimated selectivity pattern using data for 1995-1997, the same time period as was used in the 2002 assessment to determine selectivity for recent years. The estimate obtained from the 2002 assessment is also shown for comparison. The resulting patterns are similar, indicating high selectivity at young ages (especially a=2,3) and older ages (10+).

3.2 Sensitivity to year range

In order to determine the "recent" selectivity pattern, we focused on data that included the last three years available. **Figure 3** presents the estimates obtained by averaging the catch proportions for five-, four-, and three-year periods. These indicate that the estimates are somewhat sensitive to the choice of years, as the last curve (using 1998-2000 data) differs from the first two. But this result is not surprising given the observed catch proportions in which the estimated abundance of small fish in the catch for 2000 differs substantially from earlier years (**Table 1**). Because the number of years included in this analysis is smaller, the difference in small fish catches becomes more influential.

We examined how the choice of years included in the average influenced the estimates of selectivity for three major gears. **Figure 4** shows the selectivities for trap and baitboat in the eastern Atlantic, and purse seine in the Mediterranean. Note that the total selectivity appears to be more sensitive to the year range than are those of each given gear.

3.3 Historical estimates

Using data from different time periods we estimated total and gear-specific selectivity patterns to depict major changes in targeting of bluefin tuna fisheries. These are shown in **Figure 5**. The total pattern suggests that small fish were more vulnerable until the 1990s, when older fish became vulnerable as well. The other patterns are also in line with general expectations: the trap and longline patterns increase with age, targeting primarily older fish; the baitboat targets primarily young fish; and, the purse seine and other gears have shifted from targeting small fish in the earlier period, to targeting both small and large fish since the 1990s. These plots also point out temporal variations in the selectivity that do not appear to be in relation to fisheries strategies, but to fish availability, such as the peak of juveniles in the trap during the 1980s or the peak of medium size fish in the long line during the 1960s (possibly in relation to the Brazilian episode).

4. Discussion and Conclusions

The approach for estimating selectivity patterns that is followed in this paper is an alternative to the method used in recent years for eastern Atlantic bluefin tuna. We have not conducted thorough analyses, e.g., via simulation, to test the robustness of the method in comparison to the approach based on the VPA results. Both approaches make use of the same data, and both make a number of assumptions; the catch curve makes important assumptions in terms of stationarity. The catch curve approach is appealing in that it is simple, and we found some degree of comfort in the fact that the results obtained were similar to those from the VPA, and that the gear-specific patterns looked reasonable regarding our general knowledge about these fisheries. Nevertheless, the approach should be viewed as one method among several candidates.

There are several potential uses for estimates of selectivity. One of them is for making short and medium-term projections into the future. In this case, it may be preferable to derive the selectivity estimates from the same approach used to estimate current status (i.e., from the VPA in the case of eastern bluefin), so as to maintain consistency. The catch curve estimates may be useful for other analyses such as multi-gear yield per recruit, or even to obtain input values for selectivity patterns to be used in forward, separable models. Similarly, studying the selectivity estimates for a given gear over time may provide some insight into large shifts in targeting, which would in turn aid in better defining the fleets to be modeled in the assessment. Furthermore, such analyses may reveal potential changes in fish availability to some gears, here trap and long line, which can be useful in a comprehensive study.

In this paper we have used for illustrative purposes the same catch-at-age matrix that was used in the 2002 assessment. We note, however, that the Species Group has since then made changes to the substitution rules used for generating the catch-at-size data (see ICCAT 2005), and the estimates presented here are likely to change with a revised catch-at-age matrix.

Finally, we carried out an additional catch curve analysis limited to catch data from Spanish traps in the eastern Atlantic. The results are shown in **Appendix 1**.

Acknowledgments

We are indebted to I.P. Mus for logical suggestions.

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Table 1. Proportion (pa) of age-1 fish in the catch in recent years.

1996	1997	1998	1999	2000
0.26	0.24	0.29	0.31	0.52

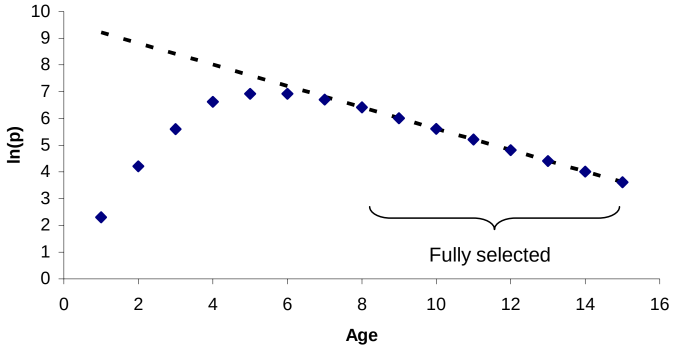


Figure 1. Hypothetical catch curve.

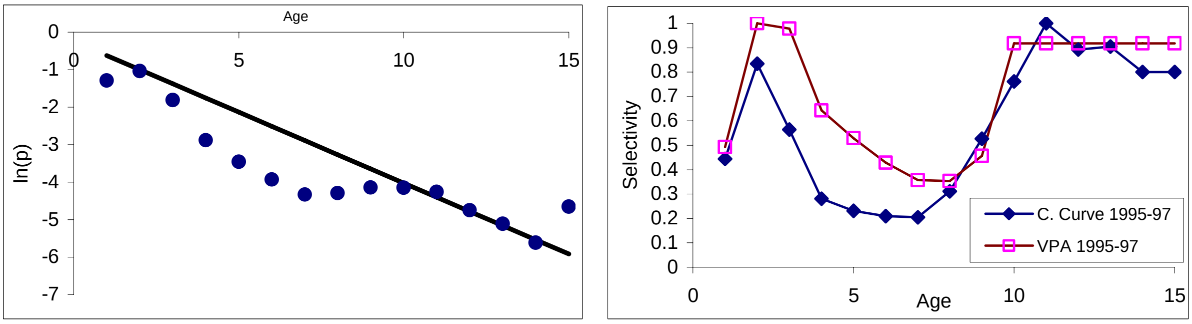


Figure 2. Catch curve and estimated selectivity using 1995-1997 data. For comparison, the selectivity estimates from the 2002 assessment are also shown.

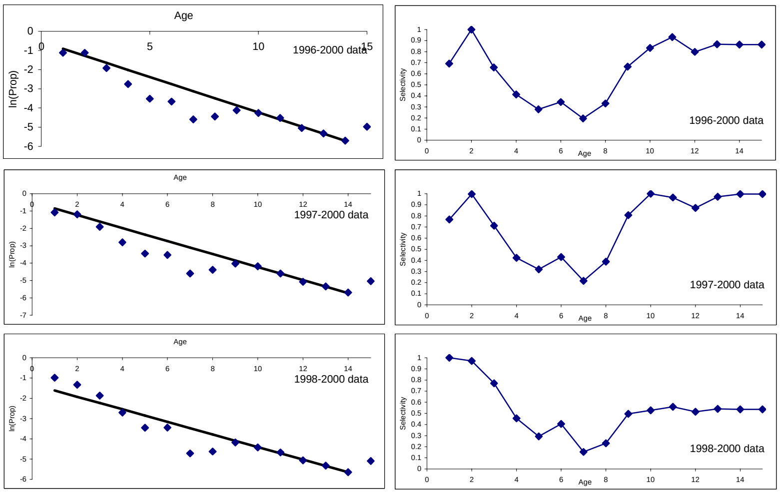


Figure 3. Catch curve regressions and selectivity estimates for three recent time periods.

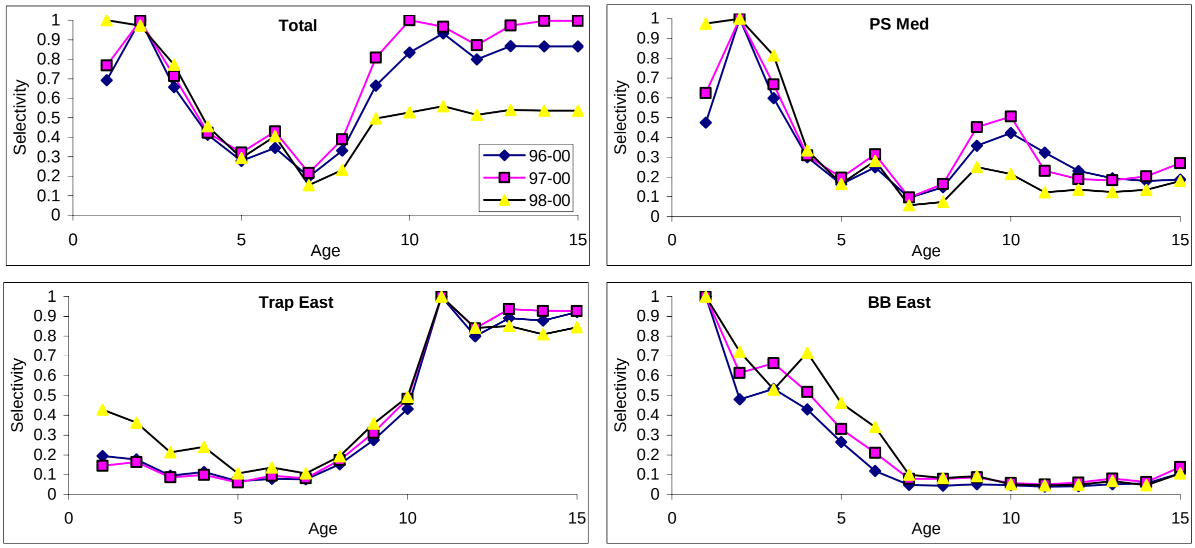


Figure 4. Estimated selectivity patterns for all gears ("Total") and for trap, purse seine and baitboat gears obtained when using catch-at-age data for three different time periods.

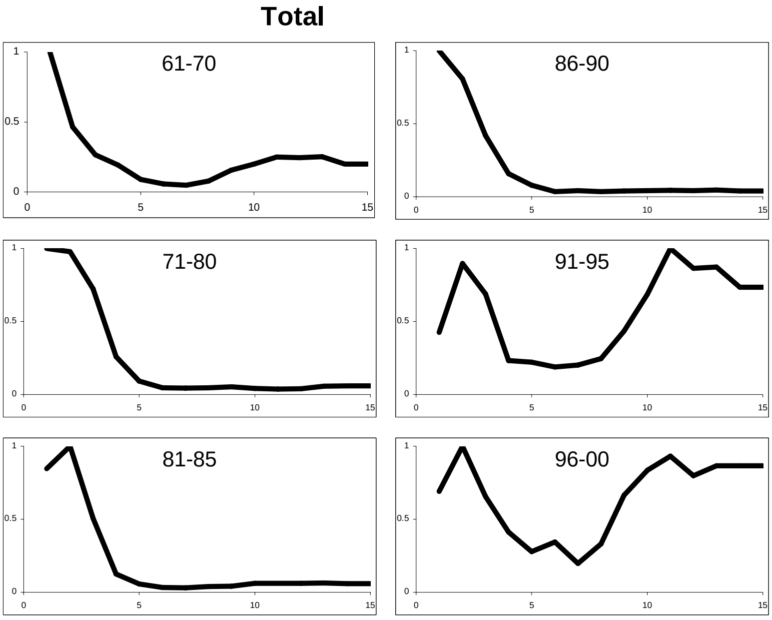
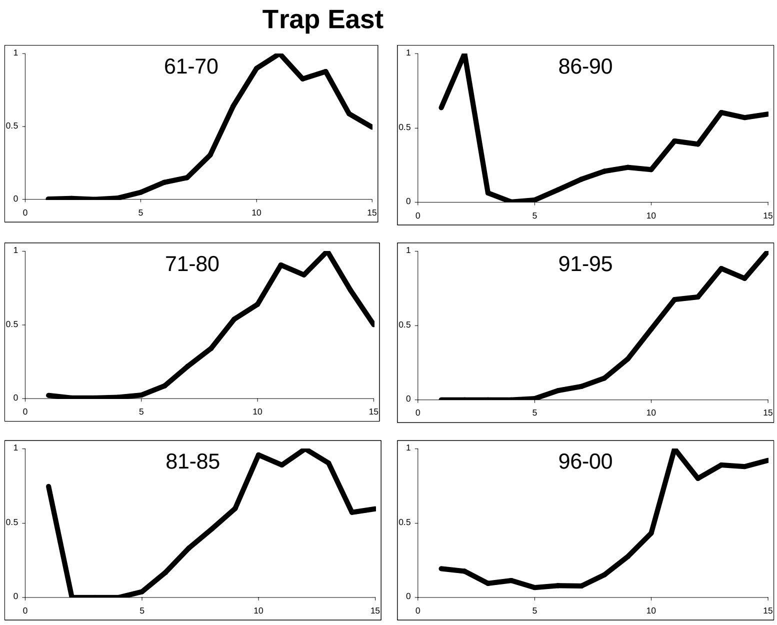


Figure 5. Estimated selectivity for different time periods.



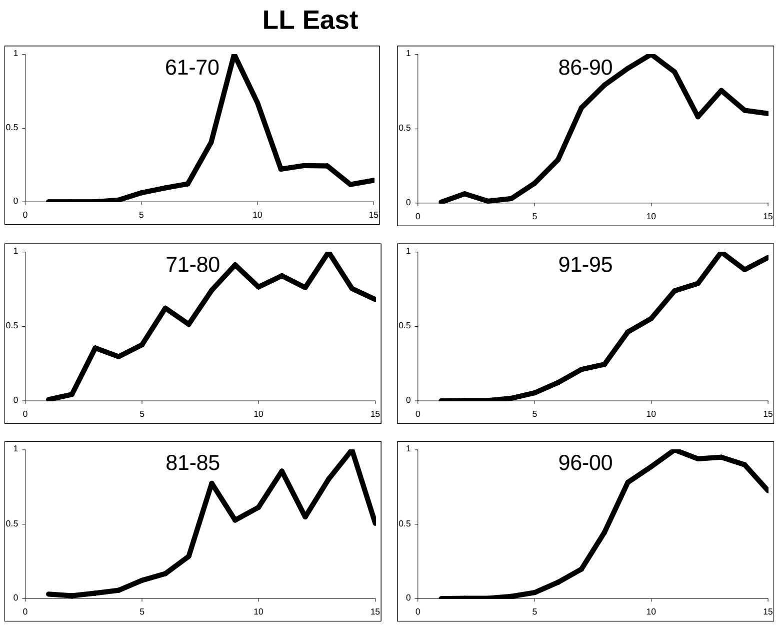
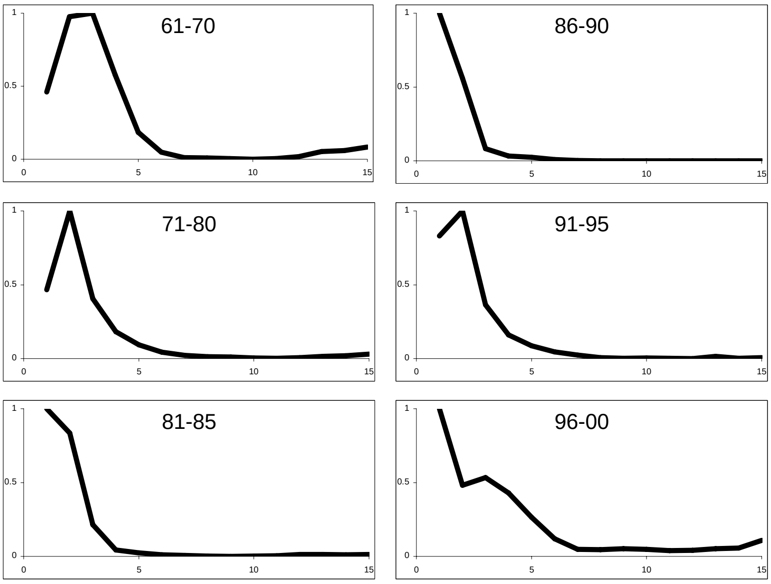


Figure 5. (cont.)

BB East



Trap Med

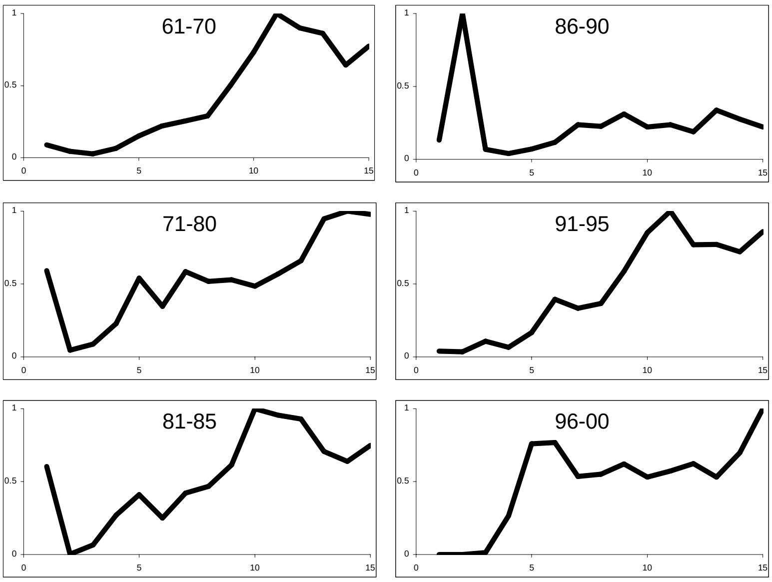
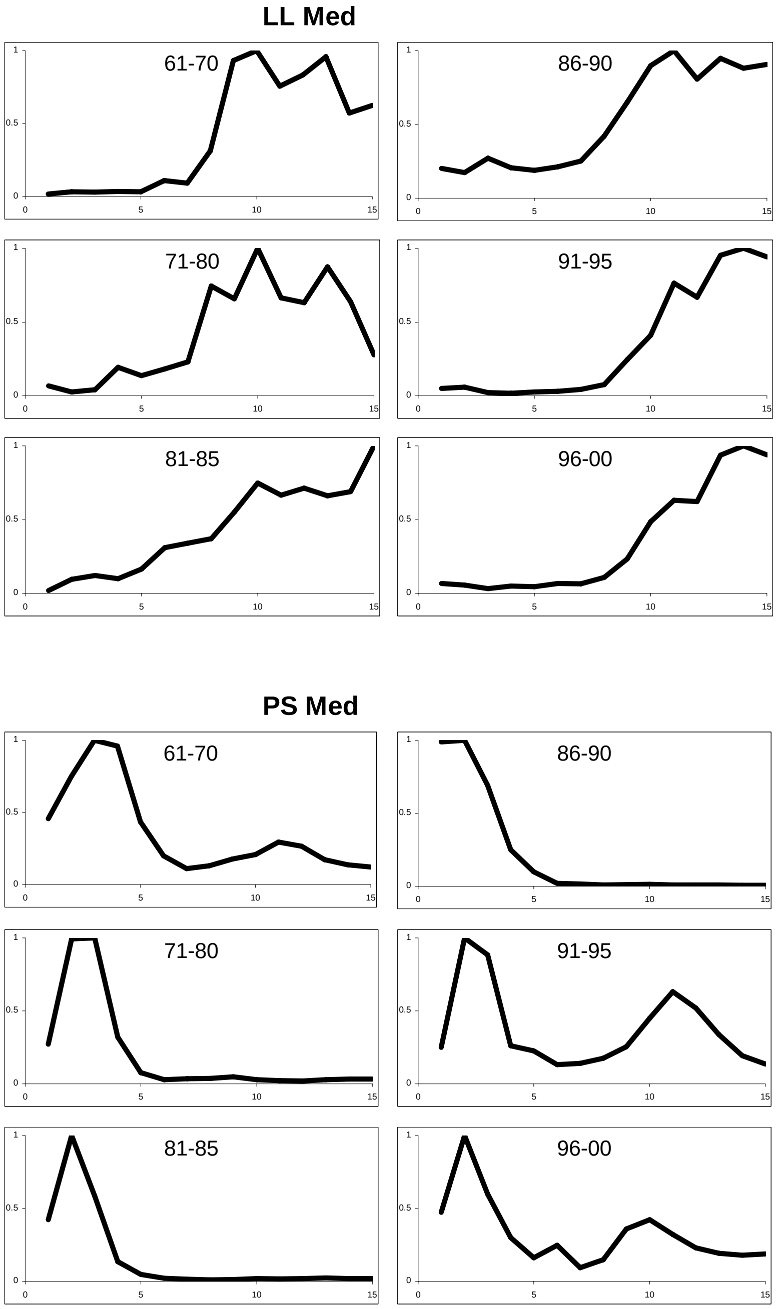


Figure 5. (cont.)



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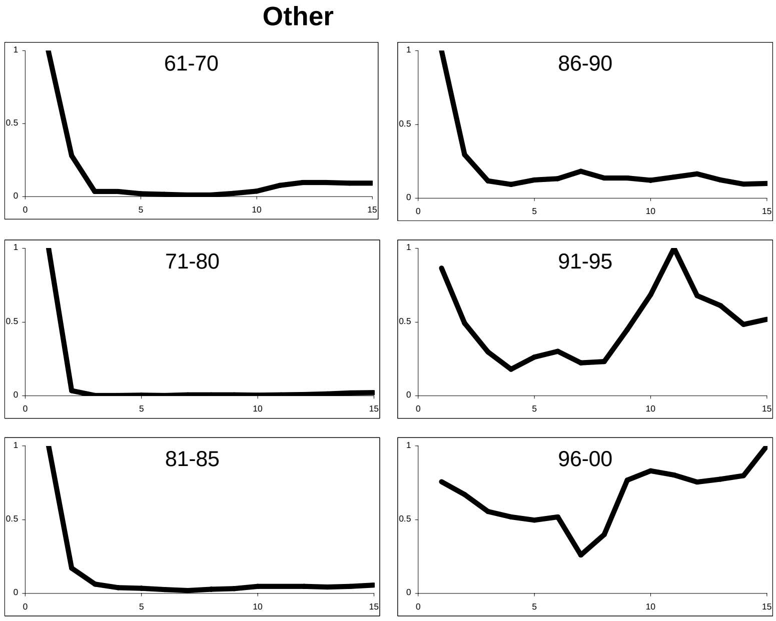


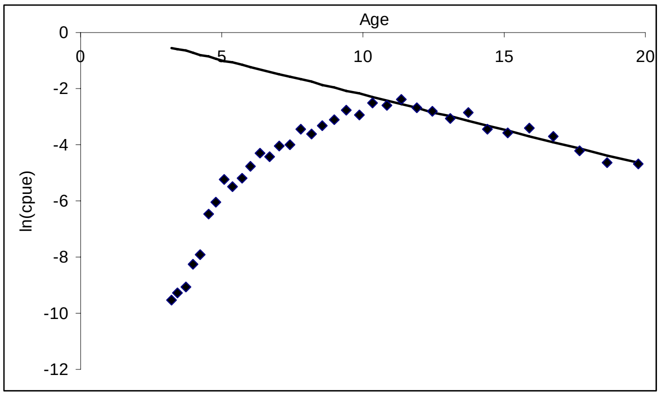
Figure 5. (cont.)

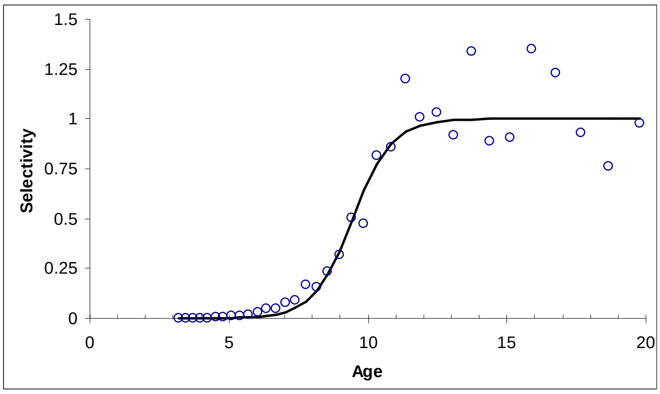
Appendix 1

Catch Curve Analyses of Spanish Trap CPUE data

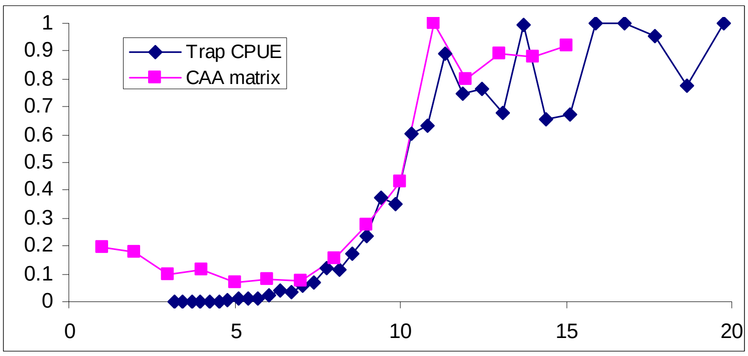
Spanish traps catch primarily large bluefin during their migration into the Mediterranean. The trap sizes and mode of operation have been fixed for many years, so their fishing effort can be considered as being constant. In this analysis, we fit catch curves to average trap catch rates at age for the period 1992-2004.

Average CPUE every 5-cm size intervals were converted to CPUE at age using Cort's (1991) growth equation. The catch curve was fitted to CPUE for ages 10+. The two figures below show the catch curve regression and corresponding selectivities (not re-scaled to a maximum of 1.0).





The next figure compares the scaled selectivity estimates from trap CPUE compared against those from the catch-at-age (see Figure 5 in the main text) for 1996-2000.



The estimated pattern suggests that on average bluefin are fully selected by traps after age 10, considerably older than the age 6+ discussed by SCRS in the past.