SCRS/2005/067 (Rev) Col. Vol. Sci. Pap. ICCAT, 59(3): 794-801 (2006)

EFFECT OF MINIMUM SIZE REGULATIONS ON EAST BLUEFIN TUNA (*Thunnus thynnus* L.) YIELD PER RECRUIT

V. Restrepo[1], H. Arrizabalaga[2], J.M. Ortiz de Urbina[3], J-M. Fromentin[4]

SUMMARY

A standard yield per recruit (YPR) analysis is used to analyse the effects of minimum size regulations on bluefin tuna from the Eastern stock (East Atlantic and Mediterranean). Analyses were based on a selectivity 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 selectivity vector was modified according to different minimum size regulations and implementation error levels. It is concluded that: (i) perfect implementation of the size limit regulation adopted in 2004 would increase YPR by 4.3% relative to the size limit adopted in 2002, and by 8.8% relative to the pattern realized in the early 1990s; (ii) YPR is however expected to decrease for some fleets, especially those targeting small BFT in the East Atlantic; and, (iii) an implementation error of 50% could cancel the gains expected due to the last size limit regulation adopted by the Commission.

RÉSUMÉ

Une analyse du rendement par recrue (RPR) est menée pour étudier les réglementations sur les tailles minimales du thon rouge de l'Atlantique Est et Méditerranée. Le vecteur de sélectivité a été calculé sur la période 1990-1994, pour laquelle les données de captures sont plus fiables et pour laquelle la VPA (lors de l'évaluation du thon rouge de 2002) commence à converger. Ce vecteur a été modifié pour prendre en compte différentes réglementations sur la taille minimale et d'erreurs d'implémentation. On conclue que : (i) la dernière réglementation sur la taille minimale adoptée en 2004 augmenterait le RPR de 8.8% par rapport à la période de référence (1990-1994) et de 4.3% par rapport à la précédente réglementation (2002), (ii) le RPR pourrait cependant diminué pour certaines flottilles, notamment celles qui ciblent les juvéniles dans l'Atlantique Est et (iii) un défaut d'implémentation de 50% annulerait cependant les bénéfices de la réglementation de 2004 par rapport à celle de 2002.

RESUMEN

Se ha realizado un análisis del rendimiento por recluta (YPR) para estudiar los efectos de las reglamentaciones sobre talla mínima en el atún rojo del stock oriental (Atlántico este y Mediterráneo). Los análisis se basaron en un vector de selectividad calculado para el periodo 1990-1994, en el cual los datos de capturas son más fiables y para el cual el VPA (realizado en la evaluación de stock de atún rojo de 2002) mostraba una convergencia relativamente buena. Este vector de selectividad se ha modificado según las diferentes reglamentaciones sobre talla mínima y los niveles de error de implementación. Se concluye que: (i) la perfecta implementación de la reglamentación sobre talla mínima adoptada en 2004 supondría un incremento del 4,3% en el YRP con respecto al límite de talla adoptado en 2002, y del 8,8% con respecto al periodo de referencia (1990-1994); (ii) sin embargo, se podría esperar que el YPR descendiese para algunas flotas, sobre todo las que dirigen su actividad a los juveniles en el Atlántico este y (iii) un error de implementación del 50% podría anular los beneficios de la reglamentación de 2004 con respecto a la de 2002.

KEYWORDS

Yield/recruit, Yield predictions, Size limit regulations, Bluefin tuna.

[1] ICCAT. Corazón de María 8, 28002 Madrid, Spain. E-mail: victor.restrepo@iccat.int
[2] AZTI. Txatxarramendi Ugartea z/g. Sukarrieta. Basque Country, Spain.
[3] Instituto Español de Oceanografía, C. O. Málaga (Fuengirola). Puerto Pesquero s/n. Apdo.: 285. 29640 Fuengirola (Málaga). Spain.
[4] IFREMER Centre de Recherche Halieutique Méditerranéen et Tropical, BP 171, 34203 Sète Cedex, France

1 Introduction

The 3rd Meeting of the "Working Group to Develop Integrated and Coordinated Atlantic Bluefin Tuna Management Strategies" (Fukuoka, April 2005), recommended that the SCRS undertake several evaluations, among which were the following:

- assess the impact and effectiveness of the current multi-annual management plan, including the new minimum size, the eradication of the tolerance and the regulation of farming activities;
- evaluate the effects and consequences on the juvenile component of the stocks of current pattern of fishing for supply of fish farming activities;
- advise on possible additional measures, which might be envisaged to reinforce the current management measures.

These recommendations were reviewed during the 3rd Meeting for Bluefin Tuna Research (Madrid, June 2005). For the East Atlantic and Mediterranean BFT stock, it was then agreed to perform preliminary analyses to be presented during the 2005 SCRS plenary session that would focus on minimum size issues, using the Yield-per-Recruit (YPR) and Spawner-per-Recruit (SPR) analyses (ICCAT 2006). This document presents preliminary results of analyses on the effects of minimum size regulations and implementation scenarios 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. Therefore, the period 1991-1996 was suggested (ICCAT 2006).

In this study, we chose a somewhat different time period for the baseline because of considerations about the time when different minimum size regulations were adopted (**Table 1**). Since [Rec. 94-11] went into force in the middle of 1995, we decided to use the period 1990-1994 for the baseline instead, so as to encompass a 5-year time period when a single minimum size regulation was in place.

The YPR and SPR analyses presented here are based on the selectivity pattern as inferred from the catch-at-age values and fishing mortality estimates obtained during the last stock assessment of the Eastern Atlantic and Mediterranean bluefin tuna stock (ICCAT 2003).

Seven selectivity patterns were considered, as explained below (for details see **Table 1**). Case 1 corresponds to the selectivity 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 and implementation errors, as follows:

Case	Min. Size Rec.	Implementation Error
1	[74-01] or [94-11][1]	Unknown
2	[74-01] or [94-11][1]	0%
3	[98-04]	0%
4	[02-08]	0%
5	[04-07]	0%
6	[04-07]	25%
7	[04-07]	50%

[1] The analyses conducted do not consider fish younger than 1 year old. Thus, Cases 1 and 2 reflect both [74-01] and [94-11] insofar as they apply to bluefin of ages 1 and above.

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 (see **Table 2** for the resulting input values):

$$\overline{F}_a = \frac{\sum_{1991}^{1996} F_{y,a}}{6}$$ Average fishing mortality vector for the 1991-1996 period (**Table 2**)

$^{c}T_a$ 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

$${}^{g}\overline{R}_a = \frac{\sum_{1991}^{1996} {}^{g}R_{a,y}}{6}$$ Average catch ratio for each gear (**Table 2**)

$${}^{c}F_a = \overline{F}_a \cdot {}^{c}T_a$$ 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 Selectivity multipliers

For simplicity, and in order to utilize the VPA results, the method of calculation proposed here assumes that fishing mortality is evenly distributed throughout the year. The computation of ${}^{c}T_a$ for each Case and its rationale are as follows:

Case 1.

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

Case 2.

The weight of 6.4 kg corresponds to age (1+8/12). For the first 7 months of age 1, a 15% tolerance is applied. The selectivity multiplier becomes 1.0 for the remaining 5 months of age 1 as well as for older ages:

$${}^{c}T_1 = \frac{7 \times 0.15 + 5 \times 1.0}{12} = 0.504$$

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

Case 3.

A weight of 3.2 kg corresponds to age (1+1/12) and 6.4 kg corresponds to age (1+8/12). Thus, for the first month of age 1, the selectivity multiplier is zero; for months 2 to 7 of age 1, 15% tolerance is applied. The multiplier becomes 1.0 for the remaining 5 months of age 1 and for older ages:

$${}^{c}T_1 = \frac{1 \times 0.0 + 6 \times 0.15 + 5 \times 1.0}{12} = 0.492$$

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

Case 4.

A weight of 3.2 kg corresponds to age (1+1/12), 4.8 kg corresponds to age (1+6/12) and 6.4 kg corresponds to age (1+8/12). In order to take into account the different size limits for the eastern Atlantic and the Mediterranean, the computations are weighted by the relative magnitude of the catches in the two areas for

1990-1994: The observed {East:Med} catch proportion is {0.4:0.6} for age 1. Following the same rationale as above,

$$^{c}T_1 = \frac{1\times 0.0 + 6\times 0.1 + 5\times 1.0}{12}\times 0.4 + \frac{5\times 0.0 + 2\times 0.1 + 5\times 1.0}{12}\times 0.6 = 0.447$$

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

Case 5.

A weight of 10 kg corresponds to age (2+3/12). The computations are carried out as above, taking into account the observed {East:Med} catch proportions of {0.4:0.6} and {0.2:0.8} for ages 1 and 2, respectively:

$$^{c}T_1 = \frac{7\times 0.0 + 5\times 1.0}{12}\times 0.4 + \frac{12\times 0.0}{12}\times 0.6 = 0.167$$

$$^{c}T_2 = \frac{12\times 1.0}{12}\times 0.2 + \frac{2\times 0.0 + 10\times 1.0}{12}\times 0.8 = 0.867$$

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

Case 6.

This is the same as Case 5, but with 25% error:

$$^{c}T_1 = \frac{7\times 0.25 + 5\times 1.0}{12}\times 0.4 + \frac{12\times 0.25}{12}\times 0.6 = 0.375$$

$$^{c}T_2 = \frac{12\times 1.0}{12}\times 0.2 + \frac{2\times 0.25 + 10\times 1.0}{12}\times 0.8 = 0.900$$

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

Case 7.

This is the same as Case 5, but with 50% error:

$$^{c}T_1 = \frac{7\times 0.5 + 5\times 1.0}{12}\times 0.4 + \frac{12\times 0.5}{12}\times 0.6 = 0.583$$

$$^{c}T_2 = \frac{12\times 1.0}{12}\times 0.2 + \frac{2\times 0.5 + 10\times 1.0}{12}\times 0.8 = 0.933$$

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

3 Results and Discussion

Overall YPR and SPR as well as gear specific YPR are shown in **Table 3.** For the various Cases, SPR varies between 67.7 kg and 78.9 kg and YPR between 10.9 and 11.9 kg. **Table 4** shows the same information expressed as percent change relative to Case 1 (early 1990s selection pattern).

Cases 1 and 2 can be compared to obtain a rough estimate of the implementation error of the minimum size limit in [Rec. 94-11] during the early 1990s. Overall, perfect implementation of this limit would have been expected to result in a 3.9% increase in YPR (**Table 4**). Comparing this value to the differences noted between Cases 5, 6 and 7 would advocate for a rather high level of implementation error (close to 50%). However, such crude estimate must be interpreted with care since the partial catch by gear and the fishing mortalities are different among the ages and time periods.

Implementation of Cases 3 and 4 (corresponding to the size limits in [Rec. 98-04] and [Rec. 02-08], respectively), would be expected to result in similar YPR levels to Case 2 (**Tables 3** and **4**).

A more substantial increase in per-recruit levels would be expected from Case 5 (i.e., perfect implementation of [Rec. 04-07]): Overall YPR would be expected to be 8.8% higher than that resulting from the early 1990s selection pattern. Using the average recruitment values estimated in the 2002 assessment (geometric mean = 2,889,678 recruits), the difference in expected equilibrium yield between Cases 5 and 1 is 2,754 tons.

However, implementation errors could erode the expected gains in yield: Implementation of [Rec. 04-07] with 50% error (Case 7) results in a gain in YPR that is of similar magnitude to the gain that would be obtained by implementing [Rec. 94-11] without error (Case 2). This means that 50% implementation error for the most constraining size limit regulation leads to the same result as a less constraining regulation with perfect implementation.

Nonetheless, gear specific outputs shows that YPR can significantly decrease for some fleets, e.g. by 39.8% (Case 2) to 67.4% (Case 5) for the purse seine fleet in the eastern Atlantic and by 3.2% (Case 2) to 8.1% (Case 5) for the bait boat fleet in the eastern Atlantic. Note that fleets targeting large BFT, such as long line, trap and secondarily the purse seine in the Mediterranean, would increase their YPR substantially with more restrictive minimum size regulations (**Table 4**).

Figure 1 shows overall yield per recruit curves of each of the first five scenarios. Associated reference points, F_{max}, $F_{0.1}$, $F_{30\%}$ and $F_{40\%}$ are further given in **Table 5**. YPR indicate that the highest F_{max} (regarding the above hypotheses) will be of 0.780 for Case 5 and the lowest of 0.694 for Case 1. Intermediate values were obtained in other Cases, with Cases 2 and 7 giving again similar results.

This work presents a way to explore in a simple way the impact of minimum size regulations on the overall and fleet specific yields. Results should be interpreted with circumspection, as uncertainty about total and fleet specific catch-at-age matrices influence the VPA results and the corresponding estimates of selectivity vectors. Moreover, no area-specific growth or implementation levels are evaluated, which could impact the results obtained in this work. Further and more detailed analyses should be undertaken for the 2006 stock assessment, using the corrected catch-at-age proposed by the 2004 BFT data exploratory meeting (ICCAT 2005).

References

ICCAT. 2003. Report of the 2002 Atlantic Bluefin Tuna Stock Assessment Session. Col. Vol. Sci. Pap. ICCAT, 55(3): 710-937.

ICCAT. 2005. Report of the 2004 data exploratory meeting for the East Atlantic and Mediterranean bluefin tuna. Col. Vol. Sci. Pap. ICCAT, 58(2): 662-699.

ICCAT. 2006. Report of the 2005 ICCAT planning meeting for bluefin tuna research. Col. Vol. Sci. Pap. ICCAT, 59(3): 717-749.

Table 1. Summary of minimum size (weight) regulations adopted historically by ICCAT for BFT-East. Black shading indicates zero tolerance.

		Weight (kg): 1.8 / 3.2 / 4.8 / 6.4 / 10
[74-01]	E+Med	15% tolerance
[94-11]	E+Med	15% tolerance
[98-04]	E+Med	15% tolerance
[02-08]	E. Atl.	10% tolerance
[02-08]	Med.	10% tolerance
[04-07]	E. Atl.	
[04-07]	Med.	

Table 2. Inputs used for ages 1 to 25 (50 ages were considered, see text for a description).

Age (a)	Weight	Mat	M	$\overline{F}_a$	${}^{c}T_a$							${}^{g}\overline{R}_a$									
					1	2	3	4	5	6	7	LL(E)	PS(E)	TP(E)	BB(E)	OT(E)	LL(M)	PS(M)	TP(M)	BB(M)	OT(M)
1	5.42	0	0.49	0.1252	1	0.504	0.492	0.447	0.167	0.375	0.583	0.000	0.089	0.000	0.250	0.051	0.026	0.454	0.003	0.009	0.117
2	12.76	0	0.24	0.361	1	1	1	1	0.867	0.9	0.933	0.000	0.000	0.000	0.154	0.031	0.013	0.765	0.001	0.005	0.031
3	23.44	0	0.24	0.3308	1	1	1	1	1	1	1	0.001	0.000	0.000	0.084	0.014	0.008	0.846	0.005	0.003	0.038
4	37.15	0.5	0.24	0.1308	1	1	1	1	1	1	1	0.011	0.000	0.000	0.114	0.018	0.017	0.753	0.009	0.001	0.076
5	53.48	1	0.24	0.1154	1	1	1	1	1	1	1	0.045	0.003	0.007	0.090	0.013	0.024	0.653	0.028	0.002	0.135
6	71.93	1	0.2	0.052	1	1	1	1	1	1	1	0.112	0.003	0.058	0.054	0.010	0.037	0.393	0.097	0.006	0.230
7	91.98	1	0.175	0.0884	1	1	1	1	1	1	1	0.198	0.003	0.089	0.019	0.009	0.039	0.369	0.124	0.001	0.150
8	113.16	1	0.15	0.0972	1	1	1	1	1	1	1	0.189	0.004	0.121	0.005	0.006	0.060	0.383	0.103	0.000	0.130
9	135.04	1	0.125	0.119	1	1	1	1	1	1	1	0.193	0.004	0.117	0.001	0.005	0.112	0.340	0.103	0.000	0.125
10	157.24	1	0.1	0.116	1	1	1	1	1	1	1	0.179	0.001	0.116	0.001	0.005	0.132	0.384	0.063	0.000	0.118
11	179.43	1	0.1	0.116	1	1	1	1	1	1	1	0.157	0.000	0.122	0.000	0.003	0.180	0.326	0.053	0.000	0.157
12	201.36	1	0.1	0.116	1	1	1	1	1	1	1	0.186	0.000	0.138	0.000	0.005	0.181	0.321	0.036	0.000	0.134
13	222.80	1	0.1	0.116	1	1	1	1	1	1	1	0.215	0.000	0.176	0.003	0.005	0.212	0.217	0.073	0.000	0.100
14	243.60	1	0.1	0.116	1	1	1	1	1	1	1	0.233	0.000	0.194	0.000	0.005	0.251	0.164	0.074	0.000	0.078
15	263.62	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
16	282.77	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
17	301.00	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
18	318.26	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
19	334.55	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
20	349.86	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
21	364.19	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
22	377.59	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
23	390.08	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
24	401.68	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097
25	412.46	1	0.1	0.116	1	1	1	1	1	1	1	0.262	0.000	0.225	0.000	0.005	0.211	0.133	0.066	0.000	0.097

Table 3. YPR analysis results: overall yield, spawning stock biomass and yield per fleet (LL= long line; PS= purse seine; TP= trap; BB= bait boat and OT=others) and per area (E= East Atlantic and M = Mediterranean Sea) for seven Cases (see text and Table 2).

Case	SSB	YPR Tot.	YPR LL(E)	YPR PS(E)	YPR TP(E)	YPR BB(E)	YPR OT(E)	YPR LL(M)	YPR PS(M)	YPR TP(M)	YPR BB(M)	YPR OT(M)
1	67,738	10,920	1,197	0,053	0,869	0,722	0,158	0,941	5,510	0,458	0,022	0,989
2	72,077	11,343	1,274	0,032	0,925	0,699	0,154	0,994	5,737	0,486	0,021	1,020
3	72,186	11,353	1,276	0,032	0,926	0,699	0,154	0,995	5,743	0,487	0,021	1,021
4	72,594	11,393	1,283	0,030	0,931	0,697	0,154	1,000	5,764	0,490	0,021	1,024
5	78,882	11,876	1,394	0,017	1,012	0,664	0,149	1,078	5,929	0,531	0,020	1,082
6	75,944	11,624	1,342	0,027	0,974	0,679	0,151	1,042	5,820	0,512	0,021	1,058
7	73,115	11,382	1,292	0,036	0,938	0,694	0,154	1,007	5,713	0,493	0,021	1,034

Table 4. YPR analysis results from Table 3, expressed relative to Case 1.

Case	SSB	YPR Tot.	YPR LL(E)	YPR PS(E)	YPR TP(E)	YPR BB(E)	YPR OT(E)	YPR LL(M)	YPR PS(M)	YPR TP(M)	YPR BB(M)	YPR OT(M)
1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2	6,4	3,9	6,4	-39,8	6,4	-3,2	-2,5	5,7	4,1	6,2	-4,4	3,1
3	6,6	4,0	6,6	-40,8	6,6	-3,3	-2,6	5,8	4,2	6,4	-4,5	3,2
4	7,2	4,3	7,2	-44,6	7,2	-3,6	-2,8	6,3	4,6	6,9	-4,9	3,5
5	16,5	8,8	16,4	-67,4	16,5	-8,1	-6,2	14,6	7,6	16,0	-10,4	9,4
6	12,1	6,5	12,1	-50,0	12,1	-6,0	-4,6	10,8	5,6	11,8	-7,7	6,9
7	7,9	4,2	7,9	-32,9	7,9	-3,9	-3,0	7,0	3,7	7,7	-5,0	4,5

Table 5. 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
Fmult=1	1,000	1,000	1,000	1,000	1,000	1,000	1,000
YPRfmult1	10,920	11,343	11,353	11,393	11,876	11,624	11,382
Fmax	0,694	0,729	0,730	0,734	0,780	0,756	0,733
YPRmax	11,325	11,642	11,650	11,680	12,060	11,861	11,673
F01	0,444	0,460	0,460	0,462	0,483	0,472	0,462
YPR01	10,716	10,994	11,001	11,028	11,360	11,187	11,023
F30%	0,555	0,574	0,575	0,577	0,605	0,592	0,579
YPR30%	11,170	11,464	11,471	11,499	11,859	11,674	11,498
F40%	0,407	0,420	0,421	0,422	0,441	0,432	0,423
YPR40%	10,473	10,732	10,738	10,763	11,087	10,924	10,767

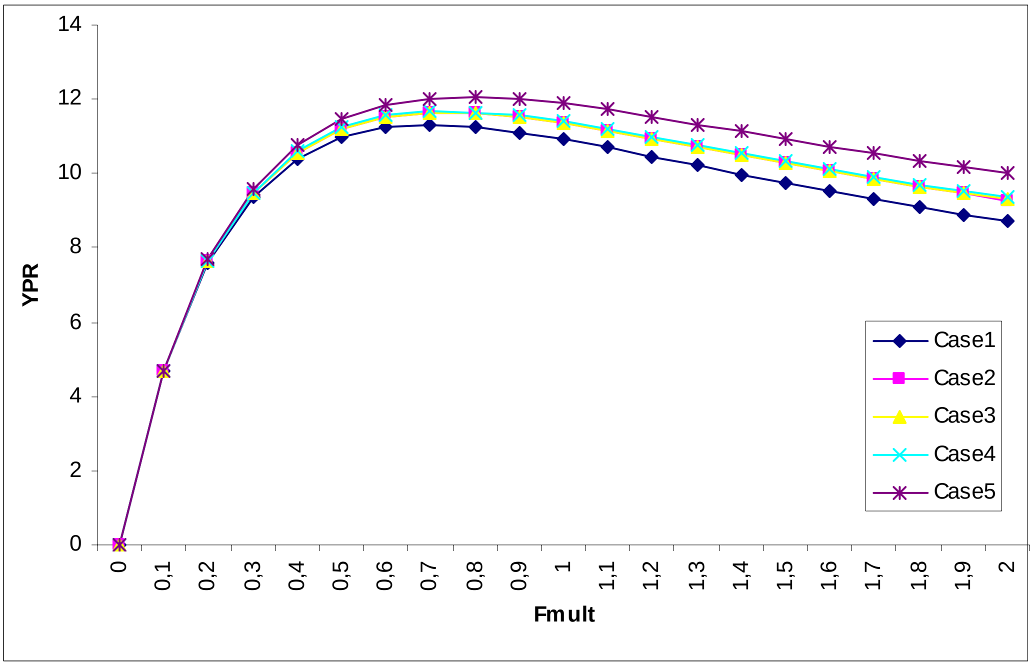

Figure 1. Yield per recruit curves for Cases 1-5.