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REFINEMENTS IN EXPLORATORY SURPLUS-PRODUCTION ANALYSES OF ATLANTIC BLUE MARLIN

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SUMMARY

Exploratory assessments of Atlantic blue marlin (Makaira nigricans) were conducted under two stock hypotheses: that of separate north and south Atlantic stocks and that of one total-Atlantic stock. A non-equilibrium stock-production model (ASPIC) that can analyze several simultaneous data series was used for the analysis. Under the total-Atlantic stock hypothesis, the analysis suggests that the stock has been at very low levels of biomass since the late 1960s. Under the hypothesis of separate north Atlantic and south Atlantic stocks, different conclusions are reached for the two stocks. In the north Atlantic, the stock appears to be recovering during the last few years from the heavy exploitation of recent decades. In the south Atlantic, the stock appears to be continuing a decline that has been occurring for about three decades.

RESUME

Des évaluations expérimentales du makaire bleu de l'Atlantique (Makaira nigricans) ont été menées selon deux hypothèses de stock: celle de stocks distincts pour l'Atlantique nord et sud, et celle d'un stock unique pour l'ensemble de l'Atlantique. Un modèle de production ne postulant pas de conditions d'équilibre (ASPIC), capable d'analyser plusieurs séries simultanées de données, a été utilisé pour l'analyse. Selon l'hypothèse du stock Atlantique entier, l'analyse suggère que la biomnasse du stock se situe depuis la fin des années soixante à un niveau très faible. Selon l'hypothèse de stocks distincts nord et sud, on arrive à des conclusions différentes pour les deux stocks. Dans l'Atlantique nord, le stock semble se remettre ces dernières anées de la forte exploitation des récentes décennies. Dans l'Atlantique sud, le stock semble poursuivre la baisse qui dure depuis près de trois décennies.

RESUMEN

Se llevaron a cabo evaluaciones tentativas de la aguja azul atlántica (Makaira nigricans) bajo dos hipótesis de stock: stocks separados al norte y sur del Atlántico y un sólo stock en todo el Atlántico. En el análisis se aplicó el modelo de producción de no equilibrio ASPIC, capaz de analizar varias series de datos simultáneamente. Bajo la hipótesis de un sólo stock atlántico, el análisis sugiere que dicho stock ha permanecido a niveles de biomasa muy bajos desde finales de la década de los 60. Bajo la hipótesis de stocks separados en el Atlántico norte y Atlántico sur, se obtienen diferentes conclusiones para ambos stocks. En el Atlántico norte, el stock parece estar recuperándose en los últimos años de la fuerte explotación sufrida en las décadas recientes. En el Atlántico sur, el stock parece continuar el descenso que se ha venido produciendo durante aproximadamente tres décadas.

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1. INTRODUCTION

Previous assessments of Atlantic blue marlin, *Makaira nigricans*, used surplus production models that included an equilibrium assumption; i.e., the models assumed that each year's catch was the equilibrium catch. Those assessments relied on a single source of data—the Japanese longline database (Conser and Farber 1979; Farber and Conser 1981; Farber 1982; Farber and Conser 1983). In general, results of those assessments suggested that blue marlin were at least fully exploited by the early 1970s and overexploited by the late 1970s. In those analyses, questions were raised about the quality of the data available for this species.

More recently, a number of assessments of blue marlin have been performed with a non-equilibrium production model. Cramer and Prager (1992) used the ASPIC production model (Prager 1991, 1992a, 1992b) in an exploratory assessment of the stocks of blue marlin in the Atlantic Ocean. That analysis used ASPIC because of the model's relative simplicity and ability to analyze data from several fisheries in one model without prior standardization. Refinements of those initial assessments of north and south Atlantic stocks of blue marlin are contained in the Report of the recent ICCAT billfish Workshop (SCRS/92/xx). It appeared from those assessments that the North Atlantic stock biomass of blue marlin had declined below B_{MSY} by the mid-1960s, and has been relatively stable since, with some increase in recent years. Results for the south Atlantic stock were less precise, but indicated similar declines in biomass, continuing, however, into the most recent years. Since time was limited, the Billfish Working Group could not finish an assessment of blue marlin under the total-Atlantic stock hypothesis and recommended that this be accomplished as soon as possible. In addition, the Billfish Working Group recommended that sensitivity analyses be conducted to evaluate how model results vary under differing assumptions, and that refinements in the data bases be made when possible.

An assessment of blue marlin under the single-stock hypothesis is presented here. Because we were uncertain of the robustness of the method by which "unallocated catch" (catch data without corresponding effort data) were incorporated into assessments during the Billfish Workshop, we have also revisited the north and south Atlantic blue marlin assessments. The current assessments should also be considered exploratory because of what appear to be continued uncertainties in the data bases, which necessitated a number of *ad hoc* decisions about the data.

2. DATA AND METHODS

Many uncertainties exist in life history, population dynamics, and other factors affecting delineation of Atlantic blue marlin stocks; thus analyses were conducted under the two stock-structure hypotheses mentioned. ICCAT Task I data (total catch in MT) had been updated at the Second ICCAT Billfishes Workshop (Miami, July, 1992), and were accepted as the best estimates of annual landings. The analysis also required estimates of fishing effort by fleet, which were obtained by dividing landings (in weight) by the corresponding CPUE series. Unfortunately, this introduces an assumption of constant average weight, as the CPUE indices are usually in number of fish (not weight) per unit of effort. We attempted to use workshop data on catch in numbers to eliminate this assumption, but those attempts were discontinued when we observed wild fluctuations in the calculated average weight. The fluctuations were traced to apparent errors in the data on catch in number. For example, those data indicated that with an effort of 26 million hooks, only 15 blue marlin were caught by Japan in 1979. Efforts to improve the data base would help to improve future billfish assessments.

The Billfish Working Group at the recent workshop used general linear models (GLM) to standardize effort within fisheries for confounding effects such as gear changes and geographical inconsistencies when this information was available. The CPUEs for the Venezuelan recreational (Gaertner 1992), U.S. recreational (Farber et al. 1992), and Japanese longline (Nakano et al. 1992) fisheries were presented by scientists of those nations attending the Workshop. The Japanese index was modified slightly during the workshop to conform to the methods used by the U.S. and Venezuela.

The CPUE indices developed during the workshop were for Brazilian and Taiwanese longline fisheries. A Brazilian scientist was present to contribute to the development of the Brazilian longline CPUE series. This series, however, was based on limited data, and continued development by Brazilian scientists familiar with these fisheries was recommended. The Taiwanese CPUE series was developed from ICCAT data without the advice of Taiwanese national scientists. Since detailed knowledge of the Taiwanese fishery was not available, this series was considered the least reliable of those used in the model.

Limitations in the data reported to ICCAT prevented development of CPUE indices for the Cuban and Korean fisheries. This is unfortunate because the combined catch from these two nations in some years has accounted for up to 50% of the reported annual landings of Atlantic blue marlin.

Recent refinements in the ASPIC software, introduced during the Billfish Workshop, allow estimation of effort rather than yield (Prager 1992b). This was considered an improvement because yield data are usually more reliable than effort data, and thus accumulating residuals in effort is more consistent with statistical theory. This improvement also allows a series of catch data to be used without a corresponding series of data on fishing effort. Since the workshop, there have been indications that the results from this treatment of unallocated catch may be very sensitive to small changes in the data. In the present analysis, therefore, when no fishery-specific effort data were available, Japanese longline CPUE for the corresponding years was used to estimate effort for unallocated catch. In addition, in order to evaluate the effect of the Taiwanese series, models were run with and without Taiwanese CPUE series. In cases where the Taiwanese CPUE series was not used, Taiwanese longline catch was also combined with Japanese longline catch.

Iteratively weighted and unweighted models were examined within each hypothesized stock region (north Atlantic, south Atlantic and total Atlantic), and several models were bootstrapped in order to evaluate the variability of estimated and derived parameters. We attempted to estimate nonparametric confidence intervals on MSY and related quantities through bootstrapping, but for technical reasons were unable to accomplish this for many of the models.

The quantities estimated most precisely by production models are MSY, effort at MSY, and biomass and fishing mortality levels relative to the respective optimum levels. Production models in general do not estimate the absolute abundance of the stocks very precisely, but the abundance relative to the optimum level (B_{MSY}) is estimated more precisely. For this reason, estimates of stock biomass presented here are normalized to the estimate of B_{MSY}.

3. RESULTS

3.1 North Atlantic

Models that did not include effort derived from the Taiwanese CPUE index produced estimates of MSY as much as 219,000 MT (Table 1), which we believe to be an unrealistic result. Our conclusion is that information in the Taiwanese data series is needed to estimate model parameters of the north Atlantic stock under the two-stock hypothesis. In the balance of this section, we present the results of the models that did include the Taiwanese data series.

Estimates of MSY (Table 1) from weighted and unweighted models with the Taiwanese data series are similar to one another, and also similar to estimates made during the billfish workshop (Table 2). Because the weighted model was preferred by the Working Group, we emphasize its results. The estimate of MSY is 1,718 MT, somewhat higher than recent yields from the north Atlantic. However, the estimate of the stock biomass level at the start of 1990 (B_{90}) relative to the level at which MSY can be attained (B_{MSY}) is 80%, indicating that the stock cannot at present produce sustainable yields at the MSY level. The estimated biomass trajectory over time (Fig. 1) indicates that North Atlantic blue marlin stocks have been considerably below B_{MSY} since the late 1960s but have increased during the last five years. (Estimates from the unweighted model are less optimistic in this respect, but the basic trends are similar.)

The optimum level of fishing mortality, denoted F_{MSY}, is the level at which MSY can be attained from a stock whose biomass is at B_{MSY}. The estimated trajectory of F/F_{MSY} (Figure 2) indicates that fishing mortality has been very high throughout the time period analyzed, often twice as high as the optimum level. It has been lower than F_{MSY} in only in two years, 1987 and 1988. (Results of the unweighted model are very similar.)

3.2 South Atlantic

Exclusion of the Taiwanese CPUE series made very little difference in analyses of the south Atlantic under the two-stock hypothesis (Table 1). This seems to indicate a desirable robustness to the results. Because there is no *a priori* reason to exclude the Taiwanese data series, we present the results of models using all available data. Both weighted and unweighted models estimated that the stock is at less than half of B_{MSY} (Table 1). Comparatively, the unweighted model estimated a higher MSY, but MSY estimates from both models are lower than catches from the south Atlantic in the most recent years. The unweighted model also estimated that the stock level in 1990 was lower relative to B_{MSY}. Both models estimated that the stock biomass has been steadily declining throughout the period studied (Fig 3). The last few years exhibit an accelerated decline, probably due to much increased fishing mortality in recent years (Fig. 4). The fishing mortality rates were estimated to have been well above F_{MSY} in most years (Fig. 4).

3.3 Total Atlantic

Exclusion of the Taiwanese CPUE series made very little difference in analyses under the single-stock hypothesis (Table 1), and we present the results of models using all data series. Because weighted and unweighted models gave very similar estimates (Table 1), we discuss the weighted model only. The estimate of MSY (3,623 MT) is higher than recent catches, but the estimates of recent relative biomass levels (Fig. 5) are quite low (about 40% B_{MSY}), suggesting that the stock cannot support continued harvest at present levels. The model also estimates that fishing mortality rates throughout the time period examined have been well above the optimum level.

4. DISCUSSION

Estimates of MSY from this study are lower than estimates made in the late 1970s and early 1980s (Table 2). However, when considered in the context of declining biomass levels, the current estimates do not seem unreasonable. The estimates made in the 1970s and 1980s used equilibrium models, which may provide overestimates of MSY when used on a declining population.

Assessments of Atlantic blue marlin in the early 1980's (Conser and Beardsley 1979; Conser and Farber 1981; Farber 1982; and Farber and Conser 1983) generally showed a precipitous decline in the stock(s) biomass from the early 1960's through 1980. Those results suggested that blue marlin were at least fully exploited and likely overexploited by 1980 or so. Concerns about the quality of the data base were voiced in those studies.

The main distinction between the early assessments and those presented here are that these analyses included an additional 10 years of data and used a more flexible model (ASPIC). The current model does not assume equilibrium, and it allows analysis of several data series. Despite the differences in models, results from ASPIC suggest declines in biomass to very low levels and in that respect are very similar to the early stock assessment results; the present analysis of the north Atlantic estimates a moderate increase in recent years. We consider these results tentative until sensitivity analyses, as recommended in Report of the 1992 Billfish Workshop (Miami), can be conducted. The 1992 Working Group was particularly concerned about the accuracy and completeness of landings data, and we share that concern. Even with that in mind, the results presented here provoke concern about the status of Atlantic blue marlin stock(s).

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Table 1. **Production model results for Atlantic blue marlin. Estimates of maximum sustainable yield (MSY) in metric tons and biomass in 1990 relative to the biomass that can sustain MSY (B90/BMSY) for models including (TAI) and omitting (NT) Taiwanese CPUE data. Results are also shown for weighted (W) and unweighted (U) models, and for the north Atlantic and south Atlantic (two-stock hypothesis) or total Atlantic (single-stock hypothesis).**

Area	Data	W/U	MSY	*B90/BMSY*
North	TAI	U	1,864	0.593
North	TAI	W	1,718	0.804
North	NT	U	26,520	0.038
North	NT	W	219,800	0.005
South	TAI	U	1,278	0.343
South	TAI	W	704	0.451
South	NT	U	1,185	0.139
South	NT	W	734	0.286
Total	TAI	U	3,517	0.323
Total	TAI	W	3,623	0.406
Total	NT	U	3,288	0.374
Total	NT	W	3,499	0.459

Table 2. **Comparative estimates of MSY (MT) and relative biomass level in 1990 from several sources. Sources: Second ICCAT Billfish Workshop 1992 (BFW); Kikawa & Honma, 1978 (KH); Farber & Conser 1983 (FC); Cramer & Prager 1992 (CP); Conser and Beardsley 1978 (CB). 1978 (CB).**

Area	Source	W/U	MSY	*B90/BMSY*
North	BFW	U	1,739	0.59
North	BFW	W	1,542	0.89
North	KH		2,300	
North	FC		2,232 to 2,623	
North	CP		1296 to 3,072	1 to 2
North	CB		2884 to 3,136	
South	BFW	U	1,207	0.34
South	BFW	W	561	1.29
South	FC		2,074 to 2,353	
South	CB		2,516 to 2,871	
Total	FC		3,807 to 5,040	
Total	CB		4,768 to 5,333	

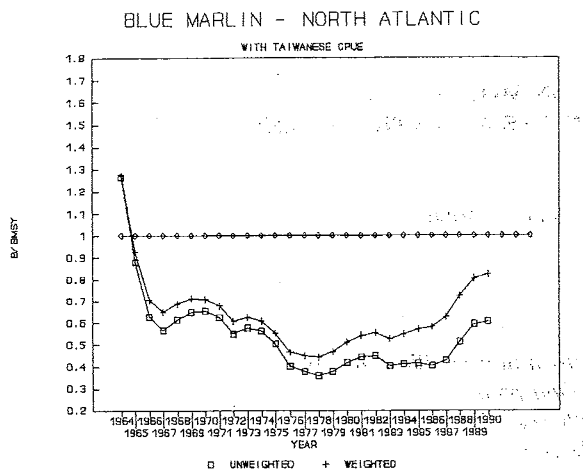

Figure 1. Blue marlin, north Atlantic. Estimated trajectory of $\underline{B}/\underline{B}_{MSY}$. The first three years have been omitted, as estimates are less precise.

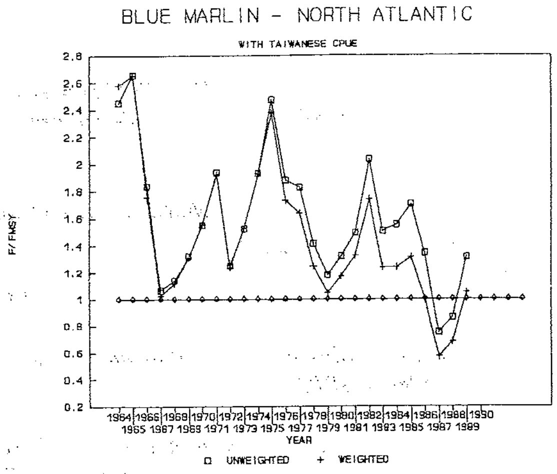

Figure 2. Blue marlin, north Atlantic. Estimated trajectory of $\underline{F}/\underline{F}_{MSY}$.

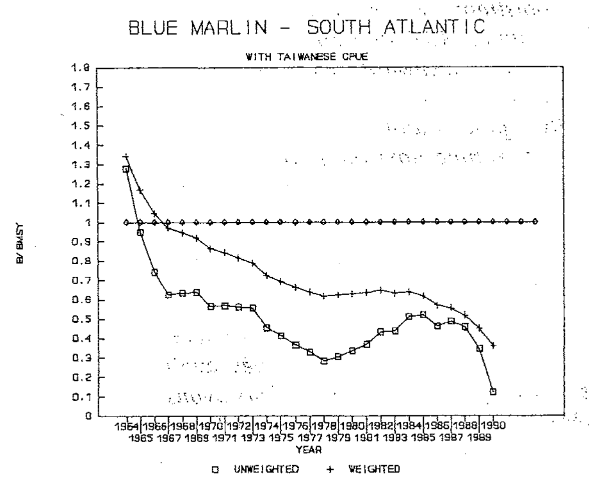

Figure 3. Blue marlin, south Atlantic. Estimated trajectory of $\underline{B}/\underline{B}_{MSY}$. The first three years have been omitted, as estimates are less precise.

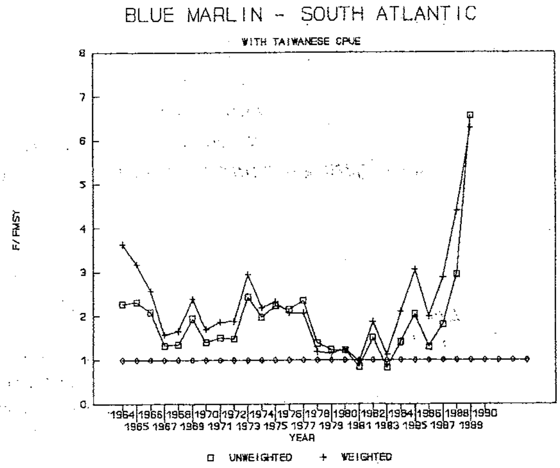

Figure 4. Blue marlin, south Atlantic. Estimated trajectory of $\underline{F}/\underline{F}_{MSY}$.

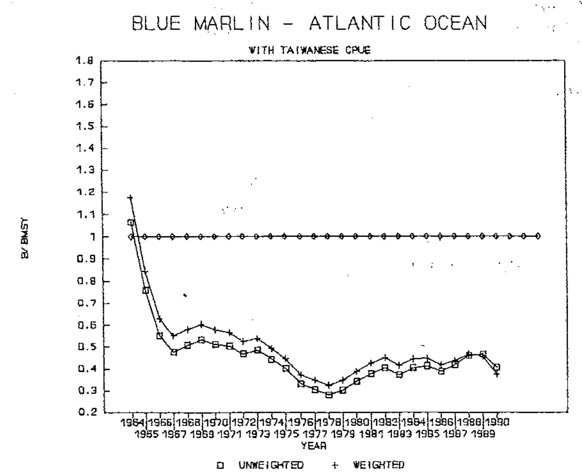

Figure 5. Blue marlin, total Atlantic. Estimated trajectory of $\underline{B}/\underline{B}_{MSY}$. The first three years have been omitted, as estimates are less precise.

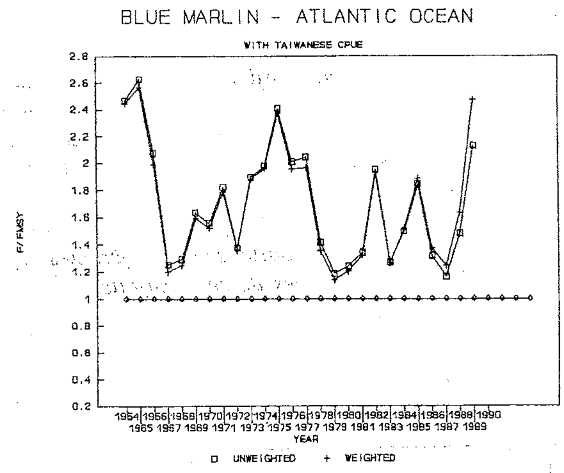

Figure 6. Blue marlin, total Atlantic. Estimated trajectory of $\underline{F}/\underline{F}_{MSY}$.