Exploitation of the Dolphin-Fish *Coryphaena hippurus* L. off Ecuador: Analysis by Length-Based Virtual Population Analysis

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Abstract

Dolphin-fish *Coryphaena hippurus* in the east Central Pacific are principally exploited by Ecuador. A length-based virtual population analysis of this fishery was sensitive to assumed values of growth parameters in respect of calculated fishing mortalities, but relatively robust in the estimation of exploitation rates. Comparison of estimated actual exploitation rates with estimated rates for $F_{0.1}$ obtained from length-based stock projections indicates the fishery to be somewhat overexploited.

Introduction

The dolphin-fish *Coryphaena hippurus* is one of the main fishery resources for the coastal fisheries of Ecuador. Over 2,000 artisanal fishers, operating some 680 vessels, are directly involved in the industry, which also supports a large number of associated workers. A large proportion of the catch is exported to the USA, resulting in significant foreign exchange earnings. In 1990, catches exceeded 11,600 t, valued at US$ 29 million in USA markets (Scott 1992).

The biology and population dynamics of the dolphin-fish were reviewed by Palko et al. (1982) and Oxenford and Hunt (1983, 1986). *C. hippurus* is a migratory pelagic fish which grows very quickly to a large size and has a worldwide offshore and coastal distribution in tropical waters warmer than 21°C (Scherbachev 1973). One of its several stocks occurs in the Panama Bight area, extending approximately from Ecuador to Costa Rica along the western coast of Central America. This stock appears to be principally exploited by Ecuador, as negligible landings have been reported by Colombia and neighboring countries to the north (Anon. 1988, 1989).

The fishery for dolphin off Ecuador, where it is known as "dorado", has been reviewed by Fallows et al. (in press). It is highly seasonal, with peak catches between November and May, and prosecuted by a small vessel artisanal fleet, fishing principally with sets of surface longlines of between 100 and 700 hooks, although surface gillnets are an alternative fishing gear. Hooks are baited with fish or squid and the longlines are set for 3-5 hours, usually in the early morning, with the lines being continually checked and re-baited. The principal fishing areas are located some 40-60 miles off the coast and over depths of around 150 m. Some fishers prefer to shoot their hooks where mixing of water masses can be discerned. The vessels are mostly light and fast fiberglass dories of 6-8 m length, powered by two-stroke outboards of 75-85 hp. Fuel in Ecuador is very cheap (ca. US$0.1 per liter in 1991) so that the vessels' high fuel consumption is not a great disadvantage.

Landings prior to 1985 were low. The history of catches by the fishery is given in Fig. 1, which shows a steady increase in catches in succeeding fishing seasons up to a decrease in the 1990-1991 season. This, coupled with the possible overfishing reported by Campbell et al. (1991), caused concern about the state of the fishery and prompted the calculation of the present assessment.

Methods

Reasonably good catch estimates by port and regular length-frequency sample data are available for dorado caught in Ecuador, as collected by the Instituto Nacional de Pesca (Guayaquil), following

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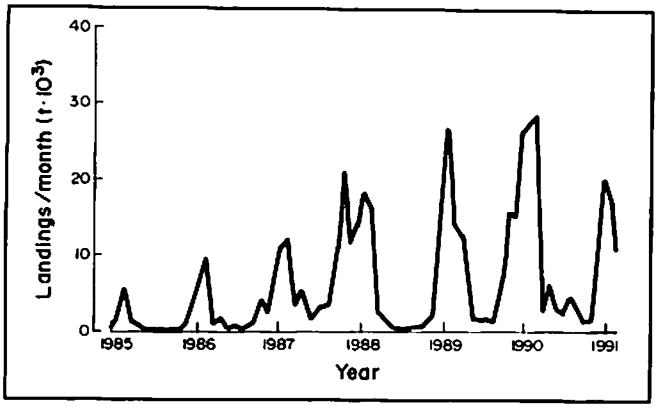

Fig. 1. Estimated monthly landings of dolphin *Coryphaena hippurus* in Ecuador. Based on catch per unit effort, effort and export data of the Instituto Nacional de Pesca and Dirección General de Pesca, Guayaquil, Ecuador, respectively.

the methodology of Fallows and Contreras (1991) and Fallows and Rideout (1991). However, no age data are available for this stock, and consequently a length-based stock assessment method was chosen. The key input for this study is a set of catch-at-length data for the period December 1988 to March 1991. Regular monthly samples were available, for the peak fishing season of November to May, from the ports of Anconcito, Santa Rosa, San Mateo and Manta while only a few samples were obtained from the remote northern port of Esmeraldas. Relatively few samples were available from outside the peak season, but as total catches during this period were very low, the errors introduced by this sampling deficiency were considered to be small. Initial estimates of von Bertalanffy growth parameters from modal progressions were rejected because size-specific migrations tended to produce misleading modal groups in the landings of different ports. Instead, growth parameter estimates from the Caribbean population were used, as derived from data in Beardsley (1967). Sea surface temperatures (SST) off Florida, where Beardsley took his samples, are typically in the range 22-26°C, which is similar to the SST off Ecuador.

The growth parameters estimated from Beardsley's data were then used for cohort slicing in a steady-state length-based virtual population analysis (Jones 1984). The results of this type of analysis depend largely upon the growth parameters used to slice the cohorts and so is sensitive to assumptions about these parameters. Thus, the analyses based on the parameter estimates based on Beardsley's data were repeated using values of K 10% above and below these estimates, and values of L_∞ 10% above, and as low as could be consistent with the available data on catch at length (Table 1). For each analysis, (i.e., combination of L_∞ and K), estimates of natural mortality M were obtained using Pauly's (1980) model, with SST held constant. Nine length-based virtual population analyses were then run for the various parameter combinations, each being iterated by setting terminal F to the mean F over the previous five 6-cm length-groups.

The results of each model fitting were then used to generate length-based yield-per-recruit projections in order to calculate $F_{0.1}$ values and the corresponding exploitation rates (E = F/Z).

Table 1. Mean seasonal catch at length of dolphin *Coryphaena hippurus* over the period December 1988 to March 1991 off Ecuador. Data recalculated from records of the Instituto Nacional de Pesca, Guayaquil.

Lower limit of 6-cm length class (cm)	No. of fish (·10³)
42	3
48	70
54	156
60	1,688
66	803
72	855
78	897
84	656
90	634
96	677
102	725
108	518
114	445
120	336
126	242
132	208
138	163
144	53
150	24
156	10
162	10
168	5
174	7
180	2

Results

Beardsley (1967) calculated mean fork lengths at age for dolphin of 72.5 cm at age 1; 117.5 cm at age 2; 142.5 cm at age 3, and 152.5 cm at age 4. These were converted to total lengths and the growth parameters K = 0.41 and L_∞ = 195 cm were estimated from these data. From this, and a mean annual sea surface temperature of 23.8°C (Anon. 1991), Pauly's model predicts a natural mortality M for the stock of 0.55 $year^{-1}$ with a range of M = 0.50 to 0.59 $year^{-1}$ for the various parameter combinations.

Estimated mean fishing mortalities (F) and exploitation rates (E) are given in Table 3. The estimated F is quite sensitive to the selected parameter combination, but the estimated mean exploitation rate is relatively insensitive and lies in the range of 0.5 to 0.6. The estimated exploitation pattern is also relatively insensitive to the choice of K and L_∞ (Fig. 2), as is the form - though not the level - of the yield-per-recruit curve (Fig. 3). Exploitation rates for $F_{0.1}$ were calculated and lie in the range 0.43 to 0.49.

Discussion

The fishing mortalities derived from length-based virtual population analysis were found to be rather sensitive to the choice of growth parameters. However, since, in this type of analysis natural mortality is derived from SST and growth parameters, some of this sensitivity is compensated for when exploita-

Table 2. Estimates of mean fishing mortality (F; $year^{-1}$) and of exploitation rate (E = F/Z; in brackets) by steady-state length-based virtual population analysis, for input L_∞ and K equal to and +/- 10% of central estimates.

Input L_∞ (cm)	Input K ($year^{-1}$) 0.36		0.41		0.44	
215	0.78	(0.61)	0.88	(0.62)	0.97	(0.63)
195	0.60	(0.54)	0.67	(0.55)	0.75	(0.56)
189	0.54	(0.51)	0.61	(0.53)	0.68	(0.54)

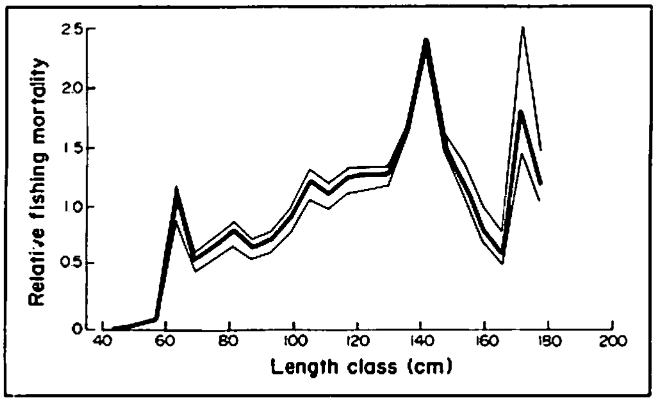

Fig. 2. Estimated exploitation pattern of dolphin in the Ecuadorian fishery (F relative to the overall unweighted mean F). Note the increase in selection with size and the irregular estimates of F at larger sizes due to incomplete sampling. Different curves were generated from separate analyses, using a range of values of K and L_∞ as in Table 2. The estimated curve for K = 0.41 $year^{-1}$ and L_∞ = 195 cm is drawn in bold.

tion rates are calculated. The values of E estimated here range from 0.51 to 0.63, with a central estimate of 0.55.

The corresponding length-based yield-per-recruit projections (Fig. 3) appear, similarly, to be relatively robust to assumptions made about growth parameters. The exploitation rates corresponding to $F_{0.1}$ ranged from 0.40 to 0.49, which is well below the observed range of 0.51 to 0.63, irrespective of the choice of growth parameters. This leads to the conclusion that the dolphin fishery in Ecuador is probably exploited well past $F_{0.1}$, and hence, that economic and growth overfishing occurs (Patterson 1991).

Length-based methods suffer from a number of disadvantages and are not the ideal way to assess a stock, as they tend to be strongly affected by incorrect choices of parameters and by gear selection and emigration. However, until a more reliable, age-based method can be applied, a cautious management policy would be to restrict further expansion in this fishery.

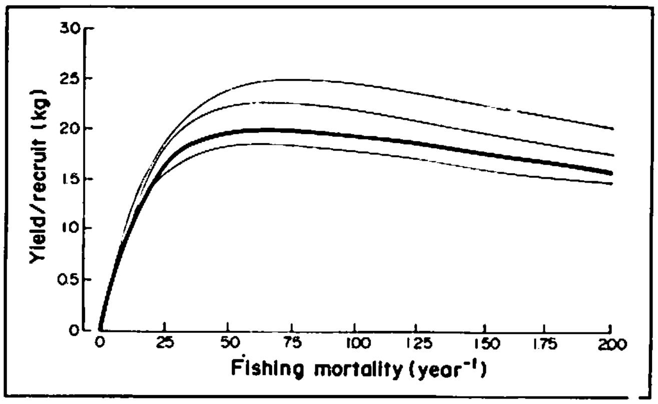

Fig. 3. Yield per recruit as a function of F for dolphin in the Ecuadorian fishery, calculated using length-based VPA adjustments for various combinations of K and L_∞. The line for K = 0.41 $year^{-1}$ and L_∞ = 195 cm is drawn in bold.

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