AN EVALUATION OF ASSUMPTIONS ASSOCIATED WITH BLUE MARLIN DEPTH DISTRIBUTION TOWARDS THE POSSIBLE INCORPORATION INTO THE STANDARDIZATION OF CATCH AND EFFORT STATISTICS FOR USE IN STOCK ASSESSMENT¹

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SUMMARY

Attempts to improve the accuracy of stock assessments of blue marlin (Makaira nigricans) and white marlin (Tetrapturus albidus) have included efforts to standardize CPUE data derived from by-catches of the longline fisheries in the Atlantic Ocean. It has been suggested that by failing to account for the temporal changes in the relative vertical distribution of marlins and longline gear, a bias will be present in the CPUE analysis. This paper examines the estimation of CPUE under the assumption that blue marlin are restricted to a narrow depth and temperature range.

RESUMEN

En un intento de mejorar la precisión de las evaluaciones de stock de aguja azul (Makaira nigricans) y aguja blanca (Tetrapturus albidus) se han hecho esfuerzos para estandarizar los datos de CPUE obtenidos partiendo de las capturas fortuitas de las pesquerías palangreras en el Atlántico. Se ha sugerido que al no tener en cuenta los cambios temporales en la distribución vertical relativa de los marlines y el palangre, los análisis de CPUE contendrán un sesgo. El documento examina la estimación de la CPUE con el supuesto que la aguja azul se circunscribe a una escala limitada en cuanto a profundidad y temperatura.

RÉSUMÉ

Afin d'améliorer la précision des évaluations du stock de makaire bleu (Makaira nigricans) et de makaire blanc (Tetrapturus albidus), on s'est efforcé de standardiser les données de CPUE dérivées des prises accessoires réalisées par les flottilles palangrières dans l'océan Atlantique. Il a été suggéré que si l'on ne tenait pas compte des modifications temporelles qui interviennent dans la distribution verticale relative des makaires et des engins de palangre, les analyses de la CPUE seraient faussées. Le présent document examine l'estimation de la CPUE en supposant que le makaire bleu se confine dans une gamme étroite de profondeur et de température.

KEYWORDS

Stock assessment, Longlining, Gear selectivity, Habitat, Dissolved oxygen, Fish physiology

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INTRODUCTION

Catch and effort data from the commercial longline fisheries for tuna and swordfish are a major component in the stock assessment of Atlantic marlins. Key biological assumptions concerning the random distribution of the stock are incorporated into the catch rate standardization procedures currently in use for generating indices of abundance. Changes in pelagic longline gear configurations in the Atlantic Ocean have raised questions concerning the possible disparity between the distribution of marlins and hook depth. Hinton and Nakano (1996) constructed a method for standardizing catch and effort data to account for the greater number of hooks used in the Pacific longline fishery. By estimating the depth at which the hooks are fishing in the water column and assuming that marlins are restricted to the mixed layer, the standardized CPUE in Hinton and Nakano (1996) showed an inverted pattern from that obtained from nominal CPUE. While the deeper gear deployment in the past two decades is well documented in both the Pacific and Atlantic Oceans, questions concerning the vertical distribution of marlins remain.

DISCUSSION

CPUE Standardization

General Linear Model (GLM) analysis has been used to standardize CPUE estimates of blue marlin and white marlin from the U.S. recreational sport fishery throughout the past decade. These indices of abundance were then incorporated into various stock assessment models. The most recent standardization of U.S. recreational CPUEs for marlins (Jones 1998) followed the methodology of Farber *et al.* (1994) used in the white marlin assessment by Farber and Jones (1994). They defined region, wave (twomonth period), and type (tournament or non-tournament) as the factors included in the GLM.

The CPUEs for marlins caught by the Japanese longline fishery in the Atlantic Ocean have been standardized using GLM analysis. Nakano et al. (1994a and 1994b) standardized blue marlin and white marlin data, respectively, for 1956-1989. The main effects in the model were fishing season, fishing area, and gear configuration. Data on gear configuration were available beginning in 1975 and were categorized by three levels of numbers of hooks between floats. The numbers of hooks between floats is an indication of both depth of gear and target species: low numbers (4-8) indicate shallow deployment with the target species being yellowfin tuna (Thunnus albacares), while high numbers (12-15) indicate deep deployment with the target being bigeye tuna (T. obesus). The deep longline was developed to fish in deeper water below the thermocline by the extension of the mainline between floats and to target the dominant catch of bigeye tuna (Uozumi and Nakano 1994). The calculated theoretical maximum hook depth for the "typical regular" longline was about 170 m and for the deep longline was about 300 m (Uozumi and Nakano 1994). Similarly, updated analyses by Uosaki (1998a and 1998b) incorporated the same effects in standardizing blue marlin and white marlin data for 1960-1995, where data on gear configuration beginning in 1975 further stratified the number of hooks between floats into four levels. The fourth level (15-20 hooks between floats) was added because gear with 16 or more hooks per basket was introduced in the late 1980s and has become more common in recent years.

Fishing Depth

Fishing efficiency of longline gear is dependent upon the shape assumed by the mainline while suspended underwater. Ideally, the main line remains a catenary on a vertical plane. However, eddies, currents, internal waves and other hydrographic features distort the shape of the catenary creating significant depth fluctuations (Hanamoto 1987, Boggs 1992, Okamoto and Uozumi 1997, Yano and Abe 1998, Berkeley and Edwards 1996, Mizuno *et al.* 1999). As a result, there is considerable uncertaintly associated with estimating the depth distribution of longline gear. Berkeley and Edwards (1996) found that depth among sections of mainline within a single set may vary between 30 and 180 m. Okamoto and Uozumi (1997) reported that hooks suspended at depths of 100 to 250 m in the absence of currents were

elevated to between 50 and 100 m for up to 10 hours when vertical shear was present. Boggs (1992) monitored longline gear deployed off Hawaii with electronic timing devices and noted that "achieving deep sets when intended was sometimes difficult". Although fish appeared to be caught at greater depths, the hook-timer devices established that sets averaged 54% to 68% of the target depth.

Ecological Aspects

Models correcting for changes in gear deployment are also based on biological information. Due to the difficulty and expense of sampling large, highly migratory fish (Prince and Brown 1991), there is a scarcity of data on the depth and temperature range of marlins. Assumptions about their vertical distribution are used in catch rate standardization but these are based on a limited understanding of the biological, physiological and behavioral characteristics of the species. Hinton and Nakano (1996) suggested that ecological factors are not adequately accounted for by the current method for standardizing CPUEs. Based on a sample size of 9 blue marlin (*Makaira nigricans*) from 2 telemetry studies, the authors proposed a departure from the current method of adjusting for hook distribution. By assuming that (1) blue marlin are confined to the mixed layer and (2) a modified catenary curve holds for the depth distribution of hooks in all longline sets, significantly different standardized CPUE estimates were obtained from nominal CPUE.

There have been 4 telemetry studies conducted to date on a total of 24 blue marlin (Yuen *et al.* 1974, Holland *et al.* 1990, Block *et al.* 1992(a), Graves *et al.* 2000). While some animals remained near the surface for several hours (Graves *et al.* 2000), others made short duration, deep dives to > 200 m (Block *et al.* 1992b). One of the 3 fish tagged with ultrasonic transmitters by Yuen *et al.* (1974) spent the entire 5.5 hrs it was tracked between 115 and 185 m, well within the hook trajectories of deep longline gear commonly used by the Japanese fishery (Okamoto and Uozumi 1997, NMFS Pelagic Observer Database 1992-1999).

Telemetry studies do not provide information on hooking injuries and post-release trauma. Upper palate injuries can be particularly damaging (Prince *et al.* In press) and the strenuous fight, typical of a capture event, probably requires energy expenditure beyond the marlins aerobic capacity (Holland *et al.* 1990, Block *et al.* 1992b). As demonstrated with tunas, which share many anatomical and physiological characteristics with billfish (Brill 1996), exhaustive exercise and anaerobic metabolism incur an oxygen debt that must be repayed while sustaining a level of swimming sufficient for hydrostatic equilibrium and ram gill ventilation (Benetti *et al.* 1995a, Benetti *et al.* 1995b, Brill 1996, Korsmeyer *et al.* 1996). A wounded fish may have even greater metabolic demands and swimming behavior and performance are likely to be atypical for an extended period of time. This possibility raises a concern that the depth distribution observed in telemetry studies may not be representative of their normal range.

The dissolved oxygen requirements of marlins are unknown. It is likely that, as with tunas, oxygen conditions are an important factor in determining gear vulnerability of marlins (Hanamoto 1987, Brill 1994). The oxygen-depth profiles of 4 major ocean basins (Pacific Ocean, Indian Ocean, South Atlantic and North Atlantic) are markedly different (Figure 1). The Pacific Ocean exhibits a considerable decrease in dissolved oxygen (to < 1 ml/l) at relatively shallow depths (Gross 1972), a potentially limiting factor in the depth distribution of highly migratory species. Comparatively, the North Atlantic Ocean has the highest dissolved oxygen concentrations of the ocean basins reviewed by Gross (1972), remaining saturated (> 6 ml/l) to at least 3000 m and providing suitable habitat for marlins and other pelagic species to greater depths than the Pacific Ocean. Consequently, blue marlin habitat models from Pacific observations are likely to be ineffectual in assessments of Atlantic stocks.

Physiologically, marlins have highly specialized adaptations that enable them to range widely throughout the water column. The presence of a thermogenic organ near the brain (Tullis *et al.* 1991, Block and Finnerty 1994) suggests that they have evolved the ability to control brain and eye temperature in order to expand their thermal range. Although the 6 blue marlin tracked by Block *et al.* (1992b) remained at relatively shallow depths (< 100 m) for most of the telemetry study, the authors concede that "it is possible that in other regions of their large range, or at other seasons of the year, blue marlin may enter colder water where thermoregulation of the brain and eyes becomes more important." This is further supported by reports of deep water prey found in the stomachs of marlins (Baker 1966, Erdman 1962, Strasburg 1970, Brock 1984, Harvey 1989, Venizelos personal observation). Although some deep water species undergo diurnal vertical migration, moving into surface waters by night (Nybakken 1988), marlin appear to be strictly daytime sight feeders (de Sylva 1974), suggesting that their feeding habits include forays into deep water.

CONCLUSION

In order to improve the existing methods for standardizing the relative selectivities of gear to accommodate changes in target depth, a greater understanding of the habitat preferences, depth distribution and gear vulnerability of billfish is required. *Ad hoc* models based on limited (non-statistical) data are unsuitable.

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Figure 1. Characteristic oxygen profiles of major ocean basins (copied from Gross 1972).