Life after Catch and Release

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Introduction

Conservation of Atlantic white marlin, *Tetrapturus albidus*, has been a concern of U.S. fishery managers since the 1980's. In 1988, domestic regulations established by the Atlantic Billfish Fishery Management Plan (FMP) (NMFS, 1988) required the release, dead or alive, of all white marlin caught in U.S Atlantic commercial fisheries. Management measures for U.S. recreational fishermen include a minimum size of 66 inches lower jaw fork length (NMFS, 1999). These measures and increased voluntary release of white marlin by recreational fishermen reduced reported U.S. commercial dead discards of white marlin by commercial fishermen from 81 t in 1990 to 41 t in 2000 and reported landings by recreational fishermen from 17 t in 1990 to 1 t in 2000.[1] However, the success of these conservation measures depends, not only on reduction of landings, but reduction in total mortality. Post-release mortality may be significant, particularly in recreational fisheries, where over 99% of the estimated 4,000 to 8,000 white marlin caught are released (Goodyear and Prince, 2003). Recent studies indicate that a minor change in hook type, from "J" hooks to circle hooks, may affect the frequency of deep-hooking and associated tissue trauma and therefore have a profound effect on post-release mortality (Horodysky and Graves, 2005). Sea turtle mitigation measures require the use of circle hooks by the U.S. longline fishery (Federal Register, 2004). U.S. recreational marlin fisheries have traditionally used "J" hooks and are not required to use circle hooks (Prince et al., 2002).

Until recently, data available for estimation of post-release mortality of large pelagic species included other factors. Low conventional tag recaptures (0.4–1.83%) (Prince et al., 2002; Ortiz et al., 2003), are confounded with tag shedding, low exploitation rate, and failure to report recaptured tags so that they do not provide sufficient information to estimate post-release mortality (Bailey and Prince, 1994; Jones and Prince, 1998). Acoustical tagging studies suggest relatively low post-release mortality rates for periods ranging from a few hours to a few days (e.g. sailfish, *Istiophorus albicans* (Jolley and Irby, 1979); blue marlin, *Makaira nigricans* (Holland et al., 1990; Block et al., 1992); black marlin, *Makaira indica* (Pepperell and Davis, 1999)). However, acoustical tagging data on Atlantic white marlin are limited (Skomal and Chase, 2002; n = 2 tracks) and furthermore, limitations and biases of acoustic tracking study procedures may limit the accuracy of the billfish post-release mortality estimates (Pepperell and Davis, 1999; Graves et al., 2002). These procedures include additional handling required to apply the acoustical tag to these animals which would be expected to increase mortality compared to mortality of animals that were only caught and released. On the other hand, animals that are in poor shape upon capture might be selectively released without the tag compared to animals that were in good shape. Selection for animals that are robust rather than average would cause a positive bias in survival rates. The acoustical data show that some billfish survive the catch and release experience in the short term. In summary, existing acoustic data cannot be relied upon to accurately estimate the fraction of fish that survive because of small sample sizes, biases due to handling, and limited observation time.

Pop-up satellite archival tag (PSAT) technology provides an improved tool for evaluating post-release mortality. PSAT's record environmental variables for predefined intervals, detach from an animal at a designated time, float to the surface, and transmit stored data to a satellite. These data allow analysis of post-release behavior of tagged fish. Although this new technology is promising, the available mortality estimates are based on small samples, are imprecise, are subject to similar procedural bias as described for acoustic tags, and are representative of only the gear and fishery studied (Goodyear, 2002).

Nine PSAT's attached to blue marlin caught on recreational gear (Graves et al.,

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ABSTRACT—Since 1988 regulations have required U.S. longline fishermen to release all Atlantic white marlin, Tetrapturus albidus. *By the late 1990's, approximately 99% of Atlantic white marlin caught by U.S. recreational fishermen were released. Recent studies using PSAT technology indicate that not all released fish survive and that a minor change in hook type, 0–5° offset circle hooks rather than straight-shank "J" hooks, may have a profound effect on post-release mortality. Beginning in 2004, sea turtle mitigation measures have required U.S. longline fishermen to use circle hooks. Estimates of total catch, releases, and post release mortality of Atlantic white marlin caught by U.S. recreational fishermen were made in order to evaluate the potential reduction in mortality that may be realized by requiring the use of circle hooks rather than straight-shank "J" hooks by U.S. recreational fishermen. These estimates were compared to estimates of Atlantic white marlin caught by the U.S. longline fishery.*

[1]ICCAT Executive Summary, White marlin 2004–2005(1). Unpubl. Rep., 8 p. 2004. Corazon de maria 8, 28002 Madrid, Spain.

2002) and nine PSAT's attached to blue marlin caught on longline gear (Kerstetter et al., 2003) did not have pre-release software or an emergency release device. Without these features it is not possible to differentiate between dead fish and lost or malfunctioning tags. Therefore the fate of the one blue marlin caught on recreational gear and two blue marlin caught on longline gear whose tags did not report is not clear. These fish may have died and sunk to a depth at which the tag was crushed, lost positive buoyancy, been eaten by sharks, or the tags could have been damaged or malfunctioned. The resulting post-release mortality estimates of 11.1% for blue marlin caught on recreational gear (Graves et al., 2002) and 22.2% for blue marlin caught on longline gear (Kerstetter et al., 2003) are not as reliable as estimates from more recent studies.

Advances in PSAT technology have improved post-release mortality estimates. Sixty-one PSAT's attached to striped marlin, *Tetrapturus audax*, caught with recreational tackle (Domeier and Dewar, 2003) and forty-one PSAT's attached to white marlin caught on recreational gear (Horodysky and Graves, 2005) contained pre-release software. The post-release mortality estimates from these studies (26.2% for striped marlin and 35% for white marlin caught on straight-shank "J" hooks and 0% for white marlin caught on circle hooks) are therefore more reliable because the PSAT's used were equipped with pre-release software or an emergency release device. These features allowed recovery of sufficient data from the tags to determine the fate of the fish. The higher post-release mortality estimate for white marlin compared to blue and striped marlin may be due to body size and/or to fishing techniques. Blue and striped marlin are generally larger than white marlin. Smaller fish may be more sensitive to catch-induced stress (Kieffer, 2000; Davis, 2002). Size and fighting time are critical factors and small marlin may be subjected to less stress in recreational fisheries because they are often fought for a shorter period of time (Kieffer, 2000).

Recreational fishing techniques in the western North Atlantic fisheries differ depending on the species targeted (Graves et al., 2002; Horodysky and Graves, 2005). High-speed trolled lures used to catch blue marlin often result in the fish being hooked in the mouth and head while aggressively pursuing the lures. White and striped marlin are more likely to be caught on natural baits with longer drop-back durations and are more likely to be deep-hooked (Horodysky and Graves, 2005).

The incidence of tissue trauma varied by species and by hook type. Straight-shank "J" hooks consistently resulted in more deep-hooking and tissue trauma compared to non-offset or 5° offset circle hooks in PSAT studies of striped and white marlin caught on recreational gear (Domeier and Dewar, 2003; Horodysky and Graves, 2005). Half of the 20 white marlin caught on straight-shank "J" hooks were deep-hooked, and 70% of those were bleeding. All (20) of the white marlin caught on non-offset or 5° offset circle hooks were hooked in the jaw, and only one fish appeared to be bleeding (Horodysky and Graves, 2005). Deep-hooking and tissue trauma were not observed in blue marlin. Most (89%) of the blue marlin caught on straight-shank "J" hooks were hooked in the jaw (Graves et al., 2002; Kerstetter et al., 2003). Prince et al. (2002) reported a greater incidence of hook-induced trauma in sailfish caught on straight-shank "J" hooks compared to fish caught on non-offset or minor offset circle hooks.

In recreationally-caught white marlin, hook type and subsequent hook induced tissue trauma appears to affect post-release survival. All (20) of the fish caught on non-offset or 5° offset circle hooks survived. All of these fish were jaw-hooked. Thirteen of twenty white marlin caught on straight-shank "J" hooks survived. Four of the seven observed mortalities were deep-hooked and bleeding. Of the other three mortalities, one was foul-hooked, not bleeding. The other two mortalities were jaw-hooked. One was bleeding and one was not bleeding (Horodysky and Graves, 2005).

Although the available estimates of post-release mortality are preliminary, the data indicate that some white marlin released from the recreational fishery do not survive, and that mortality of white marlin caught on straight-shank "J" hooks is higher than the mortality of white marlin caught on non-offset to 5° offset circle hooks. This paper uses recent post-release mortality estimates from PSAT studies to estimate total removal of white marlin by U.S. commercial and recreational fisheries over 5 years (1998–2002) and evaluates the potential reduction in mortality that may be realized by requiring the use of circle hooks rather than straight-shank "J" hooks in the recreational fishery.

Materials and Methods

U.S. recreational landings and U.S. longline dead discards reported to the International Commission for the Conservation of Atlantic Tuna (ICCAT) for white marlin were obtained from the 2003 U.S. National Report (Table 1) (NMFS, 2003). The recreational landings are recent estimates based on both U.S. NMFS Marine Recreational Fishery Statistics Survey (MRFSS) and Recreational Billfish Survey (RBS) data (Goodyear and Prince, 2003). While these estimates are more complete than the former minimum estimates based only on RBS data (Goodyear and Prince, 2003), they are still likely to be an underestimate since the MRFSS does not cover the Caribbean, and coverage by RBS of non-tournament fishing effort is limited.

Summarized RBS and MRFSS data, including numbers of white marlin kept and released by year, were obtained from the NMFS[2] (Table 2). These are numbers of fish reported to the survey, not estimates of total catch. RBS data were used to estimate the percentage of white marlin released by the U.S. recreational fishery because they are considered to be more accurate than the MRFSS data (Goodyear and Prince, 2003). The 4-year (1998–2001) MRFSS estimate of percentage released (99%) is similar to the 5-year (1998–2002) RBS estimate of percentage released (98%). RBS percent released estimates for 1998 through 2002 were 98%, 97%, 99%, 98%, and 99%, respectively (Table 2). The release esti-

[2]Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149

mates from RBS data along with landings reported to ICCAT (NMFS, 2003) were used to estimate the metric tons of white marlin caught (kept and released) by the U.S. recreational fishery (Table 3).

Horodysky and Graves (2005), estimated a post-release mortality of 35% for white marlin caught on straight-shank "J" hooks by recreational fishermen. The 95% CI for this estimate was 15–59%. Their estimate of post-release mortality for white marlin caught on non-offset or 5° offset circle hooks was 0%. Although these estimates are based on relatively small sample sizes and a limited spatial coverage, they demonstrate the importance of hook type to post-release survival of white marlin. The precision of their estimate for "J" hooks is low, and it may not be representative of the recreational fishery as a whole. However, the estimated range for this gear highlights the need to consider post-release mortality in this fishery which still relies heavily on "J" hooks. I applied their 35% estimate and 95% CI to compute the additional biomass of white marlin that may have been removed from the stock as a result of post-release mortality in the recreational fishery (Table 3, Fig. 1).

U.S. longline dead discards reported to ICCAT are based on effort reported by U.S. longline fishermen to the NMFS and catch per unit effort from NMFS longline observer program. The estimates are made by matching year, quarter, and area strata (Cramer, 1999). Since the NMFS observer program was designed to monitor swordfish catch, estimates of catch for less common species, such as white marlin, are subject to great variability; both underestimation and overestimation are likely.

An estimate of the percentage of white marlin released alive of 51% from NMFS observer data (Beerkircher et al., 2004) was considered to be more appropriate than estimates based on self-reported data from U.S. longline fishermen (NMFS, 1999) since observer data were used to estimate catch per unit effort. This estimate of live releases from longline vessels is based on a scientific observer's judgment of the status of the fish while the recreational released estimates are based on the fishermen's reports of whether the fish was kept or released with no information about the status of the released fish (NMFS, 1999). Estimates of white marlin discarded alive by U.S. longline vessels were obtained using the metric tons of dead discards reported to ICCAT and the observer data estimate of the percentage of white marlin released alive (Table 4). No post-release mortality estimates for white marlin caught by U.S. longline fishermen are presently available. Therefore, the range of possible longline post-release mortality was 0–100% in Figure 1.

Table 1.—White marlin catch estimates reported to ICCAT (Task I). "Total Atlantic" data are the total metric tons of white marlin reported to ICCAT by all nations[1], "U.S. LL discards" are the estimated metric tons of white marlin discarded by U.S. longline vessels, and "U.S. landings (recreational)" are the estimated metric tons of white marlin landed by U.S. recreational fishing vessels (NMFS, 2003).

Year	Total Atlantic	U.S. LL dead discards	U.S. UNCL or purse seine	U.S. landings (recreational)	U.S. percentage of total landings
1998	1,069	32	1	5.2	4%
1999	1,025	56.7	0.1	5.2	6%
2000	935	40.8		1.3	4%
2001	642	16.5		3.4	3%
2002	822	29.3	0.4	5.6	4%

[1] ICCAT report 2004-2005(1) Executive Summary, White marlin. Unpubl. Rep., 8 p. 2004. Corazon de maria 8, 28002 Madrid, Spain.

Table 2.—U.S. recreational catch statistics for white marlin from the U.S. Marine Recreational Statistics Survey (MRFSS) and the NMFS Recreational Billfish Survey (RBS) from Louisiana through Maine (excludes Texas). The columns labeled "Kept" are the numbers of landed white marlin. The columns labeled "Rel" are the numbers of released white marlin. These are numbers of fish reported to the survey, not estimates of total catch.

	Marine Recreational Statistics Survey (MRFSS)			Recreational Billfish Survey (RBS)		
Year	Kept	Rel	%Rel	Kept	Rel	%Rel
1998	0	15,968	100%	96	3,769	98%
1999	58	3,592	98%	105	2,909	97%
2000	26	8,180	100%	8	1,070	99%
2001	0	12,547	100%	62	2,734	98%
2002	0	4,650	100%	33	2,218	99%

Table 3.—Estimated U.S. recreational white marlin catch (landed and released) in metric tons, estimated U.S. recreational landed white marlin in metric tons, estimated U.S. recreational released white marlin in metric tons, and total recreational mortality in metric tons if post-release mortality (prm) is equal to 35% (Horodysky and Graves, 2005).

Year	U.S. estimated recreational catch	U.S. estimated recreational landed	U.S. estimated recreational released	U.S. estimated mortality recreational (prm=35%)
1998	209.4	5.2	204.2	76.7
1999	149.3	5.2	144.1	55.6
2000	175.2	1.3	173.9	62.2
2001	153.3	3.4	149.9	55.9
2002	382.0	5.6	376.4	137.3
5-year average	213.8	4.1	209.7	77.5

Table 4.—Estimated U.S. longline catch (live and dead discards) in metric tons, estimated U.S. longline dead discards in metric tons, and estimated U.S. longline live discards in metric tons.

Year	U.S. estimated longline catch	U.S. estimated longline dead discards	U.S. estimated longline live discards
1998	65.3	32.0	33.3
1999	115.7	56.7	59.0
2000	83.3	40.8	42.5
2001	33.7	16.5	17.2
2002	59.8	29.3	30.5
5-year average	71.6	35.1	36.5

Results and Discussion

The impact of post-release mortality on white marlin from the U.S. recreational fishery has the potential to be very large compared to the post-release mortality of white marlin from the U.S. longline fishery (Fig. 1). The estimated average total catch of white marlin for the 5-year period (1998–2002) by the U.S. longline fishery is 72 t compared to 214 t caught by the U.S. recreational fishery. While approximately 49% of U.S. long-

line catch is currently reported to ICCAT, only 1–2% of recreational landings are reported. If post-release mortality of white marlin caught by the recreational fishery is 35% or more, then the removals of white marlin by the U.S. recreational fishery are, on the average, greater than the total catch of white marlin by the U.S. longline fishery (Tables 3 and 4). Even at the low end of estimated post-release mortality (15%) the estimated removal is 32 t.

Conclusion

There is considerable evidence that the use of 0-5° offset circle hooks rather than straight-shank "J" hooks reduces incidence of hook-induced trauma in billfish (Prince et al., 2002; Domeier and Dewar, 2003; Horodysky and Graves, 2005) and results in lower post-release mortality in white marlin (Horodysky and Graves, 2005). Use of circle hooks by the U.S. longline fishery is already required for sea turtle mitigation measures (Federal Register, 2004). The mandatory use of 0–5° offset circle hooks by recreational fishermen has a great potential for reducing the mortality of white marlin in the U.S. fishery. For instance, a reduction in U.S. recreational post release mortality of 20% could save a minimum of 40 t of white marlin each year.

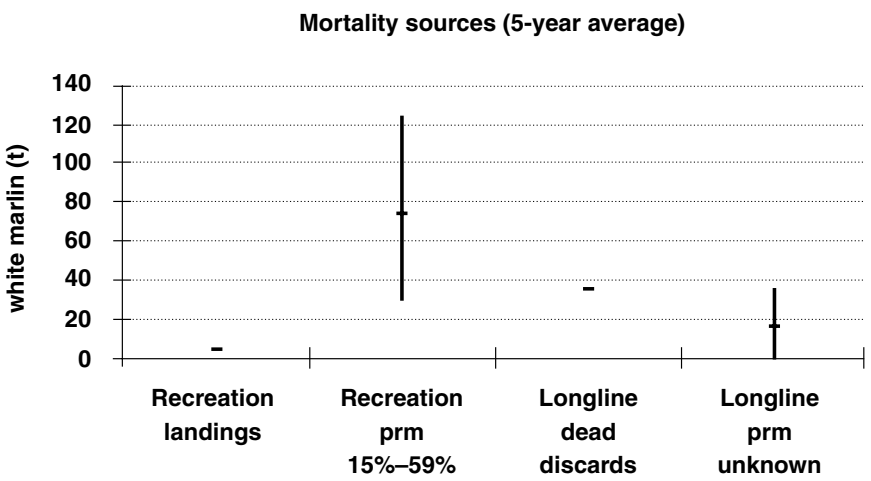

Figure 1.—Comparison of sources of white marlin mortality from U.S. recreational and U.S. longline fisheries. Sources include: reported landings of white marlin in metric tons from the U.S. recreational fishery (recreation landings) (NMFS, 2003), range of estimated recreational post-release mortality (95% CI) (recreation prm 15–59%) (Horodysky and Graves, 2005), reported metric tons of dead discards from U.S. longline vessels (longline dead discards) (NMFS, 2003), range of possible longline post release mortality (longline prm unknown).

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