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[Management Brief]

Postrelease Survival of Sailfish Caught by Commercial Pelagic Longline Gear in the Southern Gulf of Mexico

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Abstract.—The biomass levels of several target species of the Atlantic pelagic longline fishery, including various tunas of the genus *Thunnus* and swordfish *Xiphias gladius*, are estimated to be close to those required to support the maximum sustainable yield. In contrast, several species captured incidentally are severely depleted. Live release of incidental catch is one means of reducing the fishing mortality of these species without sacrificing the target catch, but the efficacy of such a measure is predicated on the assumption that postrelease survival is relatively high. Prior work has evaluated postrelease survival from pelagic longline gear for the larger istiophorid billfishes, such as blue marlin *Makaira nigricans* and white marlin *Kajikia albida*, but survival rates are unknown for sailfish *Istiophorus platypterus*. To estimate the postrelease survival of sailfish caught on pelagic longline gear in the southern Gulf of Mexico, short-duration pop-up satellite archival tags (PSATs) were deployed on captured sailfish for 10-d periods. Of the 29 sailfish captured, 20 (68.9%) were alive at the time of longline haulback, and the first 17 encountered alive were tagged. All tags transmitted at the preprogrammed times, and data from 15 of the 17 PSATs (88.2%) were consistent with the survival of the tagged sailfish for the 10-d tag deployment. Our results clearly demonstrate that sailfish can survive the trauma from interaction with pelagic longline gear and that management measures promoting the release of live individuals from this fishery can significantly reduce sailfish mortality without reducing the catches of target species.

Pelagic longline (PLL) fishing gear is used throughout the world in tropical and temperate waters to commercially harvest a variety of large pelagic fish species (Table 1), including swordfish and various tunas such as yellowfin tuna, bigeye tuna, and albacore. This gear is often considered to be more selective than pelagic trawling or gill netting (Yamaguchi 1989), though a significant bycatch of nontarget fishes remains. Within the Atlantic Ocean, the biomass of most of the major species targeted by the international PLL fishery are at levels estimated to be close to those necessary to support maximum sustainable yield (ICCAT 2007; Table 1). In contrast, the biomass levels for several species taken incidentally in this fishery, including many of the istiophorid billfishes, are severely reduced (ICCAT 2007). An increased level of attention has been given to incidental (retained nontarget) catch and bycatch in commercial fisheries (e.g., Myers and Worm 2003; Sibert et al. 2006). Management measures to reduce the fishing mortality of overfished species taken incidentally on PLL gear include reductions in effort, time and area closures, gear modifications, and combinations of these measures. Recent changes in terminal gear types (e.g., the use of circle hooks) have shown some promise to reduce bycatch mortality with little impact on target species catch rates (Watson et al. 2005).

In the Atlantic Ocean, sailfish are managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Separate western and eastern management units (stocks) have traditionally been recognized for assessment purposes based on historical catch-and-effort records and conventional tag returns (ICCAT 2007). Atlantic sailfish are targeted with a variety of fishing gears, including local artisanal handline fisheries in several developing countries and economically important rod-and-reel recreational fisheries. However, sailfish are also caught as bycatch in the PLL fishery, which is estimated to account for approximately one-third of the western sailfish fishing mortality over the last decade (ICCAT 2007). Formal assessments have not been conducted recently for either sailfish stock, and even quantification of landings remains difficult (ICCAT 2007). Assessment efforts have been hampered by the historical lumping of Atlantic sailfish landings with spearfishes of the genus *Tetrapturus*; efforts to separate out these landings post hoc have proved difficult (Kikawa and Honma 1982; ICCAT 2001). Current removals of sailfish from the western Atlantic stock probably exceed replacement (ICCAT 2007), and international

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TABLE 1.—Comparison of biomass estimates for target and nontarget species in the Atlantic Ocean, as reported by ICCAT (2007), for the international pelagic longline fishery. The annual catch percentage, (reported landings + reported discards) is the proportion of the total sport and commercial catch for that species. Estimates of biomass and fishing mortality are from the most recent available assessments; the first subscript indicates the year in question, the second (MSY) the biomass necessary to produce maximum sustainable yield.

Species, stock	Relative biomass (B)	Relative fishing mortality (F)	Longline means: 2000–2005 Landings (metric tons)	Longline means: 2000–2005 Annual catch (%)
Target species				
Swordfish *Xiphias gladius*, South Atlantic	B_{2006}/B_{MSY} = likely >1	F_{2005}/F_{MSY} = likely <1	13,797	96.1
Swordfish, North Atlantic	$B_{2006}/B_{MSY} = 0.99$ (0.87–1.27)	$F_{2005}/F_{MSY} = 0.86$ (0.65–1.04)	11,163	94.5
Bigeye tuna *Thunnus obesus*	B_{2003}/B_{MSY} = 0.85–1.07	F_{2002}/F_{MSY} = 0.73–1.01	82,152	62.7
Yellowfin tuna *T. albacores*[d]	B_{2001}/B_{MSY} = 0.73–1.10	F_{2001}/F_{MSY} = 0.87–1.46	29,468	41.9
Albacore *T. alalunga*, North Atlantic	$B_{2005}/B_{MSY} = 0.81$ (0.69–0.97)	$F_{2005}/F_{MSY} = 1.50$ (1.30–1.70)	27,819	22.9
Nontarget species				
White marlin *Kajikia albida*[a]	$B_{2004} < B_{MSY}$	$F_{2004} > F_{MSY}$, possibly	251[b]	90.8[a]
Sailfish *Istiophorus platypterus*, Western Atlantic	[c]	[b]	1,731	67.8
Blue marlin *Makaira nigricans*	$B_{2004} < B_{MSY}$	$F_{2004} > F_{MSY}$	781[a]	64.0[a]

[a] Formerly *Tetrapturus albidus* (see Collette et al. 2006).
[b] Catches from North Atlantic only.
[c] Not estimated during the most recent stock assessment.
[d] Catches from western Atlantic only.

management actions such as live release may be required to prevent further stock reductions.

No ICCAT management measures for sailfish are currently in effect. However, U.S. management measures have prohibited the retention of sailfish by domestic commercial fishers since the approval of the first National Marine Fisheries Service (NMFS) fishery management plan for Atlantic billfish in 1988 (NMFS 1988). The available literature suggests that one-third to more than one-half of the sailfish caught in PLL fisheries are alive at the time of longline retrieval (haulback), the percentage that is alive being greater for fish caught with circle hooks than for those caught with J-hooks (Farber and Lee 1991; Jackson and Farber 1998; NMFS 2007). The efficacy of live release in reducing sailfish mortality depends on the rates of survival at PLL haulback and the rates of survival for animals released from the gear.

The survival rate of sailfish released from PLL gear is presently unknown. Pop-up satellite archival tags (PSATs) provide a means to overcome many of the limitations of conventional and acoustic tags that preclude their use in determining postrelease survival (reviewed in Graves et al. 2002; Kerstetter and Graves 2006a). For example, the use of PSATs to assess fishery impacts on white marlin has revealed high postrelease survival rates for billfish species from both recreational rod-and-reel and commercial PLL gear types (Horodysky and Graves 2005; Kerstetter and Graves 2006a; Graves and Horodysky 2008).

Our study was undertaken to estimate the survival of sailfish released alive from coastal PLL gear and thereby (1) to assess the efficacy of the current domestic management measure requiring live release and (2) to determine whether such a measure could have a significant conservation benefit for sailfish stocks if adopted throughout the Atlantic region.

Methods

Deployments of PSATs on sailfish occurred in the southern Gulf of Mexico, about 90 km south-southwest of Key West, Florida, in an area traditionally targeted by the U.S. coastal PLL fleet. All (17) PSATs were deployed opportunistically aboard the 16.5-m commercial fishing vessel *Kristin Lee*, 1 PSAT in November 2005, 9 in May 2006, and 7 in June 2007. The primary target species for all three trips was swordfish and, as is standard in the fishery, all sets used chemical lightsticks. The gear was deployed at dusk, and haulback was at dawn. The gear configuration consisted of 18.3-

m leaders and buoy float-line lengths and either 16/0 nonoffset circle hooks (Model 39960: O. Mustad & Son, Gjövik, Norway) or size 18/0 less than 10 degree-offset circle hooks (Model lpcirbl: Lindgren-Pitman, Pompano Beach, Florida). The bait was mostly frozen squid of the genus *Illex* but occasionally included frozen Atlantic mackerel *Scomber scombrus*.

Microwave Telemetry (Columbia, Maryland) Model PTT-100 HR satellite tags were rigged with a fluorocarbon monofilament tether and a large nylon dart head per Graves et al. (2002). This tag, which sampled temperature, pressure (depth), and irradiance (light level) approximately every 90 s, included emergency release software that automatically initiated PSAT detachment if the pressure sensor indicated depths approaching the crush limit of the tag casing (about 2,000 m). The PSATs deployed in 2007 had additional "fail-safe" programming that would trigger the release of the tag from the animal if it remained at a constant depth (±20 m) for more than 96 h, suggesting a mortality resting on the ocean floor or a prematurely released tag floating on the surface. All PSATs were preprogrammed to release from the fish after 10 d. Data were transmitted through the Advanced Research and Global Observation Satellite (ARGOS) system after detachment from the animal.

The PSAT tagging procedures used were identical to the ones described in Kerstetter and Graves (2006a), although a smaller applicator tip (8 cm) was employed to compensate for the more laterally compressed sailfish body form. The first 17 sailfish evaluated as alive were tagged, regardless of size, hooking location, or physical condition. Hook type and hooking location (following Yamaguchi 1989) were noted, and fish condition was evaluated with the 10-point ACESS scale (see Kerstetter et al. 2003). Sailfish were released as soon as possible after tagging by the standard commercial protocol of cutting the leader near the hook unless the hook was readily accessible for manual removal. A conventional NMFS Cooperative Tagging Center streamer tag was also attached posterior of the PSAT on all fish. No fish were resuscitated after tagging, and the total time at boatside for each animal was less than 5 min.

The survival of tagged animals was inferred from three types of environmental data provided by the tag: water temperature changes, depth changes, and ambient light intensity. Frequent short (<15-min) variations in both depth and temperature throughout the 10-d period with daily changes in light level were taken as indicators of a live sailfish.

The 95% confidence intervals associated with the postrelease mortality estimates were calculated per Kerstetter and Graves (2006a) using the release mortality software (version 1.1.0) developed by Goodyear (2002). Confidence intervals were based on 10,000 simulations, the assumed underlying postrelease mortality rate being derived from the transmitted data with no error sources (e.g., no premature releases or tag-induced mortality). For the purpose of these simulations, natural mortality was also assumed to be zero (because of the relatively short tagging deployment period) and the full deployment period was used as the time for full expression of postrelease mortality.

Results

Three trips comprising 17 sets (approximately 6,300 total hooks) were taken to deploy PSATs on sailfish caught by coastal PLL gear targeting swordfish. The bycatch of istiophorid billfishes was minimal, comprising less than 3% by number of the total catch. Of 29 sailfish on the gear at the time of haulback, 20 (68.9%) were alive, including 3 that broke off the leader before tagging. The estimated fork lengths (lower jaw to tail fork) of the 17 PSAT-tagged and released sailfish ranged from 107 to 183 cm (mean, 139 cm; Table 2). Twelve of the fish were hooked inside or about the mouth, four were foul-hooked, and another was not hooked but entangled in the leader. Only one sailfish (5-01; Table 2) was so deeply hooked that the hooking location was not visible on examination alongside the vessel. One sailfish tagged during this study was hooked through the eye orbit (but damage to the eye itself was not visible). Of the 9 sailfish that were dead at haulback, 4 were hooked internally, 2 were foul-hooked around the tail, and 3 had lost their hooks before the hooking location could be ascertained.

All 17 PSATs reported to the ARGOS satellites, although 3 had a 1-d or 2-d delay from expected pop-up date to the date of first transmission. An average of 69.8% (range, 25–88%) of the archived data were transmitted through the ARGOS system. Four (23.5%) of the PSATs were found on shore following cessation of the transmission period and returned to the authors, one in 2006 and three in 2007. All (100%) of the archived data were recovered from these four returned PSATs.

The depth and temperature data transmitted from the PSATs indicated that 15 of the 17 (88.2%) sailfish released from the PLL gear survived for the full 10-d deployment period (Figure 1a, b). Fifteen fish showed similar short-scale vertical movements throughout the 10-d period. Although all of the surviving fish spent the majority of time within 50 m of the surface, several demonstrated frequent movements to depths in excess of 100 m (Figure 1a, b).

TABLE 2.—Summary of tagging (pop-up satellite archival tags) efforts for sailfish in the southern Gulf of Mexico, 2005–2007. The ACESS score refers to a physical condition index based on a 10-point scale (10 = best possible condition; see Kerstetter et al. 2002), and the reporting percentage is the amount of archived data transmitted back via satellite (ARGOS system). Estimated lengths are from the lower jaw to the tail fork.

Fish[a]	Hooking location	Hook size	Hook removed?	ACESS score	Estimated length (cm)	Reporting percentage	Survived?
5-01	Not visible	18/0	No	9	152	25	No
6-01	Corner	16/0	Yes	9	137	59	Yes
6-02	Lower jaw	18/0	Yes	9	183	82	Yes
6-03	Fouled	16/0	No	8	168	63	Yes
6-04	Isthmus	18/0	Yes	10	183	55	Yes
6-05	Corner	16/0	No	10	168	68	Yes
6-06	Eye socket	16/0	No	9	152	75	Yes
6-07	Fouled	16/0		8	152	65[b]	Yes
6-08	Lower jaw	18/0	Yes	8	168	40	Yes
6-09	Corner	18/0	Yes	8	152	68	Yes
7-01	Corner	16/0	No	9	122	75	Yes
7-02	Corner	16/0	No	8	122	88	No
7-03	Corner	16/0	No	6	122	87	Yes
7-04	Corner	16/0	No	10	122	74[b]	Yes
7-05	Corner	16/0	No	10	137	86[b]	Yes
7-06	Corner	16/0	No	5	107	88	Yes
7-07	Corner	16/0	No	6	122	88[b]	Yes

[a] Fish with at number starting with 5 were tagged in November 2005, fish with a number starting with 6 in May 2006, and fish with a number starting with 7 in June 2007.

[b] Original reporting percentage; tags were later found and returned, giving a 100% data recovery rate.

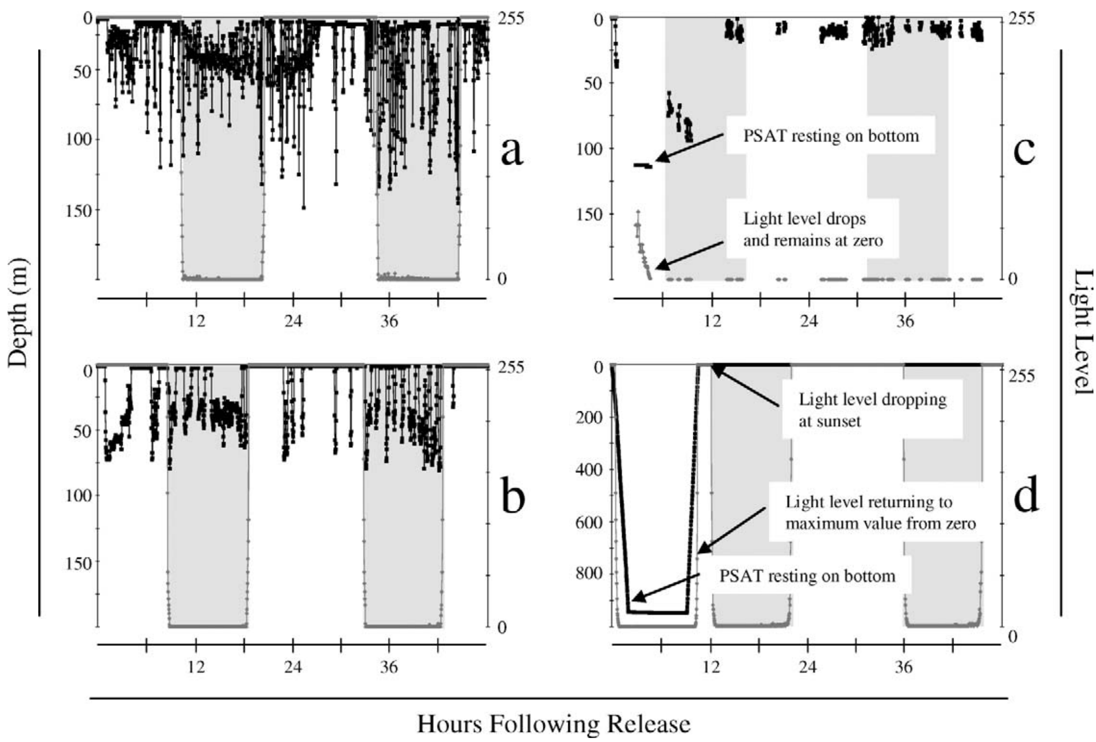

FIGURE 1.—Vertical movements (dark lines) of four sailfish tagged with pop-up satellite archival tags (PSATs) in the southern Gulf of Mexico and associated light levels (light lines [red in the online version]). Light level values are unitless and range from 0 (minimum) to 255 (maximum). The shaded bars represent nighttime periods. Each track is the beginning 48-h segment of a 10-d PSAT deployment period. Panels **(a)** and **(b)** are for animals 6-07 and 7-05, respectively (Table 2), which survived the experiment; panels **(c)** and **(d)** are for animals 5-01 and 7-02, which did not.

Both sailfish mortalities occurred soon after the fish were released from the gear. One deeply hooked sailfish (5–01; Figure 1c) exhibited some vertical movements during the first 12 h following release, and then apparently came to rest on the seafloor for at least 2 h with no movement or temperature fluctuations. During the next 48 h, the PSAT showed extensive vertical movements with minimal changes in temperature (25.5–26.2°C) and no recorded ambient light, even during daylight hours. As in Kerstetter et al. (2004), we conclude that this PSAT (and probably part of the dead sailfish) was eaten by a scavenging animal such as a shark and subsequently regurgitated. Sailfish 7-02 (Figure 1 d) also apparently died shortly after release from the PLL gear. This individual was located offshore of the continental shelf at the time of death because the archived depths increased rapidly before the PSAT (and presumably the sailfish) came to rest at 944 m. Light intensities were below the detection sensitivity of the tag sensor at this depth, hence archived light level readings fell to zero. The PSAT subsequently detached from the animal after approximately 7 h, and archived light levels returned to the maximum value again while floating at the bright surface.

The directional movements of the tagged sailfish were variable (Figure 2). However, most (12) of the surviving fish probably remained within the U.S. Exclusive Economic Zone (EEZ), many in the 2007 tagging season moving east-northeast within the Gulf Stream along the shelf on the east coast of Florida toward West Palm Beach and northward (see Nelson and Farber 1998). Two fish that remained in the U.S. EEZ traveled westward into the eastern Gulf of Mexico. For the remaining three, the first reported locations of two sailfish were within the EEZ of the Commonwealth of the Bahamas (one 88 km due west of Andros Island at the edge of the Great Bahama Bank and the other 90 km west-northwest of Walker Cay off the northern edge of the Little Bahama Bank). Only one sailfish in the study was within the EEZ of the Republic of Cuba at the end of the 10-d period, the first PSAT transmission occurring in northern Cuban shelf waters just west of Bahía de Cabañas.

These data result in an overall postrelease survival rate of 88.2%. Assuming an underlying true postrelease mortality rate of 11.8% and a study of 17 total satellite PSATs, the results of the Goodyear (2002) simulation indicate a 95% confidence interval of 0–23.5% mortality for sailfish within 10 d of release. To date, none of the conventional (dart) tags applied to the PSAT-tagged fish have been reported or returned to the NMFS Cooperative Tagging Center.

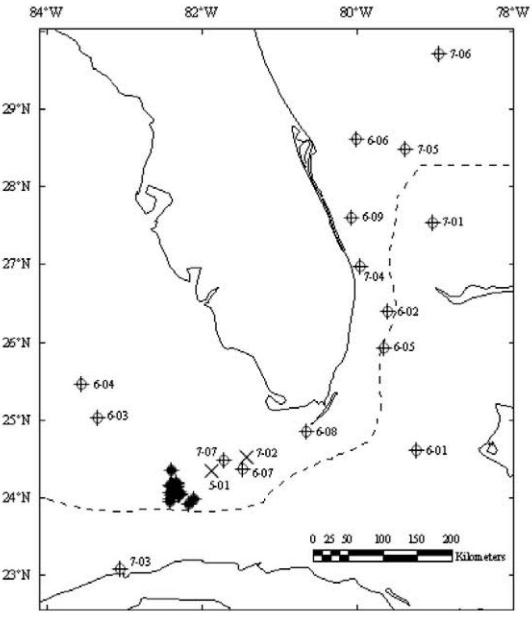

FIGURE 2.—Map showing the locations of release and first transmission for 17 sailfish (Table 2) tagged with pop-up satellite archival tags. Filled circles with crosses denote the tagging locations, open circles with crosses the first points of contact with transmitting tags after release from the fish; mortalities are indicated by times signs. The dashed line indicates the boundary of the U.S. Exclusive Economic Zone.

Discussion

Previous studies of blue and white marlin have revealed relatively high rates of postrelease survival. A study of white marlin using PSAT technology showed that a 16-kg individual was capable of carrying a longer-duration PSAT for 43 d, traveling almost 1,500 km during the deployment period (Kerstetter and Graves 2006a). Like the sailfish studied by Hoolihan (2005) in the Arabian Gulf, sailfish tagged from recreational vessels in the Pacific Ocean off Central America (Prince et al. 2006) carried similar-sized satellite archival tags for up to 118 d; however, these fish (mean weight, 19.0 kg) were generally smaller than the white marlins (21.2 kg) tagged by Kerstetter and Graves (2006a). We do not believe that the size of any individual sailfish was a factor in either survival or mortality within this study.

Our estimate of postrelease survival for sailfish is based on inferences from short-duration tag attachments that represent a balance between accounting for all relevant sources of mortality while minimizing the potential for exogenous sources of mortality unrelated to our experiment. Five- to 10-d deployment periods are considered appropriate for postrelease studies of billfishes because most mortalities occur within 1–144 h of release (Domeier et al. 2003; Horodysky and Graves 2005; Kerstetter and Graves 2006a); conventional tag recaptures within a few days of release indicate a return to feeding behavior. Both of the mortalities in this study occurred within 48 h. Longer deployment periods would increase the potential of the observation of natural mortality events, confounding our inferences of relevant predictors and thereby biasing the postrelease survival results downward (Goodyear 2002).

The number of PSATs deployed in this study (17) was limited. As a result, the 95% confidence interval surrounding the observed rate of postrelease survival (88.2%) was quite large (76.5–100%). Using the simulation software of Goodyear (2002), about 325 PSATs would be required to reduce the confidence intervals to within 5% of the observed rate of postrelease survival. Considering the relatively high costs for equipment (PSATs cost approximately US$3,500 each), vessel time, and personnel, it may simply be unrealistic to obtain the funds for a more precise estimate that accounts for all of the variables associated with such fishing activities (area, bait types, depths, etc.). Our results nonetheless qualitatively reveal high postrelease survival from PLL gear, further supporting U.S. regulations requiring live release and suggesting the efficacy of implementing these measures internationally through the ICCAT. The survival of 15 of 17 sailfish (88.2%) caught on circle hooks is also consistent with results obtained for blue marlin (100% both hook types, excluding nonreporting tags; Kerstetter et al. 2003) and white marlin (80% J-style hooks and 92.8% circle hooks; Kerstetter and Graves 2006a) caught on PLL gear.

There was no clear trend between sailfish condition at the time of haulback and survival for the 17 tagged with PSATs. Three of the surviving sailfish (fish 7-03, 7-06, and 7-07) were in marginal condition at the time of gear retrieval (ACESS scores, ≤ 6), yet survived the duration of the tag deployment period. Of the two that died after release, one was hooked internally while the other was hooked in the corner of the mouth; both had an ACESS score of 8. Although there was not a clear relationship between the ACESS score and the fate of the fish, we believe that the scoring methodology provides an easy assessment of physical condition that would be useful with the larger sample sizes associated with conventional tagging studies. Individual 6-06, which was hooked through the orbit of the eye but not the eye itself, survived for the 10-d period and had activity patterns similar to those of the other surviving animals. Kerstetter and Graves (2006a) reported that white marlin caught with large circle hooks on pelagic longline gear had a relatively high incidence of individuals hooked through the orbit (31.6%).

Although other studies have assessed hooking location by hook type for sailfish caught on recreational fishing gear (e.g., Prince et al. 2007), this issue has not been well examined for sailfish caught on PLL gear. In the studies of Falterman and Graves (2002) and Kerstetter and Graves (2006b), too few sailfish were caught on PLL gear for analyses of hooking location, although eight of the nine sailfish caught on circle hooks in the latter study were either hooked in external locations or entangled in the leader (D.W.K., unpublished data). Sailfish in the Brazilian pelagic longline fishery were significantly more likely to be hooked "externally" (i.e., with the hook visible) with size 18/0 nonoffset circle hooks, and such animals showed a higher rate of survival at haulback than those caught with J-style hooks (Kerstetter et al. 2006). Although limited, the available data nonetheless support the argument that circle hooks more frequently hook fish in external rather than internal locations, thereby reducing the chance of serious injury (see Skomal et al. 2002). The use of circle hooks rather than J-style hooks could therefore promote higher rates of postrelease survival for sailfish from the PLL fishery. However, the differences in hook performance between hook types should be taken into consideration when applying our results to international fisheries or stock assessments where circle hooks are not used.

The sailfish movements noted in this and other studies show a significant connectivity among different fisheries. Even during the relatively short 10-d period in our study, several fish crossed international boundaries. These results complement those by Prince et al. (2006) showing transboundary movements by sailfish along the Pacific coast of Central America and reinforce the need for effective international management of this species. In a regional context, there is clearly interaction between the PLL fishery and the directed recreational fisheries throughout the western North Atlantic, such as the year-round recreational fisheries for sailfish in the Florida Straits and southern Gulf of Mexico (Nakamura and Rivas 1974; NMFS 2006). As Goodyear (2007) notes, recreational fisheries frequently place higher value on catch rates rather than landings, especially for catch-and-release fisheries like those targeting marlins and sailfish. Considering the movements of sailfish within the Gulf of Mexico and northern Caribbean Sea region, a reduction in incidental mortality from the PLL fisheries should have direct benefit to catch rates of sailfish in the local recreational fisheries.

The ICCAT Standing Committee on Research and Statistics has continued to recommend exploring

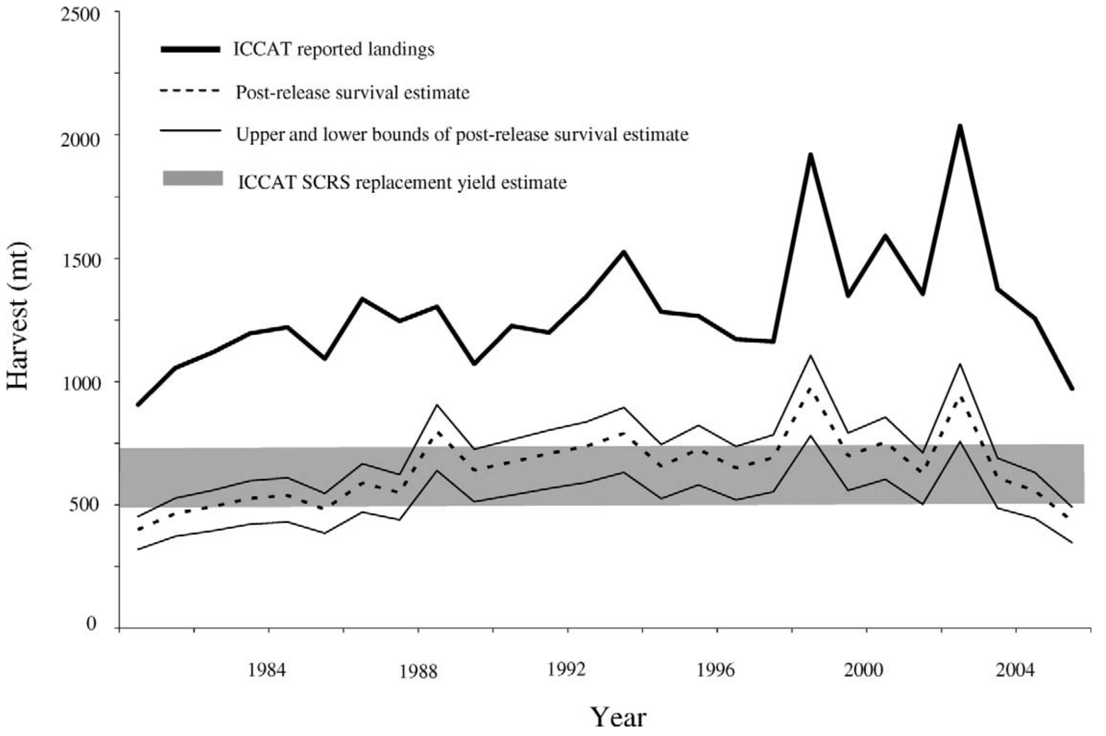

FIGURE 3.—Estimated annual reduction in sailfish mortality from 1980 to 2005 for the western Atlantic stock resulting from the release of animals that were alive at the haulback of the pelagic longline gear. The bold line represents the total catch reported to the International Commission for the Conservation of Atlantic Tunas (ICCAT) for this stock. The dashed line represents the total reported catch adjusted for both a hypothetical aggregate 50% mortality rate at haulback and the 88.2% postrelease survival rate obtained in this study; the thin solid lines on either side represent the upper and lower bounds of the postrelease survival rate (70.6% and 100%) obtained by simulations with software from Goodyear (2002). All values are in metric tons (mt). Note that because the U.S. pelagic longline fishery has not been allowed to retain sailfish since 1988, the three 50% mortality lines do not include U.S.-reported dead discards for the years 1988–2005. The shaded area shows the harvest level of approximately 600 metric tons recommended by ICAAT's Standing Comittee on Research and Statistics (SCRS) as replacement yield for the western Atlantic stock (ICCAT 2001).

methods to reduce the bycatch of sailfish (and other billfishes) in the Atlantic PLL fisheries. As previously mentioned, reductions of sailfish bycatch can be achieved by several management strategies. One method would be to implement time–area closures based on historical catch reports of target and bycatch species. Questions exist regarding the appropriate scale of such closures, which would only be effective if enforced in conjunction with onboard observers or satellite-based vessel monitoring system (VMS) coverage. The historical reluctance within the ICCAT to adopt measures requiring observer or VMS coverage suggests that the probable levels of compliance with such time–area closures would be low. Furthermore, any effort reduction that would lead to reduced catches of target species would not be strongly supported by most ICCAT members. Changes in gear technology, such as circle hooks, are also possible; several studies (see Kerstetter and Graves 2006b) have demonstrated increased survival at haulback with this terminal gear type, but such measures would only be effective in conjunction with mandatory live release.

Mandatory live release provides a management alternative that could also be effective in reducing stockwide fishing mortality on sailfish without impacting the catches of target species. The values of mortality at haulback for sailfish obtained by fisheries observers range from around 40% on circle hooks to around 60% on J-style hooks (NMFS 2007). Assuming that approximately half of the sailfish caught by PLL gear are alive at haulback and applying the postrelease survival estimate from this study, if there had been mandatory live release of western Atlantic sailfish over the past 20 years, catches would have remained within the 600 metric tons estimated as the replacement yield of the stock (Figure 3). Goodyear (2007) argued a similar point with recreational catch-and-release fisheries, suggesting by extension that reducing mortalities in the PLL fishery through live release alone could result in lowering harvests below the replacement yield. In the absence of another, better-defined sustainable harvest level target, maintaining harvests within or below the replacement yield level should result in direct benefits to the sailfish stocks. In the absence of a live release ethic on PLL vessels, fisheries observer coverage might be necessary for compliance purposes. Management in the U.S. PLL fishery prohibits the landings of sailfish by PLL vessels, thereby removing the incentive for retaining live animals. A similar strategy might be useful in other areas. Calls for mandatory live release of sailfish by PLL fisheries have been opposed in international fisheries management forums, the arguments against them being based on anecdotal evidence of high mortality rates for released sailfish from this gear type. The relatively high level of postrelease survival observed in this study clearly supports mandatory live release of sailfish as an effective measure to reduce fishing mortality on these overfished stocks without sacrificing catches of valuable target species.

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