Asymmetric conservation benefits of circle hooks in multispecies billfish recreational fisheries: a synthesis of hook performance and analysis of blue marlin (*Makaira nigricans*) postrelease survival

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Abstract—We evaluated the conservation benefits of the use of circle hooks compared with standard J hooks in the recreational fishery for Atlantic istiophorid billfishes, noting hooking location and the presence of trauma (bleeding) for 123 blue marlin (*Makaira nigricans*), 272 white marlin (*Kajikia albida*), and 132 sailfish (*Istiophorus platypterus*) caught on natural baits rigged with one of the two hook types. In addition, we used pop-up satellite archival tags (PSATs) to follow the fate of 61 blue marlin caught on natural baits rigged with circle hooks or on a combination of artificial lure and natural bait rigged with J hooks. The frequencies of internal hooking locations and bleeding were significantly lower with circle hooks than with J hooks for each of the three species and were significantly reduced for blue marlin caught on J hooks than for white marlin and sailfish taken on the same hook type. Analysis of the data received from 59 PSATs (two tags released prematurely) indicated no mortalities among the 29 blue marlin caught on circle hooks and two mortalities among the 30 blue marlin caught on J hooks (6.7%). Collectively, the hook location and PSAT data revealed that blue marlin, like white marlin and sailfish, derive substantial conservation benefits from the use of circle hooks, and the negative impacts of J hooks are significantly reduced for blue marlin relative to the other two species.

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Istiophorid billfishes in the Atlantic Ocean experience considerable fishing pressure and most stocks are overfished. The greatest source of fishing-induced mortality for istiophorids results from the pelagic longline fishery that targets tunas and swordfish; however, artisanal and recreational fisheries also represent significant sources of mortality for some species (Arocha and Ortiz, 2006). The United States National Marine Fisheries Service (NMFS) manages the recreational billfish fishery with relatively large minimum sizes released to ensure that the majority of billfishes are released: 251 cm (99 in) lower jaw fork length (LJFL) for blue marlin (*Makaira nigricans*), 168 cm (66 in) LJFL for white marlin (*Kajikia albida*), and 152 cm (60 in) LJFL for sailfish (*Istiophorus platypterus*). No recreational landings are allowed for longbill spearfish (*Tetrapturus pfluegeri*), and no management measures currently exist for roundscale spearfish (*T. georgii*). As a result of these management measures and changes in angler behavior promoting live release of these species (Ditton and Stoll, 2003), the U.S. recreational billfish fisheries are primarily catch-and-release fisheries, and up to 99% of white marlin are released alive annually (Goodyear and Prince, 2003). However, not all billfishes that are released alive survive capture; postrelease mortality can be significant in some fisheries (Domeier et al., 2003; Horodysky and Graves, 2005).

A growing body of evidence indicates that the use of circle hooks can greatly reduce the incidences of internal (deep) hooking, hook induced trauma (bleeding), and postrelease mortality of piscivorous fishes (Muoneke and Childress, 1994; Skomal et al., 2002; Cooke and Suski, 2004), including billfishes (see Serafy et al., 2009). For istiophorid billfishes, live and dead natural baits rigged with J hooks reveal higher frequencies of internal hooking locations and trauma for sailfish, striped marlin (*K. audax*), and white marlin than the same baits rigged with circle hooks (Prince et al., 2002, 2007; Domeier et al., 2003; Horodysky and Graves, 2005). Using pop-up satellite archival tags (PSATs) to follow the fate of released fish, Domeier et al. (2003) noted a reduced but nonsignificant postrelease mortality for striped marlin caught on live natural baits rigged on circle hooks, and Horodysky and Graves (2005) reported a highly significant reduction in postrelease mortality of fish caught on circle hooks compared to those caught on J hooks. In response to the depleted stock condition of Atlantic billfishes and the reduction in undesirable hooking locations and postrelease mortality resulting from the use of circle hooks, NMFS in 2008 implemented a management measure requiring the use of non-offset circle hooks in natural baits for all Atlantic billfish tournaments. During the rule-making process, NMFS received several comments stating that blue marlin have lower rates of deep hooking with J hooks than white marlin or sailfish, especially when caught on artificial lure and natural bait combinations rigged with J hooks, a common terminal tackle used in the Atlantic recreational fishery. It was also suggested that blue marlin released from the recreational fishery have high rates of survival.

Little is known about the effects of hook type on postrelease survival of blue marlin. A preliminary study on the use of PSATs to investigate postrelease survival of blue marlin inferred survival for at least eight of nine individuals caught on lures or skirted baits with J hooks trolled at relatively high speeds in the Bermuda recreational fishery (Graves et al., 2002). However, there were no data to directly compare the postrelease mortality of blue marlin caught on natural baits or on a combination of artificial lure and natural bait rigged with either circle hooks or J-hooks. To gain insights into the relative conservation benefits of circle hooks in the recreational fishery for Atlantic blue marlin and other istiophorids, we compiled data on hooking location and the incidence of trauma (bleeding) for 123 blue marlin, 272 white marlin, and 132 sailfish caught on natural baits rigged with either J hooks or circle hooks. Furthermore, to estimate the postrelease mortality of blue marlin caught on natural baits with circle hooks or artificial lure and natural bait combinations with J hooks, we deployed 61 PSATs to follow the fate of blue marlin caught on one of the two types of terminal tackle.

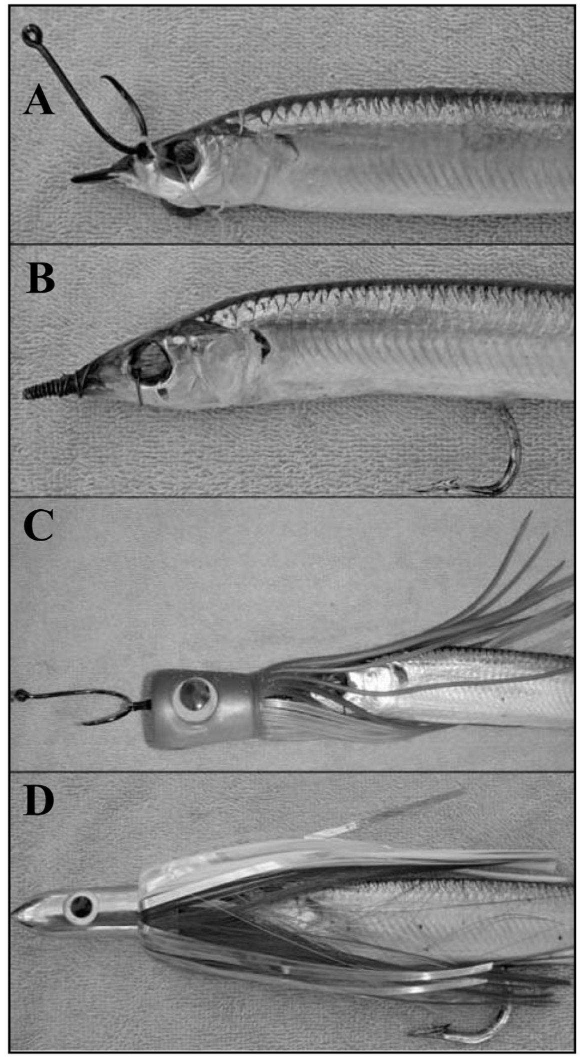

Figure 1

Bait and terminal tackle combinations used to investigate hooking location, presence or absence of trauma, and postrelease survival of western Atlantic istiophorid billfishes caught in the recreational fishery: (**A**) naked ballyhoo with circle hook; (**B**) naked ballyhoo with J hook; (**C**) artificial lure (chugger) and ballyhoo combination with circle hook; and (**D**) artificial lure (Ilander) and ballyhoo combination with J hook (photo by Ken Neill).

Materials and methods

Hooking location

Information on hook type, hooking location, and trauma (the presence of bleeding) was collected by the authors for all blue marlin, white marlin, and sailfish caught on trolled plain (naked) ballyhoo (*Hemiramphus brasiliensis*) baits during our PSAT tagging operations in the western North Atlantic from 2006 through 2009. Similar information was recorded by three cooperating charter captains (one from Oregon Inlet, NC, USA, and two from La Guaira, Venezuela) for billfishes caught during fishing operations in 2006. To accommodate captain and charter angler preferences, a variety of hook models and sizes were employed in the different fishing operations, but the most common J hook model was the Mustad 9175, size 7/0 (Mustad, Gjövik, Norway), and the most common circle hook model was the Eagle Claw L2004EWF, size 8/0 (Eagle Claw, Denver, CO). As is typical for this fishery, circle hooks were left exposed, rigged to the head of the bait, whereas J hooks were inserted through the mouth of the bait fish with the tip exiting the ventral surface (Fig. 1, A and B).

Baits were trolled at approximately 6 nm/hr (11.1 km/hr) during daylight hours on 30–50 lb (13.6–22.7 kg) class fishing tackle. As billfish approached the trolled bait, anglers would typically decrease tension on the line for periods of 4–10 s, “dropping back” the ballyhoo bait to the feeding billfish, which provided time for the animal to ingest the bait before feeling tension on the line (see Jolley, 1974; Mather et al., 1975; Prince et al., 2007, for a description of this fishing method), although, in some instances the fish attacked trolled baits before an angler could reach the rod and drop back. The location of the hook and the presence or absence of bleeding (visible blood) was noted at the time of capture. Hooking locations were classified as external when all or part of the hook was visible outside of the fish's mouth, including fish that were foul hooked (hooked in areas away from the fish's mouth), and internal if no part of the hook was visible when the fish's mouth was closed.

Postrelease survival

PSATs were attached to 61 blue marlin caught in recreational fisheries in the western Atlantic Ocean. Fish were caught by using J hooks and circle hooks that were rigged with natural baits consisting of ballyhoo or Spanish mackerel (*Scomberomorous maculatus*). Baits were rigged in a manner typical for the fishery. J hooks were inserted inside the baits, which were fished in combination with a skirted artificial lure (e.g., Ilander [L & S Bait Company, Largo, FL], chugger [Mold Craft Lures, Pompano Beach, FL], or Seawitch [C & H Lures, Jacksonville, FL]) attached directly ahead of the bait (Fig. 1, C and D). Circle hooks were rigged externally on the baits, either on top of the head or directly in front of the bait. In some cases, a small artificial lure (chugger) was placed between the circle hook and the bait.

Blue marlin were caught on 30–130 lb (13.6–59.1 kg) class sportfishing tackle in waters off the United States mid-Atlantic coast; St. Thomas, U.S. Virgin Islands; Punta Cana, Dominican Republic; La Guaira, Venezuela; and Porto Seguro, Brazil, between September 2007 and October 2009 (Appendix 1). As is typical for the fishery, the vessel was maneuvered by the captain to assist the angler in the capture of the fish. Blue marlin were not brought alongside the vessel until they were considered to be sufficiently calm to allow accurate tag placement.

The first 61 fish available to us were tagged with a Microwave Telemetry PTT 100 HR tag (Microwave Telemetry, Inc., Columbia, MD), programmed for release after 10 days. This tag model records temperature, pressure (depth), and light levels approximately every 90–120 s. The tags were rigged as described in Graves et al. (2002), and deployed as described in Horodysky and Graves (2005). The location of the hook and presence or absence of bleeding was noted for each fish at the time of tagging. If practical, the hook was removed from the fish before its release. As is customary in this fishery, blue marlin that were unable to maintain their position upright in the water column were resuscitated by using the forward motion of the vessel to facilitate movement of water over the fish's gills before release (Appendix 1).

Survival of released blue marlin was inferred from temperature and depth profiles following the protocols of Horodysky and Graves (2005). Net displacement of each fish was calculated as the minimum straight line distance from the point of release to the point of tag pop-up. Cochran-Mantel-Haenszel (CMH) or Fisher's exact tests were used to address the effect of the J hooks and circle hooks on hooking location, hook-induced trauma, and survival. A Yates correction for small sample size was applied in conducting CMH tests when expected cell values were less than 5 (Agresti, 1990). All statistical analyses were conducted in the Statistical Analysis System, vers. 9.1 (SAS Institute, Cary, NC). Bootstrapping simulations were performed to determine the 95% confidence intervals of the estimates of mortality after release by using the software developed by Goodyear (2002).

Results

Hooking location

Hooking location and the presence or absence of bleeding were noted for 123 blue marlin, 272 white marlin, and 132 sailfish caught on natural baits rigged with either J hooks or circle hooks (Table 1). The incidence of internal hooking with J hooks ranged from 19.1% (blue marlin) to 44.4% (white marlin), and the frequency of internal hooking locations for fish caught on circle hooks was considerably lower, ranging from 1.8% (blue marlin) to 6.2% (sailfish). For blue marlin, white marlin, and sailfish, J hooks had a significantly higher probability of internal hooking locations than circle hooks ($P<0.007$, $P<0.0001$, $P<0.001$, respectively). The frequency of internal hooking locations for J hooks in blue marlin (19.1%) was less than half the value observed for white marlin and sailfish (44.4% and 41.2%, respectively), and the difference between blue marlin versus white marlin and sailfish combined was significant ($P<0.0014$).

The occurrence of trauma (bleeding) mirrored the pattern observed for internal hooking locations between the two hook types for each of the three billfishes. Across the three species, over 81% of the instances of bleeding (44/54) were associated with internal hooking locations (7/9 blue marlin, 20/24 white marlin, and 16/17 sailfish). Bleeding of fish caught on circle hooks ranged from 0% in blue marlin to 2.5% in sailfish (Table 1). For blue marlin, white marlin, and sailfish, J hooks had a significantly higher probability of inducing bleeding than circle hooks ($P<0.0141$, $P<0.001$, $P<0.0001$, respectively). As with the occurrence of internal hooking locations with J hooks among the three species, the frequency of bleeding observed in blue marlin (13.2%) was less than half that observed in white marlin and sailfish (both 33.3%); blue marlin had significantly lower rates of bleeding resulting from the use of J hooks than white marlin and sailfish combined ($P<0.027$).

Postrelease survival

Sixty-one blue marlin were caught on natural baits rigged with circle hooks (30) or on a combination of artificial lure and natural bait rigged with J hooks (31),

Table 1

Hooking location (frequency; 95% confidence interval) and presence or absence of trauma (bleeding, not bleeding) for observed recreational catches of blue marlin (*Makaira nigricans*, *n*=123), white marlin (*Kajikia albida, n*=272), and sailfish (*Istiophorus platypterus*, *n*=132), caught on natural baits rigged with either J hooks or circle hooks in the western North Atlantic Ocean.

Species	Hook location		Trauma	
Hook type	Internal	External	Bleeding	Not bleeding
Blue marlin				
Circle	1 (1.8%; 0–5.4%)	54 (98.2%; 90.0–99.9%)	0 (0%; 0–2.0%)	55 (100%; 93.5–100%)
"J"	13 (19.1%; 10.6–28.5%)	55 (80.9%; 69.5–89.4%)	9 (13.2%; 6.2–23.6%)	59 (86.8%; 78.7–94.8%)
White marlin				
Circle	4 (2.0%; 0.6–5.0%)	196 (98.0%; 94.5–99.5%)	2 (1.0%; 0–2.4%)	198 (99.0%; 96.4–99.9%)
"J"	32 (44.4%; 32.7–56.6 %)	40 (55.6%; 43.4–67.3%)	24 (33.3% ; 22.4–44.2%)	48 (66.7%; 54.6–77.3%)
Sailfish				
Circle	5 (6.2%; 2.0–13.8%)	76 (93.8%; 86.0–97.8%)	2 (2.5%; 0.3–8.6%)	79 (97.5%; 91.4–99.7%)
"J"	21 (41.2%; 27.6–55.8%)	30 (58.8%; 44.3–72.4%)	17 (33.3%; 20.7–47.9%)	34 (66.7%; 52.1–79.2%)

tagged with Microwave Telemetry PSATs, and released. Three blue marlin were released off the U.S. mid-Atlantic coast; 26 off St. Thomas, U.S. Virgin Islands; 2 off Punta Cana, Dominican Republic; 21 off La Guaira, Venezuela, and 9 off Porto Seguro, Brazil (Appendix 1). Estimated fish weights ranged from 70 lb (31.8 kg) to 500 lb (227.3 kg) (mean=216.4 lb [98.2 kg]). Fight times (including tag attachment) ranged from 4 to 85 minutes (mean=19.4 minutes). After tag placement, eight fish exhibited difficulty maintaining an upright orientation alongside the boat and were resuscitated for periods ranging from one to ten minutes before their release (Appendix 1).

All 61 PSATs reported after detachment from the fish. Two tags detached prematurely—both on the first day of deployment—and were excluded from survival analyses. The 59 tags that remained attached for the ten-day deployment period successfully transmitted between 18% and 96% (mean=81%) of the archived data. Most of these PSATs remained at sea during the data transmission period which typically lasts about 30 days before the battery power is exhausted. However, six tags washed ashore during the period of data transmission, resulting in reduced data reception from these tags. Two tags were recovered by beachcombers and returned to us, allowing recovery of 100% of the archived data.

We inferred the survival of 57 of 59 fish (96.6%) that carried the tags for the 10-day deployment from analyses of pressure (depth) and temperature profiles over the 10-day tagging period (Appendix 1). Surviving blue marlin exhibited multiple daily vertical movements as evidenced by the temperature and pressure (depth) profiles throughout the course of the ten-day tagging period. Many animals demonstrated a distinct diurnal patterning to their dives, remaining near the surface at night and making deep dives during the day (Fig. 2A). Net displacement ranged from 10 to 943 km (mean=226.9 km).

The two mortalities inferred from the PSAT data occurred among the 30 blue marlin caught on artificial lure and natural bait combinations rigged with J-hooks. Both individuals were hooked internally and bled profusely from the gill area at the time of capture. The archived data indicated that these individuals sank to the bottom shortly after release and remained there for 48–96 hr, after which time a release mechanism was activated by the constant depth data in each PSAT and initiated tag release and data transmission (Fig. 2B). The two mortalities of blue marlin caught on artificial lure and natural bait combinations with J hooks resulted in an estimated postrelease mortality rate of 6.7%. The results of 10,000 bootstrap simulations at an underlying true mortality of 6.7% indicated that the approximate 95% confidence intervals (CI) for the mortality estimates of blue marlin caught on J hooks for an experiment with 30 tags would range from 0% to 22% (with the methods of Goodyear, 2002). None of the 29 blue marlin caught on natural baits with circle hooks died during the ten day period, resulting in a postrelease mortality estimate of 0%, with corresponding 95% CI ranges from 0% to 12.5%. The difference between the estimates of postrelease mortality for blue marlin caught on J-hooks and circle hooks was not statistically significant (Fisher's exact test: $P=0.26$).

Discussion

The goal of this study was to determine whether blue marlin derive similar conservation benefits from the use of circle hooks in the recreational fishery as has been previously reported for other istiophorid billfishes. A direct comparison of hooking locations with the use of J hooks and circle hooks in natural baits rigged as they are typically fished in the recreational fishery indicates that the use of circle hooks results in significantly lower rates of internal hooking locations for blue marlin, white marlin, and sailfish. We observed incidences of internal hooking locations with circle hooks ranging from 1.8% (blue marlin) to 6.2% (sailfish). The value of 2.0% (n=200) observed for white marlin is comparable to the value of 1.7% (n=59) reported for white marlin caught on natural baits with circle hooks (Graves and Horodysky, 2008). The incidence of internal hooking locations observed for circle hooks in sailfish (6.2%) is slightly higher than that reported by Prince et al. (2002) for Pacific sailfish caught on trolled natural baits with circle hooks (1.7%) but is within the range reported for circle hooks in live baits for both Atlantic sailfish (6–16%; Prince et al., 2007) and striped marlin (5–7%; Domeier et al., 2003).

The use of J hooks in natural baits resulted in incidences of internal hooking ranging from 19.1% (blue marlin) to 44.4% (white marlin). The frequency of internal hooking in white marlin caught with natural baits rigged with J hooks (44.4%) is similar to the value reported for white marlin caught on J hooks (50%) by Horodysky and Graves (2005). Internal hooking locations for sailfish caught on J hooks rigged with natural baits (41.2%) are comparable to results for Pacific sailfish caught on trolled dead baits rigged with J hooks (46.8%), and fall within the range reported for Atlantic sailfish caught on live baits rigged with J hooks using a variety of dropback times (23–57%; Prince et al., 2007), as well as striped marlin caught on live baits with J hooks (28%; Domeier et al., 2003). The use of J hooks resulted in a tenfold increase in internal hooking locations relative to circle hooks for blue marlin and a twentyfold increase for white marlin and sailfish—a trend also noted in previous studies of istiophorid billfish (Prince et al., 2002, 2007; Domeier et al., 2003; Horodysky and Graves, 2005).

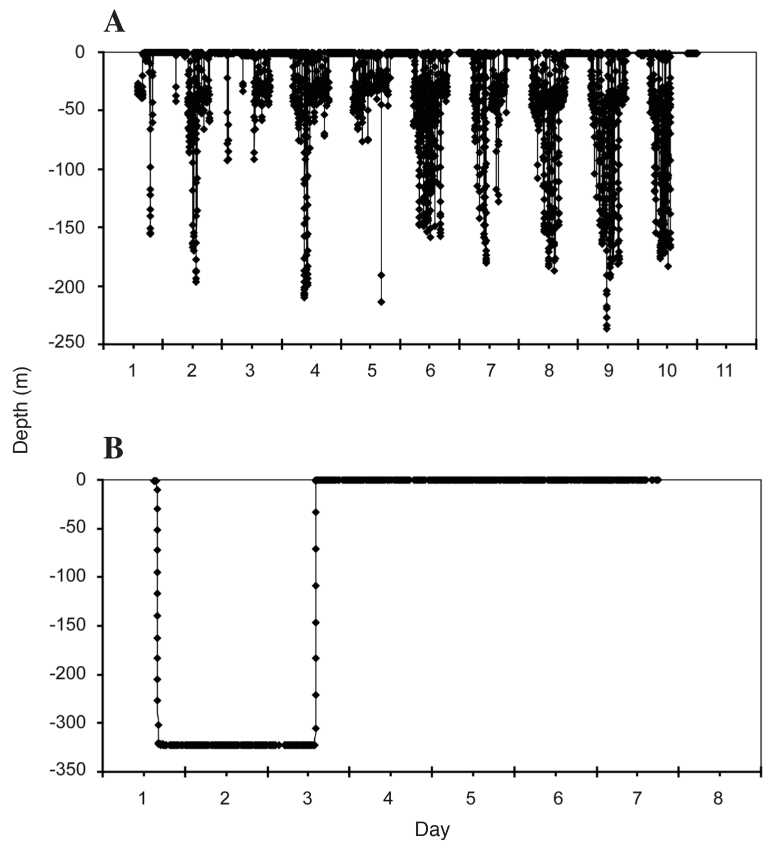

Figure 2

Depth plots derived from pop-up satellite archival tag pressure data for two blue marlin (*Makaira nigricans*) caught in the western Atlantic recreational fishery. (**A**) Blue marlin no. 49 was caught on a naked ballyhoo bait with a circle hook. This fish survived for the ten day tagging period and exhibited a strong diel pattern, diving during the day and remaining in surface waters at night. (**B**) Blue marlin no. 41 was caught on an artificial lure (Ilander) and ballyhoo combination bait with a J hook and was bleeding profusely from the gills at the time of capture. This fish died and sank to the bottom shortly after release. The release mechanism on the tag was activated by constant depth measurements for 48 hours and the tag floated to the surface and began transmitting data.

Although the frequency of internal hooking locations was significantly higher for blue marlin, white marlin, and sailfish caught on J hooks than on circle hooks, the rate of internal hooking locations for blue marlin caught on J hooks was less than half of the values observed for white marlin and sailfish. In a study of postrelease mortality in the recreational blue marlin fishery off Bermuda, Graves et al. (2002) reported no internal hooking locations for the nine blue marlin caught on artificial lures or artificial lure and natural bait combinations rigged with J hooks. The lower incidence of internal hooking locations for blue marlin caught on natural baits rigged with J hooks than for white marlin and sailfish caught on similar terminal tackle may result from interspecific differences in feeding ecology. Many billfishes follow trolled baits for a short time before striking, giving alert anglers an opportunity to pick up the rod and drop the bait back to the fish as it attacks. Dropback times of 5–10 s are common in the white marlin fishery (Mather et al., 1975; Jesien et al., 2006), and can be considerably longer in the sailfish live bait fisheries (Prince et al., 2007). By contrast, blue marlin are typically more aggressive feeders, often attacking the bait before anglers have an opportunity to react. When dropbacks are possible for this species, they are often of shorter duration than those for white marlin and sailfish, allowing less time for the bait to be swallowed and hence for the hook to lodge in an undesirable location (Prince et al., 2007).

In previous studies, internal or deep hooking locations have been associated with an increased incidence of trauma in istiophorids and other large pelagic fishes (Domeier et al. 2003; Horodysky and Graves, 2005; Prince et al., 2007; Skomal, 2007). In the present study, trauma, as evidenced by bleeding, was significantly lower for blue marlin, white marlin, and sailfish caught on circle hooks than for those caught on J hooks. The low incidence of bleeding associated with natural baits rigged with circle hooks for white marlin that we observed (1.0%) concurs with the value of 1.7% reported for white marlin by Graves and Horodysky (2008) and the range reported for the congeneric striped marlin caught on live baits with circle hooks (3–4%, Domeier et al., 2003). The frequency of bleeding with circle hooks observed for sailfish (2.5%) in this study is slightly lower than the values reported for Pacific sailfish caught on natural baits (6%) and for Atlantic sailfish caught on live baits with circle hooks (5–13%; Prince et al., 2002, 2007). We noted bleeding in 33% of the white marlin and 33% of the sailfish caught on natural baits with J hooks. This value is somewhat lower than those reported for white marlin (45%) and Pacific sailfish (56.8%) caught on trolled natural baits, and higher than those reported for striped marlin (21%) and Atlantic sailfish (21–25%) caught on live baits (Prince et al., 2002, 2007; Domeier et al., 2003; Horodysky and Graves, 2005). The incidence of bleeding in white marlin and sailfish caught on J hooks was significantly higher than that for blue marlin caught on the same terminal tackle and is consistent with an increased incidence of internal hooking rates in the former species observed in this and previous studies (Prince et al., 2002; 2007; Domeier et al., 2003; Horodysky and Graves, 2005).

To directly follow the fate of blue marlin caught on trolled natural baits or on bait and lure combinations rigged with either circle or J hooks and released, we deployed 61 PSATs, of which 59 remained attached for the ten-day tracking period. All 29 blue marlin caught on circle hooks rigged with natural baits or bait and lure combinations survived for ten days after release. In a study of 59 white marlin caught on natural baits rigged with circle hooks, Graves and Horodysky (2008) reported a single mortality. Together, these studies reveal a very low level of postrelease mortality for billfishes caught on circle hooks in natural bait trolling fisheries. In contrast, Domeier et al. (2003) reported an adjusted rate of postrelease mortality of 17.4% for striped marlin caught from stationary vessels on live baits rigged with circle hooks. These results support the contention of Cooke and Suski (2004) that the magnitude of the conservation benefits of circle hooks varies among species, gear types, and fisheries.

PSAT depth records indicated that two of 30 blue marlin caught on artificial lure and natural combinations rigged with J hooks died after release, resulting in an estimated postrelease mortality of 6.7%. This value is approximately one-fifth of the postrelease mortality reported by Horodysky and Graves (2005) for 20 white marlin caught on natural baits rigged with J hooks (35%) and less than one-fourth of the value of 29.4% reported by Domeier et al. (2003) for 24 striped marlin caught on live baits rigged with J hooks. The reduction in postrelease mortality of blue marlin caught on natural baits with J hooks relative to postrelease mortality of white marlin caught on the same terminal tackle parallels the reductions observed in the frequency of internal hooking locations and bleeding between these species.

In this study, the use of circle hooks in natural baits resulted in significantly reduced internal hooking and bleeding for blue marlin, white marlin, and sailfish. Because blue marlin caught on J hooks experienced significantly lower incidences of internal hooking locations and trauma than white marlin and sailfish caught on the same terminal tackle, the conservation benefit resulting from the use of circle hooks for blue marlin is less than that experienced by the other two species. This asymmetry was also evident in the analysis of postrelease survival. There was a trend for decreased postrelease mortality of blue marlin caught on natural baits with circle hooks (0%) than for blue marlin caught on artificial lures and natural baits with J hooks (6.7%), but the difference was much smaller than that previously reported for white marlin caught on natural baits rigged with the two hook types (0% and 35%, respectively; Horodysky and Graves, 2005). Although these results provide support for recent management measures implemented by NMFS that require the use of non-offset circle hooks in natural baits for all Atlantic billfish tournaments, it is important to realize that the conservation benefits of this measure vary asymmetrically among the different billfish species.

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Appendix 1

Summary information for 61 blue marlin (*Makaira nigricans*) caught on different types of terminal tackle in the western Atlantic recreational fishery, tagged with pop-up satellite archival tags, and released. Fish were caught off Venezuela (VZ), the Dominican Republic (DR), Virginia (VA), North Carolina (NC), the U.S. Virgin Islands (VI), and Brazil (BR) on natural baits or combination baits consisting of an artificial lure (chugger [Chug], Ilander [I], or Sea Witch [Swi]), and natural bait rigged with J hooks (J) or circle hooks (C). Hook locations were recorded as internal (I) or external (E). Fight time included the tagging process and, where applicable, resuscitation ($R^{\text{duration in minutes}}$), and trauma (bleeding) at the time of release was noted as present (Y) or absent (N). Also included are the percentage of archived data recovered, mean straight line displacement (MSLD) over the 10-day tagging period, and fate of the blue marlin (coded as live [L], dead [D], or premature release [–]).

Fish	Date	Location	Gear (lb)	Established weight	Hook type	Hook location	Fight time	Trauma	Data (%)	MSLD (km)	Fate
1	9/7/07	VZ	30	200	Chug/J	I	55	N	82	172	L
2	3/17/08	VZ	50	175	I/J	E	28 R^3	N	81	139	L
3	3/28/08	DR	50	125	I/J	E	15 R^2	N	68	49	L
4	3/29/08	DR	50	100	C	E	30	N	85	86	L
5	5/15/08	VZ	30	165	C	E	18	N	84	30	L
6	5/15/08	VZ	30	100	Chug/C	E	5	N	85	10	L
7	5/16/08	VZ	50	160	I/J	E	5	Y	73	123	L
8	5/17/08	VZ	30	75	C	E	15	N	85	87	L
9	6/15/08	VA	50	400	I/J	E	56	N	85	546	L
10	6/22/08	NC	80	350	I/J	E	35	N	88	943	L
11	8/8/08	VI	50	450	I/J	E	18	N	90	502	L
12	8/10/8	VI	50	275	I/J	I	5	N	90	646	L
13	8/10/08	VI	50	350	Chug/C	E	8	N	92	349	L
14	8/11/08	VI	50	175	Chug/J	E	11	N	83	107	L
15	8/11/08	VI	50	175	Chug/C	E	4	N	88	343	L
16	8/12/08	VI	50	200	I/J	I	10	Y	93	488	L
17	8/12/08	VI	50	125	I/J	E	12	Y	87	328	L
18	8/17/08	NC	80	375	Swi/J	E	40	N	90	709	L
19	9/7/08	VI	50	160	I/J	E	20	N	91	191	L
20	9/7/08	VI	50	250	Chug/C	E	15	N	68	20	L
21	9/7/08	VI	50	235	C	E	22	N	92	319	L
22	9/8/08	VI	50	275	Chug/J	I	55	N	90	120	L
23	9/9/08	VI	50	125	I/J	I	14	N	93	238	L
24	9/10/08	VI	50	90	Chug/J	I	20 R^{10}	Y	72	68	L
25	9/10/08	VI	50	90	Chug/J	E	13	N	88	264	L
26	9/11/08	VI	80	325	I/J	E	35	N	100	197	L
27	9/15/08	VI	50	100	Chug/C	E	12	N	92	234	L
28	9/25/08	VZ	30	70	C	E	5	N	90	13	L
29	11/1/08	BR	130	300	Chug/C	E	11 R^2	N	85	119	L
30	11/2/08	VZ	30	150	Chug/C	E	21	N	84	336	L
31	11/3/08	VZ	30	290	C	E	85	N	94	171	L
32	11/4/08	BR	50	125	C	E	5	N	74	284	L
33	11/15/08	VZ	30	250	C	E	20	N	18	263	L
34	11/17/08	VZ	30	150	C	E	20	N	87	135	L
35	11/22/08	VZ	30	150	C	E	21	N	79	115	L
36	11/30/08	VZ	30	120	Chug/C	E	36 R^4	N	86	83	L
37	12/2/08	BR	130	200	Chug/J	I	12	Y	93	47	D
38	12/2/08	BR	130	175	Chug/C	E	5	N	36	289	L
39	12/9/08	VZ	30	125	Chug/C	I	21	N	81	226	L
40	12/9/08	VZ	50	100	I/J	E	6	N	90	118	L
41	12/9/08	VZ	50	200	I/J	I	9	Y	61	109	D

continued

Appendix 1 (continued)

Fish	Date	Location	Gear (lb)	Established weight	Hook type	Hook location	Fight time	Trauma	Data (%)	MSLD (km)	Fate
42	12/11/08	VZ	30	250	I/J	E	18	N	83	107	L
43	12/11/08	BR	130	450	Chug/C	E	10	N	85	218	L
44	12/12/08	BR	130	500	C	E	15	N	90	233	L
45	12/12/08	BR	50	400	C	E	12	N	91	216	L
46	1/2/09	BR	130	300	C	E	12	N	88	19	L
47	1/2/09	BR	130	400	Chug/C	E	10	N	94	329	L
48	2/7/09	VZ	80	145	Swi/J	E	10	N	26	124	L
49	4/18/09	VZ	80	115	C	E	14	N	85	96	L
50	5/6/09	VZ	50	265	I/J	E	34	N	57	88	L
51	5/9/09	VZ	50	110	C	E	10	N	100	90	L
52	7/6/09	VI	50	170	Chug/J	E	25 R[3]	N	85	70	—
53	7/6/9	VI	50	300	Chug/J	E	45 R[1]	N	80	196	L
54	7/9/09	VI	50	200	Chug/J	E	15	N	86	143	L
55	8/1/09	VI	50	250	Chug/C	E	15	N	38	109	L
56	8/8/09	VI	50	250	Chug/J	E	15	N	31	379	L
57	8/30/09	VI	50	175	C	E	20	N	93	80	—
58	9/2/09	VI	50	150	C	E	18	N	94	214	L
59	9/4/09	VI	50	350	C	E	16	N	96	463	L
60	9/30/09	VI	50	175	C	E	14	N	90	271	L
61	10/7/09	VI	50	200	I/J	E	40	N	92	385	L