1-1-2010

Sailfish (Istiophorus platypterus) Habitat Utilization in the Southern Gulf of Mexico and Florida Straits with Implications on Vulnerability to Shallow-Set Pelagic Longline Gear

David W. Kerstetter
Nova Southeastern University Oceanographic Center, kerstett@nova.edu

Shannon Michael Bayse
Nova Southeastern University Oceanographic Center

John E. Graves
Virginia Institute of Marine Science

SCRS/2009/048 Collect. Vol. Sci. Pap. ICCAT, 65(5): 1701-1712 (2010)

SAILFISH (*ISTIOPHORUS PLATYPTERUS*) HABITAT UTILIZATION IN THE SOUTHERN GULF OF MEXICO AND FLORIDA STRAITS WITH IMPLICATIONS ON VULNERABILITY TO SHALLOW-SET PELAGIC LONGLINE GEAR

D. W. Kerstetter[1], S. M. Bayse[1], and J. E. Graves[2]

SUMMARY

A total of 19 pop-up satellite archival tags (PSATs) were deployed on sailfish in the southern Gulf of Mexico between 2005 and 2007 aboard a commercial pelagic longline vessel (n = 18) and a recreational rod-and-reel vessel (n = 1). All PSATs were programmed to collect pressure (depth), temperature, and light-level data for 10 days at approximately 90-second intervals. These point-level data were not summarized prior to transmission, allowing the reconstruction of vertical movement patterns. Three tags suggested mortality events and were excluded from subsequent analyses. We present the preliminary data analyses from the remaining 16 PSATs. Sailfish are primarily associated with the upper surface waters at 20 m or less depth. However, sailfish also exhibited numerous repeated short-duration vertical movements below the local thermocline to depths of 50-150 m. The depth utilization from these tagged fish coincide with the actively fished depths of shallow-set pelagic longline gear, yet appear to be shallower than the depths of settled deep-set gear used to target bigeye tuna.

RÉSUMÉ

Entre 2005 et 2007, 19 marques-archives pop-up reliées par satellite (PSAT) ont été apposées sur des voiliers dans le Sud du Golfe du Mexique à bord d'un palangrier pélagique commercial (n = 18) et d'un navire récréatif opérant à la canne-et-moulinet (n = 1). Toutes les marques PSAT étaient programmées pour recueillir des données sur la pression (profondeur), la température et le niveau de lumière pendant 10 jours à environ 90 secondes d'intervalle. Ces données ponctuelles n'ont pas été récapitulées avant la transmission, ce qui a permis de reconstruire des schémas de déplacement vertical. Trois marques ont suggéré des cas de mortalité et ont été exclues des analyses ultérieures. Nous présentons les analyses préliminaires des données émanant des 16 PSAT restantes. Les voiliers sont essentiellement associés aux eaux supérieures à 20 m ou moins de profondeur. Toutefois, les voiliers ont également présenté de nombreux déploiements verticaux répétés de courte durée en-dessous de la thermocline locale, à des profondeurs de 50 à 150 m. L'utilisation de la profondeur par ces poissons marqués coïncide avec les profondeurs dans lesquelles pêche activement l'engin de palangre pélagique mouillé à une faible profondeur, même si elles semblent être plus superficielles que les profondeurs de l'engin fixe calé en profondeur qui est utilisé pour cibler le thon obèse.

RESUMEN

Se colocó un total de 19 marcas archivo pop-up por satélite (PSAT) en peces vela en el Golfo de México meridional entre 2005 y 2007 a bordo de un palangrero pelágico comercial (n=18) y un buque de caña y carrete de recreo (n=1). Todas las PSAT fueron programadas para recopilar datos de presión (profundidad), temperatura y de nivel de luz durante 10 días en intervalos de aproximadamente 90 segundos. Estos datos puntuales no fueron resumidos antes de la transmisión, lo que permitió la reconstrucción de patrones de movimiento vertical. Tres marcas sugirieron sucesos de mortalidad y fueron excluidas de análisis posteriores. Se presentan los análisis preliminares de los datos de las 16 PSAT restantes. Los peces vela se asocian principalmente con aguas superficiales, a 20 m o menos de profundidad. Sin embargo, el pez vela también presenta numerosos movimientos verticales repetidos de corta duración por debajo de la termoclina local, hasta profundidades de 50-150 m. La utilización de la profundidad de estos peces marcados coincide con las profundidades en las que pesca activamente el arte de palangre pelágico de calado superficial, aunque parecen ser más

[1] Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania Beach, Florida 33004 USA.
[2] Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia 23062 USA.

superficiales que las profundidades del arte fijo de calado profundo que se utiliza para dirigirse al patudo.

KEYWORDS

Sailfish, habitat utilization, pelagic longline

1. Introduction

The expanding availability of electronic tracking and tagging technology for large pelagic fishes has resulted in an increased understanding of habitat use by these animals. This same type of technology has also enabled an increase in the understanding of fishing gear behavior, including effective fishing depths. In locations where depleted fish populations encounter fishing gears targeting other species, the combined use of these technologies may allow increased insights into the vulnerability of bycatch species to various fishing gear types.

The sailfish (Istiophoridae: *Istiophorus platypterus*) is a large, cosmopolitan teleost found worldwide in tropical and subtropical pelagic waters, generally with higher concentrations near continental shelf areas. Conventional tagging data have shown broad movements of sailfish within the western Atlantic Ocean over periods of days to years (Ortiz *et al.*, 2003). In Florida, sailfish support a large, mostly catch-and-release recreational fishery based primarily in the region between Key West and Jupiter (Jolley, 1977). The Florida Straits have been closed to U.S. pelagic longline vessels since 2001, although some vessels continue to use this gear to the west and north of this closed area and occasionally encounter sailfish as bycatch while targeting swordfish (*Xiphias gladius*). Several studies with electronic tag technologies have shown that sailfish regularly move at speeds that would rapidly move between the portions of this region that are open and closed to the pelagic longline fishery (Hoolihan and Luo, 2007; Orbesen *et al.*, 2008). However, little is known of the vertical short-duration movements of sailfish and how these movements might interact with the pelagic longline gear.

Evaluating vertical habitat use by large pelagic animals has historically presented challenges due to a combination of their individual size, movement speed, and depth ranges. Previous work generally focused on the manual tracking of animals with acoustic tag technology for short periods of time with dedicated chase vessels (e.g., Jolley and Irby, 1979). However, the development of pop-up satellite archival tag (PSAT) technology has enabled researchers to record environmental data on pelagic fishes for much longer periods and at much more detailed resolution while eliminating the need for direct monitoring of the animal or fisheries dependent returns of the tag. The present study used the point data from 16 PSATs with 90-second sampling period resolution for ten-day deployment durations attached to sailfish in order to record ambient conditions and describe the behavior and habitat use of this species in the southern Gulf of Mexico and Florida Straits, with implications on the vulnerability of this species to shallow-set pelagic longline gear.

2. Materials and methods

Sailfish tagging occurred in two locations within the southern Gulf of Mexico: location one, approximately 90 km (50 nautical miles) south-southwest of Key West, Florida, in an area traditionally fished by the U.S. coastal pelagic longline fleet, and location two, offshore of Isla Mujares, Mexico. Tagging operations off Key West occurred aboard the commercial pelagic longline fishing vessel F/V *Kristin Lee* (54' LOA) during May 2006 and June 2007. The target species for all three trips was nominally swordfish and as is standard in the fishery, all sets were made overnight, with the gear deployment at dusk and retrieval at dawn. The gear configuration was similar to that used throughout this local fishery and consisted of 18.3 m (10 fathom) leaders and 18.3 m (10 fathom) buoy float-line lengths during each set in five-hook baskets (hooks between floats). The tag deployment for the Isla Mujares fish occurred aboard a recreational vessel during May 2006. Standard sportfishing gear was used by this vessel, with a subsurface dredge attractant and several surface baits, including dead ballyhoo *Hemiramphus brasiliensis*.

The Microwave Telemetry, Inc. (Columbia, MD, USA) model PTT-100 HR satellite tag was used in all tag deployments during this study. Tags were rigged with approximately 16 cm of 136 kg (300 pound) test strength Momoi® brand (Momoi Fishing Co., Ako City, Japan) monofilament attached to a large hydroscopic nylon intramuscular tag head per Graves *et al.* (2002). The PTT-100 HR model tags sampled temperature, pressure (depth), and irradiance (light level) approximately every 90 seconds. This tag model also included emergency release software that automatically detached the tag if the pressure sensor indicated depths approaching the crush limit of the tag casing (*ca.* 2000 m). All tags were pre-programmed to release from the fish after ten days at large, and data were transmitted through the ARGOS satellite system while the tags floated at the surface following detachment from the animal.

To delineate the maximum effective fishing depths for the configuration of pelagic longline gear used by the commercial vessel, small temperature-depth recorders (TDRs; model LTD_1100; Lotek Wireless, Inc., Newfoundland, Canada) were attached to the lower end of the middle branch lines (hook three in the five-hook baskets) during gear deployments (see additional details on placement in Kerstetter and Graves, 2006). This model of TDR records pressure (as "pounds per square inch"; PSI) and temperature at 14 second intervals. The PSI data from the TDRs were standardized with latitude and seawater density corrections using Harris (2000). Data from these TDRs were also used to establish local thermocline depths.

2.1 Sailfish tagging

A PSAT was activated prior to haulback and, if necessary, during haulback immediately following the tagging of the previous fish to ensure that a tag was available for immediate deployment if a sailfish was encountered. All PSATs were allowed to cycle through the full internal activation process prior to their deployment. The captain of the pelagic longline vessel identified incoming sailfish on the line during the morning haulback of the gear and individuals were initially evaluated as live or dead based on movement (or lack thereof) alongside the vessel. The sailfish tagged from the recreational vessel was identified to species prior to striking and becoming hooked on one of the surface baits.

Live fish were manually brought alongside the vessel rail and held briefly by the leader until calm. The PSAT tagging procedures used were identical to the ones described in Kerstetter and Graves (2006), although a smaller applicator tip (8 cm) was employed to compensate for the much more laterally compressed sailfish body form. The nylon anchor attached to the PSAT tether was carefully inserted about 5-10 cm below the midpoint of the first dorsal fin to a depth of about 4-6 cm. This location on the fish provides an opportunity for the nylon tag head to pass through the dorsal pterygiophore bones without approaching the coelemic cavity (see Prince *et al.* 2002). A conventional NOAA Fisheries Cooperative Tagging Center streamer tag was also attached posterior of the PSAT on all fish tagged from the pelagic longline vessel. Sailfish were released as soon as possible after tagging by cutting the leader near the hook unless the hook was readily accessible for manual removal as described in Kerstetter and Graves (2008).

2.2 Data analysis

As with Kerstetter and Graves (2008), the net movement of tagged sailfish was estimated as the minimum straight line distance between the initial tagging location and the location of the first reliable satellite contact (calculation details in Kerstetter and Graves, 2008).

Times for sunrise, sunset, and nautical twilight for approximated local sailfish positions were obtained from the U.S. Naval Observatory (http://aa.usno.navy.mil). Because individual daily positions could not be matched with cloud cover data, no attempts were made to standardize light levels for local atmospheric conditions. Crepuscular periods were identified and excluded for diel analyses using both estimated times of local sunrise and sunset and light level data. Using only day and night period data, histograms were generated using 10 m (depth) and 1 °C (temperature) intervals for each individual sailfish.

Sea surface temperature (SST) was calculated as the average temperature for all depths 0-5 m to reduce fine-scale variability between measured data. Relationships between vertical habitat utilization and thermal structure of the water column used two calculated values for each photoperiod: SST, calculated at the photoperiod resolution, and the mixed-layer depth (MLD), which was calculated as MLD = SST - 0.5° C as per Levitus (1982).

The structure of the transmitted data from the PTT-100 HR PSATs also allowed the reconstruction of individual vertical movements (referred to hereafter as "dives"), and characteristics of individual dive events were assessed through a variety of analyses. Data from on-board vessel electronics and deployed TDRs indicated a thermocline depth of approximately 10 m in the waters of the southern Gulf of Mexico fished by the pelagic longline vessel. A vertical movement was therefore considered a single dive if it a) began at a depth < 10 m, b) incurred a maximum depth > 10 m, and c) returned to a depth < 10 m. Individual dives were then analyzed for maximum depth, minimum temperature, sea-surface temperature (SST) at beginning of dive, overall duration of dive, and the “inter-dive interval” (IDI), or the period between the end of one dive event and the start of the next. Any vertical movement not including all a-c factor data or that was missing any data from within the movement itself was considered an “incomplete” dive event and excluded from subsequent analyses. Vertical movements were assessed through a manual review of each tag dataset.

Finally, depth differences between sequential 90-second period point data were used to examine the rapidity of vertical movements in three of the fish with 100% data recovery due to physically returned tags.
Three trips were taken in the southern Gulf of Mexico between November 2005 and July 2007 to deploy 18 PSATs on sailfish caught by pelagic longline gear targeting swordfish. Per current U.S. fisheries regulations, all sailfish were caught on either non-offset size 16/0 or 10° offset size 18/0 circle hooks using squid or mackerel bait. Overall bycatch of istiophorid billfishes was minimal, comprising less than 3% by number of the total catch. One recreational angling trip was taken aboard a sportfishing vessel off Mexico in May 2006, resulting in a single successful tag deployment.

Three of the deployments from the pelagic longline vessel revealed mortality events, and these data were subsequently excluded from our analyses. (see Kerstetter and Graves, 2008 for a description of the mortality events.) Including the Isla Mujares sailfish, a total of 16 PSAT datasets were therefore examined for this study. A summary of tagging efforts and the physical condition of the surviving tagged animals is presented in Table 1. Estimated weights of released fish ranged from 11.3-29.5 kg.

For all 16 PSATs, an average of 70.3% (range: 40-88%) of the archived data were transmitted through the ARGOS system. Four of the PSATs were found on shore along the Atlantic coast 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 tags and included in subsequent analyses.

2.3 Depth and temperature

Sailfish demonstrated a very strong association with warm surface waters (Fig. 1A), spending approximately 34 % (± 13.2) of their total time at depth in the upper 10 m of the water column and 41 % (± 10.7) within the 10-20 m stratum. There were no significant diel differences in either time-at-temperature or time-at-depth distributions between the two years of this study (p > 0.25). Sailfish spent 12.4 % (± 12.9) of their time at depths ranging from 20-50 m, and only 10.6% (± 26.7) at depths greater than 50 m. Broad standard errors indicate the range of individual percentages within these broad strata rather than differences between individual depth utilization patterns. The absolute depth difference within sequential 90-second point measurements (“delta-D”) observed in three of the fish with 100% data recovery found a highly significant difference between day and night periods ($t = -4.58$, $P << 0.001$ using Satterthwaite test for unequal variances), with these fish moving vertically much more frequently between depths at night.

Pooled temperature data demonstrated that sailfish spent 89.6% (± 45.4) of their time in water temperatures ranging from 25-29 ºC (Fig. 1B), although sea surface temperatures (SSTs) measured by the tags occasionally reached over 30 ºC. The absolute temperature difference within each dive event (“delta-T”) observed in this study showed that 71.7 % (± 29.7) occurred between 0-2.0 °C, with 99.2% (± 6.4) between 0-8 °C (Fig. 2).

All of the fish in this study spent significantly more time at depths greater than the SST during daylight hours (significantly for 14 of the 16 total). However, individual fish exhibited different patterns regarding total time spent below the MLD; of the four showing a significant difference between day and night periods for time below the MLD, three were at those depths more at night and one during day. A regression analysis of the amount of time spent by the animal below the MLD and individual body size as estimated LFJL resulted in a weak, but significant relationship (Adj. $r^2 = 0.1159$; F = 2.9, $P = 0.1069$).

A total of 2279 individual dive events were examined. To minimize autocorrelation effects between individual dives, a mean maximum dive depth and mean dive duration were calculated for the day and night photoperiods for each fish. Night dives had a mean maximum depth of 38.6 m and mean dive duration of 19.4 min, while day dives had a mean maximum depth of 45.0 m and a mean duration of 14.4 min. Relationships between mean dive depth and mean dive duration for each photoperiod were significant (night: adj. $R^2 = 0.615$, $P << 0.001$; day: adj. $R^2 = 0.746$, $P << 0.001$), although the regressions were not significantly different from each other (Fisher’s z’ comparison, $z = -0.615$, $P > 0.25$; Cohen and Cohen, 1983).

2.4 Horizontal movement

Individual sailfish moved away from the tagging location at varying speeds and directions (mean distance: 337.9 km, range: 97.3-564.0 km). There was no relationship between MSLD traveled and estimated individual size. Generally, these movements are consistent with the post-spawning movements of sailfish northward along both the Atlantic and Gulf of Mexico shelf edges described in Jolley and Irby (1979). Three of the tagged fish crossed into foreign waters, including the Bahamas (n = 2) and Cuba (n = 1).

2.5 Depths of shallow-set pelagic longline gear

A total of 31 individual TDR deployments were conducted during four sets in 2006, all in hook position 3 of the five-hook baskets. Using shortening rates calculated from positions of the gear at set and haul, the estimated average depth for this gear configuration per Yoshihara (1954) was 182.1 m for hook position 3. However, the maximum depth for these TDRs at hook position 3 was only 143.8 m, with mean depths over all 31 deployments at 42.3 m. The time at depth distribution histogram for these 31 TDR deployments in 2006 is included in Fig. 3, along with the combined day and night time at depth distribution for all 16 sailfish tagged with PSATs in this study. One TDR record from these deployments can be seen with a sailfish PSAT track overlay in Fig. 4.

3. Discussion

Horizontal displacements of all 16 sailfish away from the initial tagging locations was similar to the behavior seen by Graves *et al.* (2002) with blue marlin, Kerstetter and Graves (2006) with white marlin, Sippel *et al.* (2007) with striped marlin as well as that seen for sailfish by Hoolihan and Luo (2007). It remains unknown whether this behavior is related to the tagging event or simply a factor of underlying normal movements. Jolley (1977) used detailed analyses of recreational catch records to argue that sailfish indeed undertake a seasonal movement southward into the Florida Keys during the winter and spring, then moving northward through the summer. We believe that the movement of the majority of the tagged animals in this study northward along the GOM and Atlantic edges of the shelf supports the patterns observed by Jolley (1977), as well as available conventional tagging data described by Ortiz *et al.* (2003). The close proximity of several international boundary lines, and demonstrated crossings of such lines in this study, also supports the need for international management of sailfish (see Orbesen *et al.* 2008).

Although prior PSAT studies on other billfish species have shown predominantly higher utilization percentages for depths < 20 m (e.g., Horodysky *et al.* 2006), sailfish habitat utilization in the Atlantic Ocean has not been well studied. Two acoustically tagged sailfish off Florida showed a clear preference for surface waters (Jolley and Irby, 1979). Prior work with sailfish habitat preferences in the Arabian Gulf (Hoolihan and Luo, 2007) showed only rare utilization of depths greater than 50 m. However, the range of possible depths for the sailfish tagged in the southern Gulf of Mexico far exceeded those for the animals in the Arabian Gulf, which also did not have thermoclines at depth (Hoolihan, 2005). Other possible reasons for narrow depth preferences (e.g., dissolved oxygen (DO) per Prince and Goodyear, 2006), similarly do not apply to the western North Atlantic in the same degree as other geographic areas, permitting a broad range of depth utilization. We cannot evaluate the Hoolihan (2005) hypothesis that sailfish prefer shallow depths for prey selection or predator avoidance, although this could be tested by tagging sailfish where they occasionally occur in non-oligotrophic waters with less visibility range, such as north of Cape Hatteras, North Carolina.

Nonetheless, the results presented here demonstrate movements to depth for sailfish, albeit for short periods of time. This observation is supported by several past studies of sailfish diet composition. In an examination of 241 stomachs of sailfish caught presumably during daylight hours off Florida, Voss (1953) reported finding that epipelagic fishes (i.e., Families: Scombridae, Hemiramphidae, and Belonidae) constituted the vast majority of prey items, although sea robins (Family: Triglidae), and deep-water *Grimpoteuthis* sp. octopods were also present. The occurrence of *Grimpoteuthis* sp. in particular resulted in Voss (1953) suggesting that "sailfish are not typical surface dwellers by habit." Photoperiod-specific vertical behavior differences are also supported by subsequent sailfish diet studies. Jolley (1977) used stomachs collected from sailfish caught during the daylight hours and found epipelagic fishes such as little tunny *Euthynnus alletteratus* and exocetids. In contrast, Júnior et al. (2003) used sailfish stomachs collected from pelagic longline fisheries where the animals were caught during nighttime periods and found mesopelagic fishes and cephalopods.

Several studies have suggested that istiophorids prefer a narrow temperature range, a pattern that Hoolihan and Luo (2007) would also apply to sailfish. The two sailfish tracked by Jolley and Irby (1979) did not dive below the local thermocline, although the tracks were very short in length and might instead have been reflective of a putative "recovery period" behavior. The comparatively shallow waters of the Arabian Gulf also limited the range of temperatures available to be encountered by the sailfish described there, although no such limitation exists in the southern Gulf of Mexico and Florida Straits.

Habitat utilization of pelagic fishes has been described in the literature variously by depth or temperature or both. The results of this study showing differences between years for depth distributions, but not for the corresponding temperature distributions, suggest that these fish were utilizing a specific temperature range. The effect of depth on these large energetic animals could therefore be in itself minor when compared with the effects of lower temperatures on cardiac and eye orbital muscle function and thus foraging activities. This study provides little new insights into the thermoregulatory ability of sailfish as it pertains to active foraging at colder depths, however. While the so-called "thermal inertia" hypothesis suggests that large-bodied fishes might retain heat and more effectively forage in colder waters for short periods of time, it has not been extensively tested (see Neill *et al.* 1976 for an exception with skipjack tuna, *Katsuwonus pelamis*). Nonetheless, all billfishes and swordfish possess a brain-eye heater organ (Block, 1986) that maintains these structures at higher temperatures than the ambient water, presumably to enable higher foraging efficiency in cooler waters and lower light intensities (Block and Finnerty, 1994; Fritsches *et al.* 2005). While Block (1986) reported that the heater organ of sailfish was not as robust as that of the larger billfish species such as blue marlin *Makaira nigricans*, it could still provide a competitive predatory advantage to sailfish foraging in slightly colder subsurface waters. Brill and Lutcavage (2001) hypothesized that there was an absolute value for temperature that governed the vertical behavior of pelagic teleosts, which they estimated at 8°C. The individual dive event analyses showed that 71.7 % occurred between 0-2.0°C, with 99.2% between 0-8°C, consistent with the Brill and Lutcavage (2001) assertion.

Cursory visual inspection of these dive events noted similarities with the "V" and "U" shaped patterns described in Horodysky et al. (2007) for white marlin, and suggests that this species may engage in similar "search" and "directed" behavior. Such similarities will be examined in a future publication, including possible relationships between these patterns and local environmental conditions. However, the vertical and horizontal behavior of sailfish is likely mediated by many different factors, including prey density, local oceanographic conditions, and perhaps even spawning events and seasonal effects. The varying behavior between the sailfish in the southern Gulf of Mexico and those described in Hoolihan (2005) from the Arabian Gulf may simply reflect these differences and preclude a "one size fits all" conclusion on the behaviors of sailfish as a species.

The role for habitat standardization models of pelagic longline CPUE data for stock assessment purposes such as that proposed by Hinton and Nakano (1996) remains an area of considerable disagreement. As suggested by Kraus and Rooker (2007), a good deal of the concern regarding the application of these models to the billfishes relates to the incomplete knowledge of both pelagic longline gear behavior and the behaviors of the individual istiophorid species (see also Venezelos *et al.* 2001; Goodyear et al., 2003; and Yokawa *et al.* 2001). For example, Boggs (1992) found that pelagic longline catch rates in the central Pacific were affected by overall gear depth and the position of the depth relative to the local thermocline. More recent efforts by Bigelow et al. (2006) and Rice *et al.* (2007) to describe the depths of the pelagic longline gear have at least begun to clarify the differences between the predicted depths of Yoshihara (1954) and the actual depths actively fished by the gear during the complete period from deployment to retrieval. However, the differences between geographic locations and the effects of surface and subsurface currents may preclude a simple assumption of actual fishing depths from gear characteristics alone (see discussion in Bigelow et al., 2006).

Similarly, the increasing number of studies regarding habitat utilization by swordfish, tunas, and billfishes has begun to elaborate the complex relationships involved in pelagic longline gear interactions. The higher utilization percentages for shallower depths by sailfish over several studies has suggested that it might be possible to reduce bycatch of sailfish by configuring shallow-set pelagic longline gear to fish "below" the range of utilized depths. Although more recent work in the Pacific Ocean with experimental deep-set longline gear (minimum depths >100 m) showed significant reductions in blue marlin, striped marlin *Kajikia audax*, and shortbill spearfish *Tetrapturus angustiorostris* catch, although the catch of sailfish was not significantly different (Beverly et al., 2009). The results of such experimental sets have yet to be described in the ICCAT Convention Area and so cannot be evaluated here for potential sailfish bycatch reduction. While the majority of time-at-depth for sailfish is above the depths actively fished by shallow set pelagic longline gear, the demonstrated frequent movements to depth of sailfish through this depth distribution negate most potential for bycatch reduction for the shallow-set swordfish targeting pelagic longline fishery through changes in gear depth alone. As suggested by Kraus and Rooker (2007) and others, the role of deeper depths during short-duration dives by istiophorid billfishes, presumably for foraging events, may result in an ironic situation in which the depths of least amount of aggregate time are the depths of highest feeding motivation, and hence the depths of highest interaction potential with the baited hooks of pelagic longline gear. Until time at depth and feeding motivations with respect to photoperiod can be standardized, it remains premature to apply habitat-based stock assessment models on sailfish.

Acknowledgements

The authors thank the captains and crews of the F/V *Kristin Lee* and F/V *Carol Ann* for their assistance with our tagging efforts. This study was funded by Gulf States Marine Fisheries Commission grant award BILLFISH-2005-009.

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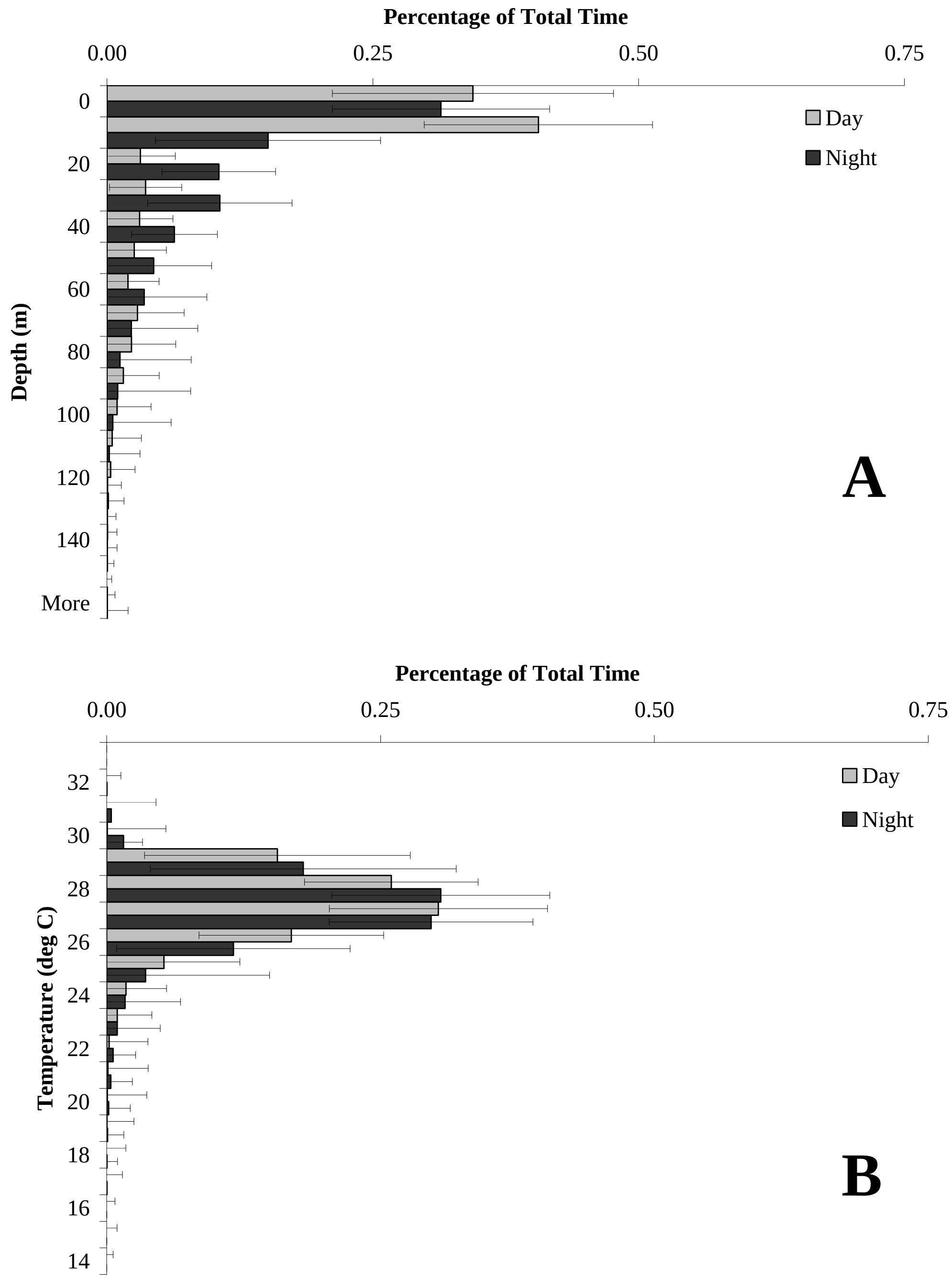
Table 1. Summary of pop-up satellite archival tagging deployments for sailfish in the southern Gulf of Mexico. "ACESS Score" refers to a physical condition index based on a ten-point scale ("10" being the highest score; see Kerstetter et al., 2002 for further details on the scale). Estimated lengths are "lower jaw-fork lengths" (LJFL). The two mortalities described within text are not included.

Sailfish Number	Date Deployed	Hooking Location	Hook Size	Hook Removed?	ACESS Score	Estimated Length (cm)	Reporting Percentage	MSLD (km)
6-01	6-May-06	Corner	16/0	Y	9	137	59%	448.0
6-02	6-May-06	Lower Jaw	18/0	Y	9	183	82%	375.5
6-03	6-May-06	Fouled	16/0	N	8	168	63%	150.1
6-04	6-May-06	Isthmus	18/0	Y	10	183	55%	188.6
6-05	6-May-06	Corner	16/0	N	10	168	68%	332.4
6-06	6-May-06	Eye Socket	16/0	N	9	152	75%	554.9
6-07	6-May-06	(fouled)	16/0	Y	8	152	65% *	97.3
6-08	6-May-06	Lower Jaw	18/0	Y	8	168	40%	193.5
6-09	6-May-06	Corner	18/0	Y	8	152	68%	447.0
6-10 (I.M.)	31-May-06	Corner	7/0	Y	10	(137)**	49%	217.1
7-01	7-Jun-07	Corner	16/0	N	9	122	75%	522.9
7-03	7-Jun-07	Corner	16/0	N	6	122	87%	125.0
7-04	7-Jun-07	Corner	16/0	N	10	122	74%*	406.2
7-05	7-Jun-07	Corner	16/0	N	10	137	86%*	564.0
7-06	7-Jun-07	Corner	16/0	N	5	107	88%	717.3
7-07	7-Jun-07	Corner	16/0	N	6	122	88%*	67.4

* Original reporting percentage – tags were later returned, allowing a 100% data recovery rate.
** NE = "not estimated".



Figures 1A and 1B. Time-at-depth (A) and time-at-temperature (B) histograms for 16 sailfish tagged with pop-up satellite archival tags for 10-day deployment durations in the southern Gulf of Mexico, 2006-2007.

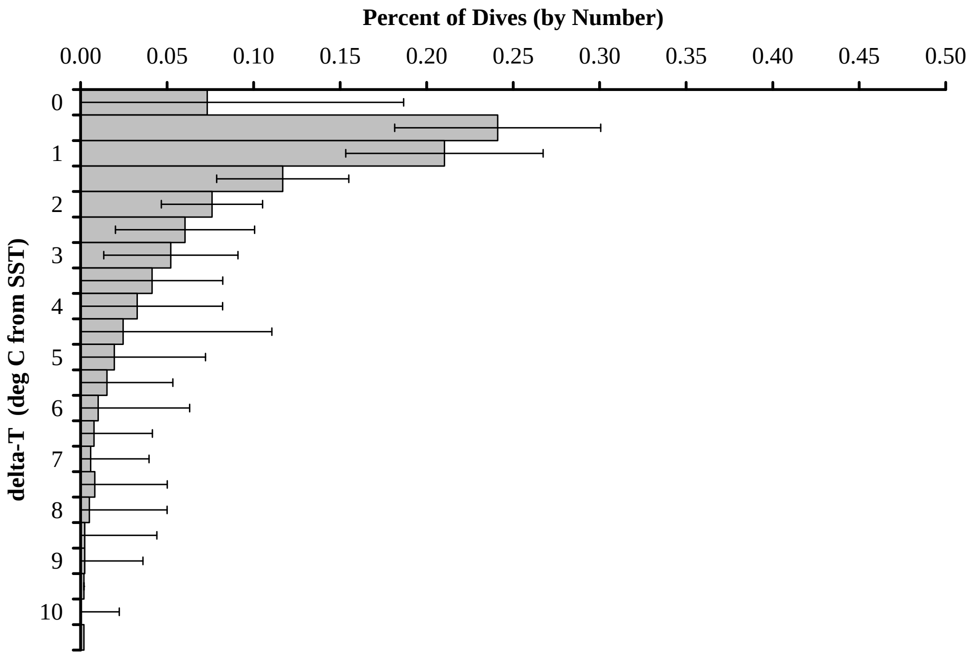


Figure 2. Percentage of temperature differences between local sea surface temperature and minimum temperature encountered on dive event (delta-T value) by 1°C intervals for 16 sailfish tagged with pop-up satellite archival tags for 10-day deployment durations in the southern Gulf of Mexico, 2006-2007.

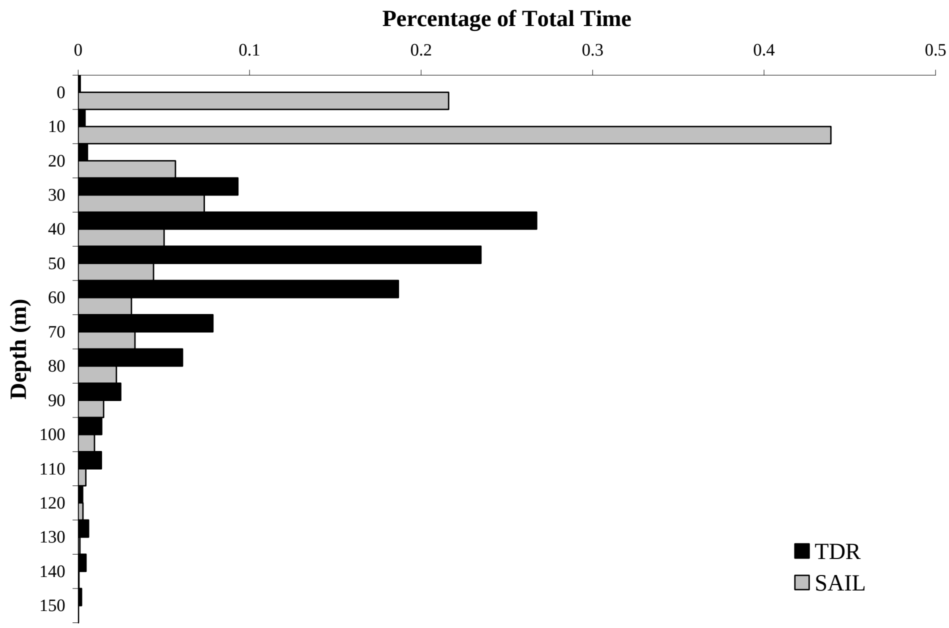


Figure 3. Total time at depth histogram for combined day and night periods for sailfish (grey; "SAIL") tagged with pop-up satellite archival tags (PSATs) and hook position 3 in shallow set pelagic longline gear monitored with temperature-depth recorders (TDRs) during 2006 in the southern Gulf of Mexico (black; "TDR").

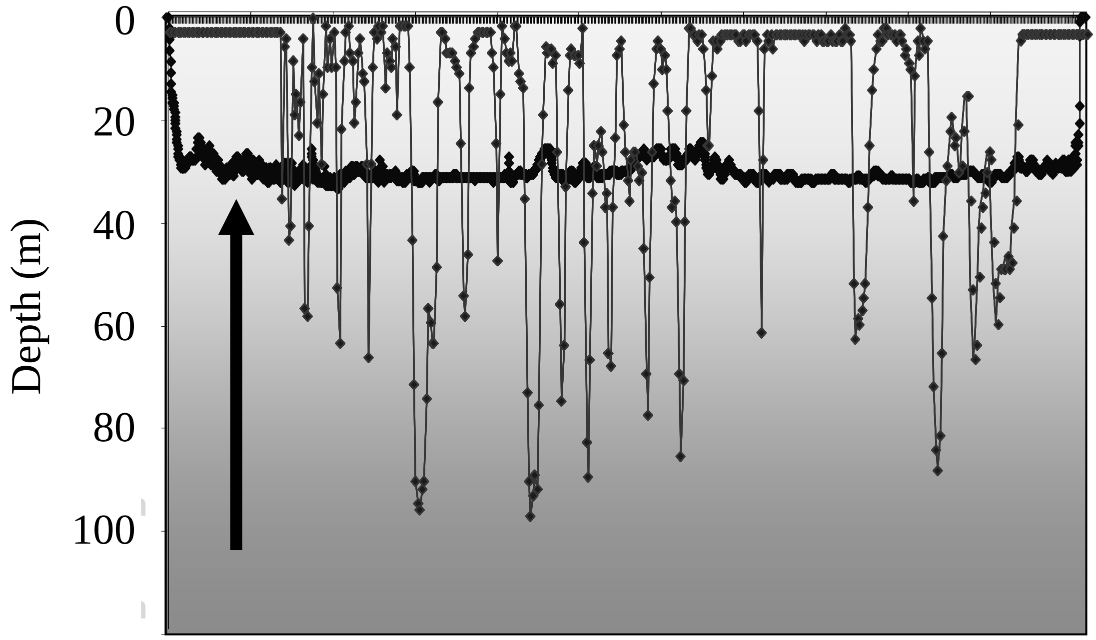


Figure 4. Overnight (one pelagic longline gear deployment period) depth record from temperature-depth recorder and concurrent depth record from sailfish tagged off the Florida Keys, May 2006 between 21:20 and 08:20 local time. Thin line indicates 90-second track of a sailfish tagged with a pop-up satellite archival tag (PSAT), while the thick line (noted with black arrow) indicates the monitored depth of the lower end of the third hook gangion on commercial coastal pelagic longline fishing gear deployed concurrently with the PSAT deployment duration. Repeated movements through the effective fishing depth range of the fishing gear suggest a high interaction potential for this individual.