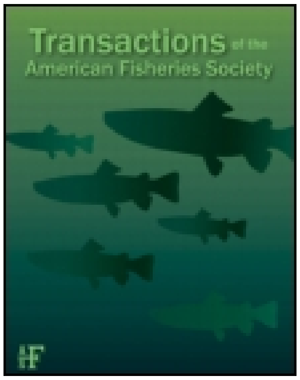

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Swordfish Vertical Distribution and Habitat Use in Relation to Diel and Lunar Cycles in the Western North Atlantic

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NOTE

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Abstract

The vertical movement patterns of eight Swordfish *Xiphias gladius* from 109- to 249-cm lower jaw fork length in the western North Atlantic were studied utilizing pop-up archival transmitting tags. Deployments ranged from 120 to 151 d. Swordfish demonstrated significant differences in depth and temperature distributions between daytime and nighttime periods. Individual Swordfish behavior was characterized by occupying surface waters of less than 100 m during the night and depths greater than 400 m during daytime hours, vertical movements between the surface and depth occurring during crepuscular hours. The maximum depth recorded was 1,448 m (one of the deepest recorded depths for the species). Daytime surfacing behavior was seen in all tagged Swordfish, a rare finding for Swordfish in tropical latitudes. A dominant diurnal period of 1 cycle/d was found from a power spectral density analysis of five of the tagged Swordfish, a novel method for determining periodicity in the behavior of tagged animals.

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Regression analysis indicated a significant positive relationship between depth and fraction of the moon illuminated, supporting anecdotal and vessel logbook information from local Swordfish fisheries indicating changes in depth in relation to lunar phase.

The Swordfish *Xiphias gladius* is an apex predator with a circumglobal distribution in tropical and temperate waters (Sedberry and Loefer 2001). Swordfish are found across a wide range of depths and temperatures, their daily movements ranging from 0 to 1,500 m and 10°C to 28°C (Sedberry and Loefer 2001; Dewar and Polovina 2005; Dewar et al. 2011). Previous studies of Swordfish have demonstrated that they undertake large-scale, long-term horizontal movements that can exceed 3,000 km (NMFS 2006; Neilson et al. 2009).

One location where Swordfish are targeted is the Florida Straits, which are characterized by a narrow continental shelf with steep depth contours that occur relatively close to shore (Fiechter and Mooers 2003). In addition, the axis of the Gulf Stream, with current velocities that often approach 5 knots and extend from the surface to the bottom, are found in close proximity to the southeast Florida coast (Knauss 1996). The combination of these unique oceanographic features allows fishers easy access to Swordfish grounds, which lie around the 500–1,000-m depth contours about 15–35 km off the southeast Florida coast. This is in contrast to most other areas along the eastern coast of the United States, where Swordfish are targeted much further offshore due to a broader continental shelf ranging from 50 to 120 km (Knauss 1996; Sedberry and Loefer 2001; Fiechter and Mooers 2003).

Historically, two fishery sectors have targeted Swordfish in the Florida Straits: a commercial pelagic longline fishery and a recreational rod-and-reel fishery. The pelagic longline fishery has been closed in this area since 2000, primarily due to concerns about high levels of undersized Swordfish bycatch (NMFS 2006). A relatively new commercial fishery using "buoy gear" has also emerged targeting Swordfish using up to 15 individually floating buoys and single or double hooks (NMFS 2006; D.W.K. and S. M. Bayse, Nova Southeastern University Oceanographic Center, unpublished report). The southeast Florida recreational fishery for Swordfish existed in the late 1970s until low catch rates resulted in the cessation of most activity. However, recreational fisheries targeting Swordfish have been expanding over the last decade between Fort Pierce and Key West, Florida. As a result, the recreational Swordfish fishery off the southeast Florida coast has experienced a rebirth in recent years (NMFS 2006; Levesque and Kerstetter 2007).

Previous electronic tagging studies in the North Atlantic and the Pacific oceans have provided evidence that Swordfish exhibit a pattern of vertical migration in response to diel and lunar cycles (Carey and Robison 1981; Sedberry and Loefer 2001; Dewar and Polovina 2005; Loefer et al. 2007; Abascal et al. 2010; Dewar et al. 2011). However, despite recent work using electronic tags to monitor Swordfish in the Atlantic (Loefer et al. 2007; Neilson et al. 2009; Dewar et al. 2011) and Pacific (Abascal et al. 2010; Dewar et al. 2011), few studies have focused on Swordfish vertical distribution in this region of the western North Atlantic. Loefer et al. (2007) reported behavior in response to lunar cycles for seven Swordfish tagged in the western North Atlantic. In addition, Dewar et al. (2011) reported habitat use in response to diel and lunar cycles from seven Swordfish tagged within this region. Therefore, the objectives of this study were to evaluate and characterize Swordfish behavior in the western North Atlantic in relation to diel and lunar cycles, and to identify habitat use within this region of limited data availability. An understanding of Swordfish behavior and habitat use in the western North Atlantic is important given the fact that Swordfish are the target of both commercial and recreational fisheries within the region.

METHODS

Tagging operations.—Swordfish were tagged about 16–32 km offshore of the southeast Florida coast. Tags were deployed during both day and night hours aboard recreational ($n = 4$) and commercial buoy gear fishing vessels ($n = 6$) using fishing techniques standard to each fishery type. The buoy gear fishery utilizes handlines attached to free-floating buoys, which contain no more than two hooks per handline (NMFS 2006). Bait was squid *Illex* spp., small "tinker" mackerel *Scomber* spp., and Little Tunny *Euthynnus alletteratus*. Hooks used during recreational rod-and-reel fishing were 11/0 J-style hooks, while 14/0 and 16/0 non-offset circle hooks were used during the commercial buoy gear operations for this project, which occurred primarily at night. The deployment locations were obtained using the vessel's onboard GPS.

Tags.—The pop-up archival transmitting tag (PAT) model used in this study was Mk10-PAT (Wildlife Computers, Redmond, Washington). Physical and operational descriptions of these tags can be found in Goodyear et al. (2008). Tags were rigged using 181-kg (400-lb) test strength nylon monofilament leader material attached to a medical-grade nylon, double-barb anchor equipped with elongated nylon toggles (see Prince et al. 2002). Deployment durations were programmed for 120 (n = 7), 130 ($n = 1$), 140 ($n = 1$), and 151 d ($n = 1$). Temperature, depth, and light data were sampled and archived by the tag at 10-s intervals. Transmitted data were summarized into 1-h bins to observe behavior during crepuscular periods. Temperature data were organized into 14 bins ranging from 6°C to greater than 30°C with a resolution of 2°C. Binned depth data were organized into 14 bins with a resolution of 25 m for the first 100 m, then 100 m for the remaining bins to > 1,000 m. The profile–depth–temperature (PDT) data set consisted of minimum and maximum depth values (with the corresponding temperatures), with up to six depth and temperature readings between the minimum and maximum depth values. Tags were also programmed to detach automatically if a fish remained at a constant depth ($\pm$ 1.5 m) for 24 h, an assumed mortality event.

Tagging procedures.—Tagging and data collection procedures were conducted on Swordfish while in the water. Fish were captured, handled, tagged, and measured following the procedures described in Prince et al. (2002). Each fish was also tagged with a conventional tag in the dorsal musculature posterior to the PAT. Hooks were removed prior to release.

Data analysis.—The resulting Mk10-PAT data sets were processed using Wildlife Computers software (WC-AMP version 1.02.0007 and WC-GPE version 1.02.0005). Data on the fraction of the moon illuminated and the times of moonrise–moonset, sunrise–sunset, and nautical twilight were obtained from the U.S. Naval Observatory (USNO; http://aa.usno.navy.mil). The fraction of the moon illuminated per USNO data was used as a proxy for the level of moonlight. Actual daily locations could not be determined; therefore, moonlight data were not corrected for potential local cloud cover.

Time at depth and PDT data sets were used to test for differences in day and night distributions. The PDT data for each fish were arranged to classify each hour-long bin into day, night, and crepuscular categories. Any 1-h period including sunrise or sunset was categorized as a crepuscular period and eliminated from the day and night analysis, and was included in the crepuscular analysis. Any negative depth values were converted to "0 m" for analyses. The median of the depth values was calculated for each 1-h bin, and the mean median depths for daytime and night periods were calculated for each fish. Temperature data were organized in the same manner as depth data. A Mann–Whitney U-test was used to assess differences in day and night depth and temperature distributions as well as day and night depths of the four smallest fish and four largest fish tagged during the study. Two "delta depth" and "delta temperature" values were defined as the difference between the minimum and maximum values recorded during each PDT 1-h summary. Methods used for sorting hourly summaries in the time at depth and temperature data sets into daytime, nighttime, and crepuscular periods were identical to those used for the PDT data set. The amount of data used to construct time at depth and time at temperature histograms varied by tag deployment. Thus, the SEs were normalized according to the equations described in Sippel et al. (2007), which were modified to normalize errors based on tag deployments.

Time at depth and PDT data sets were also utilized to test for differences in vertical distribution in relation to lunar illumination. Prior to the analysis, the lunar data set was tested for normality (Shapiro–Wilk test) and homoscedasticity (Breusch–Pagan test; Sokal and Rohlf 1995).

Using times of sunrise and sunset and moonrise and moonset, the data were filtered to only include hour summaries which occurred during nighttime hours between moonrise and moonset. Hour summaries that included moonrise and moonset were excluded, and only data in which lunar illumination was present for the entire hourly period were included. Median depths were plotted for each period of the moon fraction illuminated. The filtered data set used to compare depth and lunar illumination contained a single data point that was a suspected outlier. Grubb's test (Sokal and Rohlf 1995) indicated that this data point was an outlier ($G = 5.69$, $P < 0.01$) and it was removed from subsequent analyses. A linear regression was run on the resulting data set to determine the relationship between depth and lunar illumination. Swordfish motion is autocorrelated and preliminary calculations show that the integral time scale (the integral of the autocovariance function) is 6 h. Therefore, the effective degrees of freedom for each time series were calculated by dividing the sampling interval by twice the integral time scale. The SEs were inflated by multiplying the SEs assuming uncorrelated data by the square root of 12.

The methods used to filter hourly summaries in the time-at-depth data set were identical to those used for the PDT data, and hourly summaries were arranged by the fraction of the moon illuminated. Hourly summaries containing data from the "new moon" (0–0.25 lunar illumination) and "full moon" (0.76–1.00 lunar illumination) were then separated. Time spent in each depth bin for each of the two periods was pooled for all tags, and the proportion of time spent at each depth during the "new moon" and "full moon" were averaged and plotted.

The PDT data set was also used to determine basking behavior in Swordfish. Basking behavior was defined as a "0-m" minimum depth during the day. A basking index was calculated for each fish by dividing the number of bins with a basking event by the total number of bins to standardize frequencies for comparisons. A Mann–Whitney U-test was used to compare the basking indices of the four smallest fish with those of the four largest fish tagged during the study. When the same hourly bin was present in both the PDT and time-at-depth data sets, the time spent within the 0–25-m bin was also noted. Time spent in the 0–25-m bin was then pooled for all fish, and the average time spent in this bin was calculated.

A power spectral density analysis was used to test for significant differences in diel distributions and to determine the dominant period in the time series of average depth in five tagged fish utilizing techniques outlined by Press et al. (1986). The average value of the PDT depth measurements was calculated for each hour summary period. Given the missing data through the satellite transmission process, Press and Teukolsky's (1988) algorithm for unevenly spaced data were used to account for missing records in the time series data sets. The resulting data were subsequently plotted with frequency (in units of cycles per day) as the independent variable and power density as the dependent variable.

Based on the assumption that commercial fishers might have changed their targeting strategies based on lunar phase, a regression analysis was used to examine the relationship between setting depth of hooks and illuminated fraction of the moon. The analysis was conducted on NMFS Pelagic Observer Program data from 1992 to 2000 for 495 pelagic longline sets conducted within the Florida east coast (FEC) statistical area (the majority of the FEC was closed to pelagic longline gear in 2000).

Given the paucity of light data recorded by the tags due to the depths Swordfish frequent during daytime hours, light-based geolocations could not be estimated to determine horizontal movements. Thus, net displacement of Swordfish was calculated as the straight-line linear distance from the GPS-determined

TABLE 1. Data for 10 Swordfish tagged off the southeast coast of Florida.

PAT number	Tag date	LJFL (cm)	Programmed duration	Actual days at liberty	Release location	Location of first transmission	Horizontal displacement (km)
49857	Oct 22, 2007	132	120	57	27°09′19.73″N, 79°44′24″W	26°55′48″N, 76°59′24″W	273.98
49858	Oct 22, 2007	150	120	116	27°15′12.6″N, 79°45′36″W	12°37′48″N, 70°38′24″W	1,877.59
49859	Oct 21, 2007	173	130	132	26°54′39.06″N, 79°43′48″W	26°51′00″N, 76°36′36″W	310.07
49860	Oct 4, 2007	109	120	103	27°02′35.5″N, 79°44′24″W	21°04′48″N, 70°35′24″W	1,140.47
49861	Nov 16, 2007	249	120	2	27°00′00″N, 79°42′36″W	30°09′00″N, 79°48′00″W	349.22
49862	Sep 1, 2007	140	140	1	26°15′N, 79°48′W	27°34′33.6″N, 79°41′23.9″W	147.40
49899	Dec 1, 2007	183	151	133	25°54′21.5″N, 79°48′00″W	19°49′12″N, 81°34′48″W	698.26
81295	Apr 21, 2008	211	120	121	27°08′06″N, 79°44′12″W	27°06′36″N, 79°46′12″W	3.23
81296	Sep 17, 2008	160	120	121	26°01′00″N, 79°48′00″W	23°20′24″N, 85°01′12″W	605.74
81297	Sep 17, 2008	135	120	87	26°01′30″N, 79°47′24″W	32°03′36″N, 78°11′24″W	686.78

release location to the location of first transmission. All distances were calculated with Program INVERSE (NGS 1975; modified by M. Ortiz, NMFS–Southeast Fisheries Science Center, Miami, Florida).

RESULTS

Ten Swordfish ranging in size from 109- to 249-cm lower jaw fork length (LJFL) were tagged between September 1, 2007, and September 17, 2008, off the southeast coast of Florida (Table 1). All tags reported; however, only three tags remained attached to the fish for full-deployment periods. Horizontal displacements ranged from 3 to 1,878 km (Figure 1). Based on depth records, it was determined that two Swordfish died within 52 h of release. Data from these tags were omitted from the subsequent behavior analyses. Due to a malfunctioning tag sensor, temperature data from PAT 49857 after December 5, 2007, were also omitted from the analyses.

Swordfish demonstrated highly significant differences in daytime and nighttime depths ($U = 64$, $P < 0.001$; Figure 2, top panel). During daytime hours, the fish spent 87% of their time between 400 and 800 m. Swordfish were found closer to the surface during night, 71% of their time being spent at 100 m or less and 93% at 200 m or less. During crepuscular hours, Swordfish were distributed over a wider range of depths, spending 87% of their time from 200 to 700 m. Mean median daytime depths calculated from the PDT data set ranged from 449 to 656 m, nighttime depths ranging from 54 to 108 m. There were no significant differences in day ($U = 14$, $P > 0.05$) and night ($U = 15$, $P > 0.05$) depths between the four largest and four smallest fish tagged during the study. The Swordfish with PAT 49899 (Table 1) recorded the maximum depth during this study at 1,448 m.

There were highly significant differences in daytime and nighttime temperatures visited by Swordfish during this study ($U = 64$, $P < 0.001$; Figure 2, bottom panel). Corresponding to differences in depth distributions, Swordfish spent 96% of daytime hours at temperatures between 8°C and 16°C. During nighttime hours, Swordfish spent 82% of the time in waters between 24°C and 30°C. The widest range of temperature distributions was observed during crepuscular periods in which Swordfish spent 90% of the time from 8°C to 20°C. Mean median temperatures ranged from 8.5°C to 13.3°C during daytime hours and from 23.6°C to 26.2°C during nighttime hours.

Swordfish occupied epipelagic waters during nighttime hours and remained deeper in the water column during daytime hours (Figure 3, top panel). Daytime and nighttime delta depth

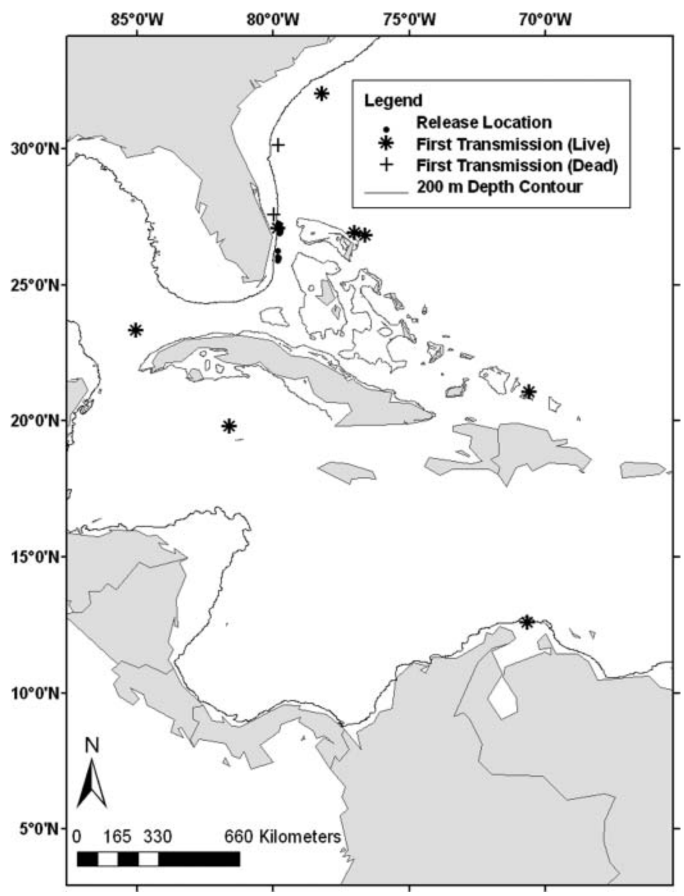

FIGURE 1. Tagging and pop-off locations for 10 Swordfish tagged with PATs in the Florida Straits, October 2007–September 2008.

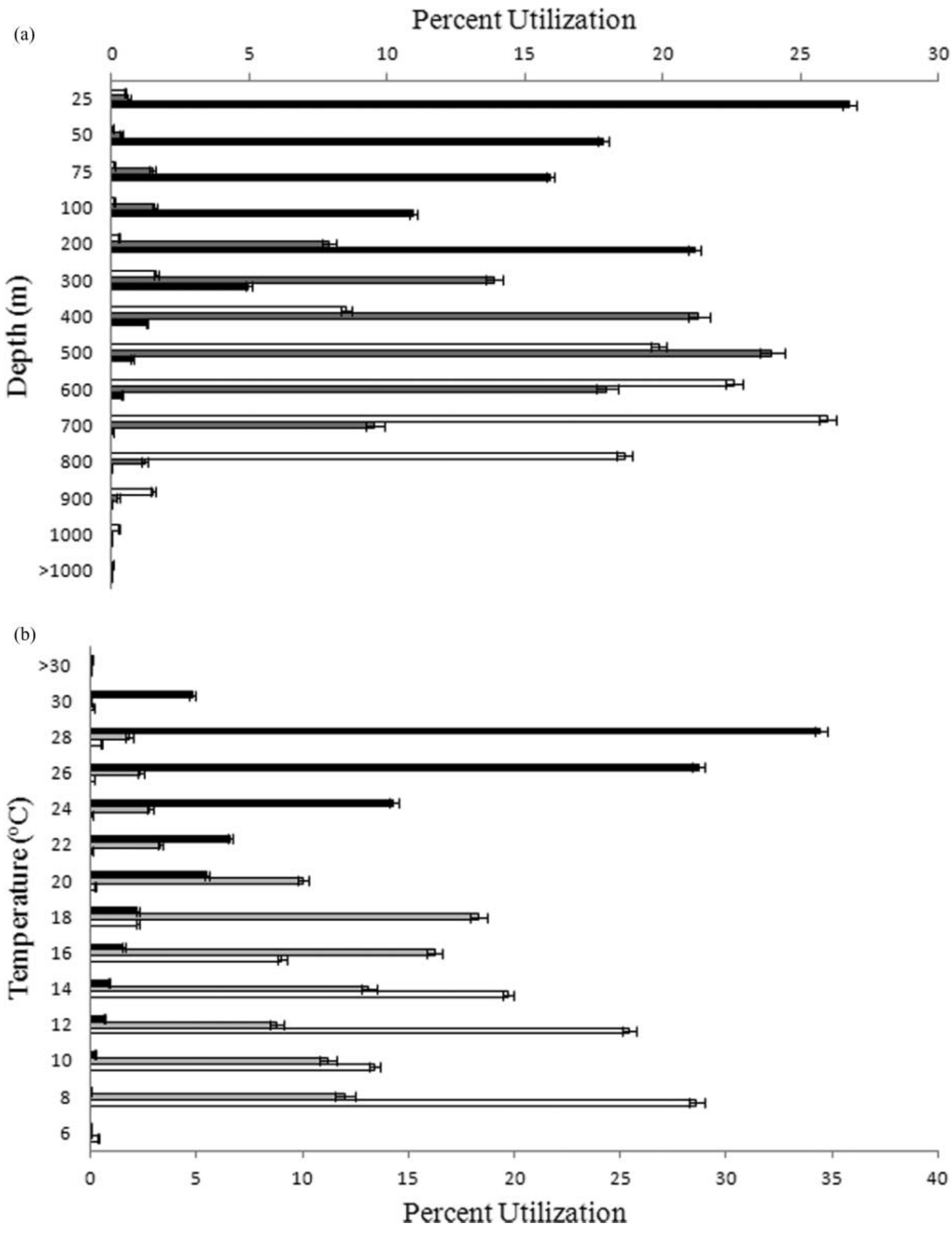

FIGURE 2. Histograms of time spent in each of 12 preprogrammed depth (top panel) and temperature (bottom panel) bins during daytime (white bars), crepuscular (grey bars), and nighttime hours (black bars) derived from (**a**) time-at-depth and (**b**) time-at-temperature data sets for eight Swordfish tagged with PATs in the Florida Straits; error bars are ± SE.

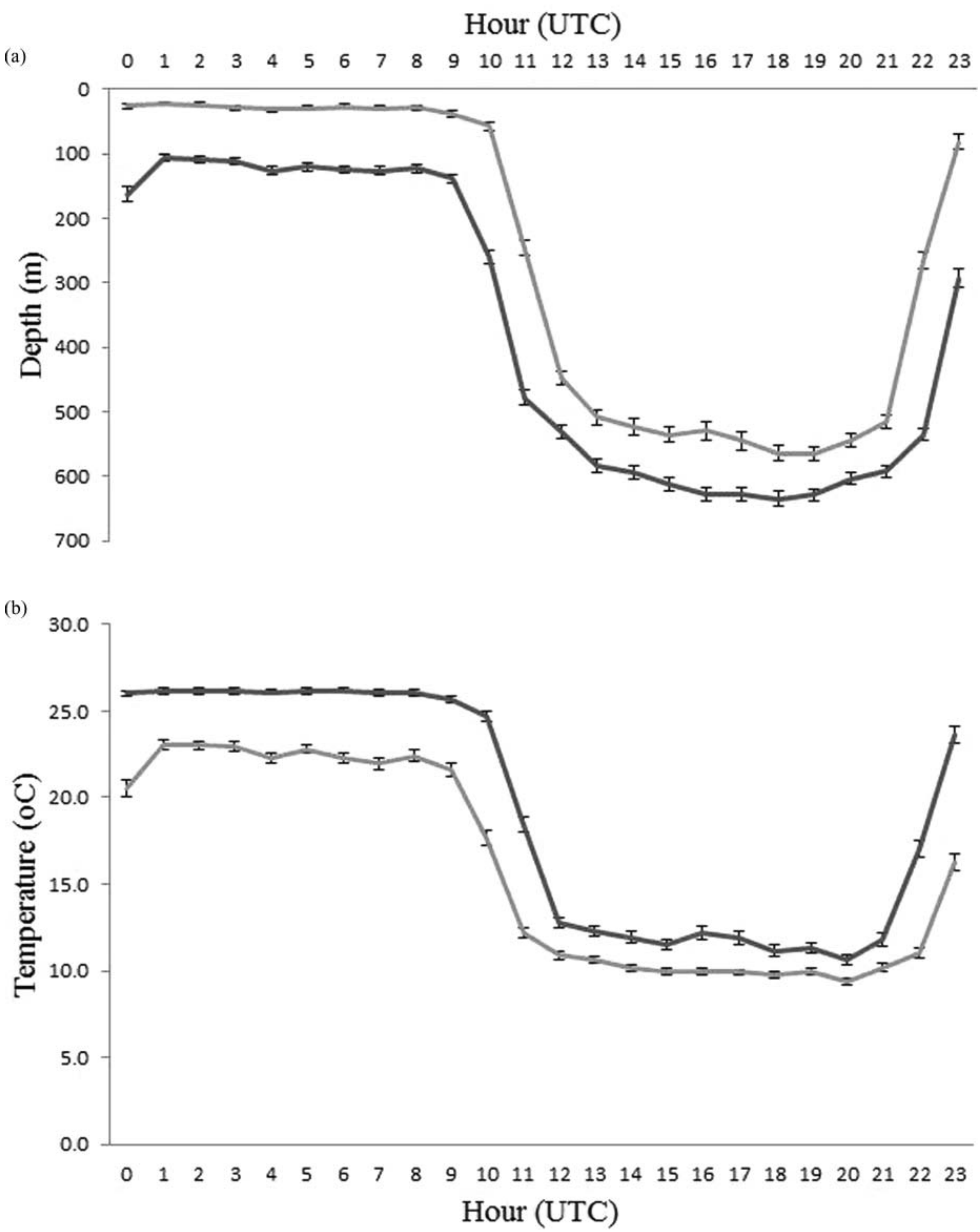

FIGURE 3. Habitat utilized by eight Swordfish tagged with PATs in the Florida Straits. Solid lines indicate the average minimum (grey line) and maximum (black line) depths (**a**) and temperatures (**b**) visited by Swordfish over a 24-h period; error bars are ± SE.

distributions were significantly different ($U = 54$, $P < 0.05$), greater delta depths occurring during hours of darkness. Delta temperature distributions were also significantly different between day and night ($U = 59$, $P < 0.01$), nighttime delta temperatures exceeding those during hours of daylight (Figure 3, bottom panel).

Swordfish behavior was influenced by lunar phase, as indicated by linear regression analysis that resulted in a highly significant relationship (adjusted $r^2 = 0.30$, $P < 0.0001$) between depth and the illuminated fraction of the moon. Regression coefficients were 32.282 and 53.039 with inflated SEs of 20.6 and 32.35, respectively. Comparisons of the time at depth during both the new moon and the full moon periods also indicated a relationship between nighttime depth and the illuminated fraction of the moon. During the new moon, Swordfish spent 82% of time at depths of less than 75 m and 18% of time from 100 to 500 m. However, Swordfish spent 64% of time during the full moon in depths from 100 to 500 m and only 36% of time at less than 75 m. The greatest percentage of time (31%) was spent at 25–50 m during the new moon, while the greatest percentage of time (41%) was spent at 100–200 m during the full moon period (Figure 4).

Plots of the power distribution calculated for five tagged fish (which clearly show the range of the estimator) as a function of frequency (1 sinusoidal cycle/d) show a distinct peak at a frequency of 1, which indicates 1 d as the dominant period of vertical migration (Figure 5). The squared amplitude of the daily (diel) cycle is one to two magnitudes greater in value than the squared amplitudes of the other frequencies. Significance values were $P < 0.01$ for all five fish (49857, 49858, 49859, 49860, and 49899).

The eight tagged fish recorded a total of 39 basking events. Basking indices ranged from 0.00151 to 0.04167 per fish per deployment. There were significant differences ($U = 16$, $P < 0.05$) between the indices recorded for the four largest fish (160–211-cm LJFL) and the four smallest fish (109–150-cm LJFL), the larger fish recording greater basking indices due to a higher frequency of basking events. This indicates that the frequency of basking events may be related to size. The average time at depth spent in the 0–25-m depth bin during a basking event was 18 min (range = 3–40 min). Basking events were recorded during all seasons. However, only one fish was at large during spring and summer; the remaining deployments ($n = 7$) occurred during fall and winter.

Regression analysis between the setting depth of hooks and the illuminated percentage of moon in the FEC longline fishery resulted in an r^2 of 0.0661, but with an F-value of 34.99 and a highly significant $P < 0.0001$. Therefore, a significant relationship exists between hook depth and illuminated percentage of the moon, fishers increasing the depth of hooks during periods of

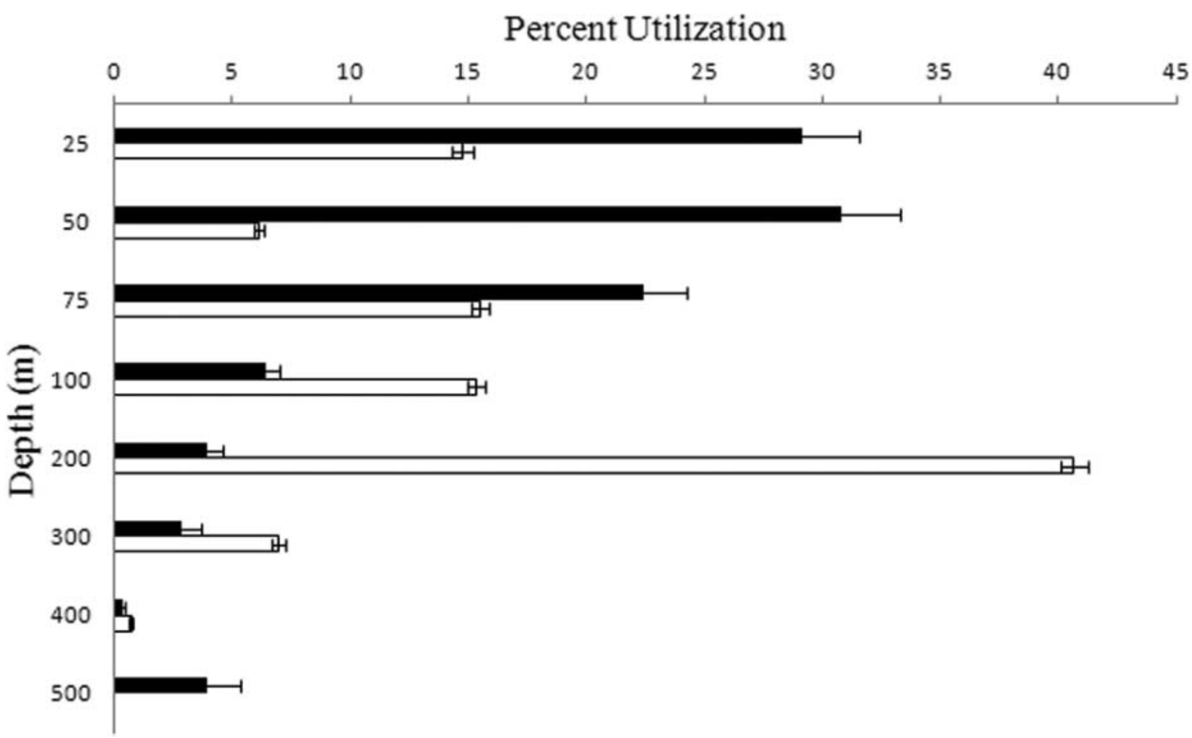

FIGURE 4. Percentage of time spent in each successive depth bin during new moon (black bars) and full moon periods (white bars) for eight Swordfish tagged with PATs in the Florida Straits. New moon period was defined as 0–0.25 lunar illumination, and full moon period was defined as 0.76–1.00 lunar illumination; error bars are ± SE.

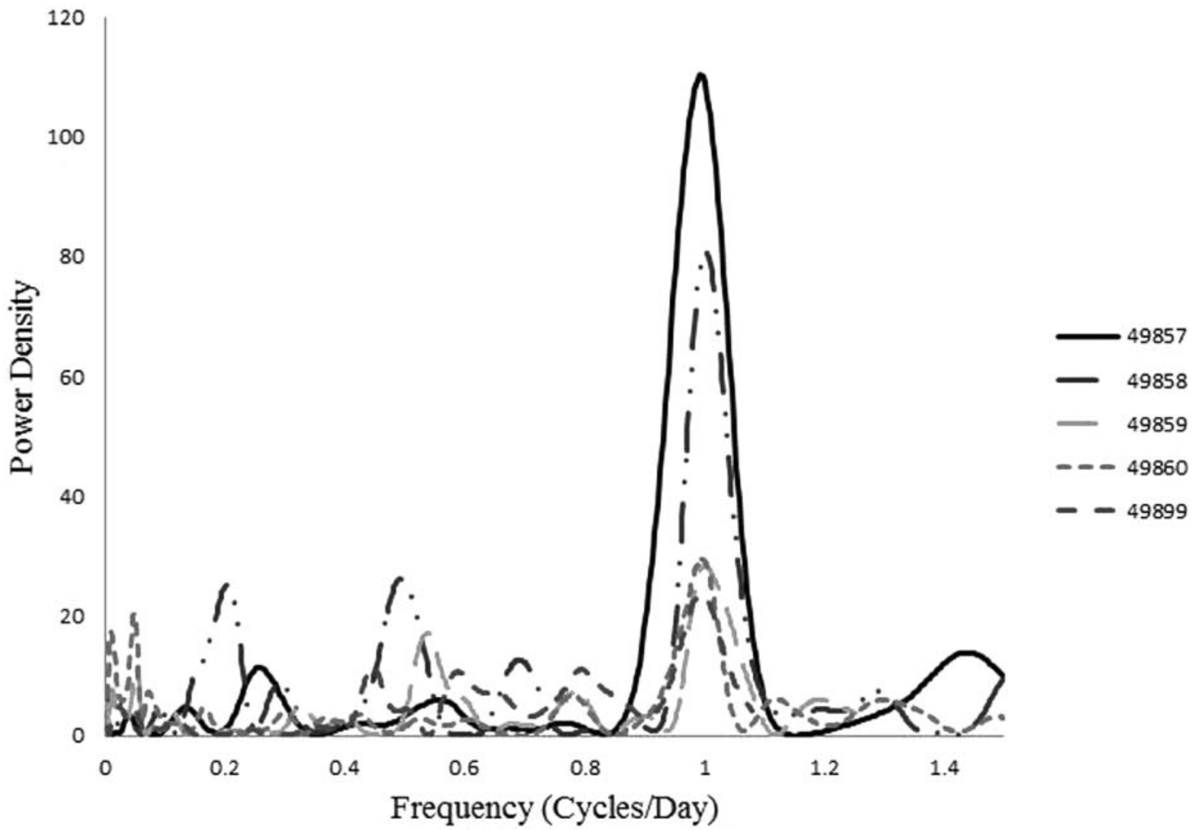

FIGURE 5. Plots of the power distribution as a function of frequency (1 sinusoidal cycle/d) for five Swordfish tagged in the Florida Straits. The largest peaks in each data series occur at a frequency of 1, indicating 1 d as the dominant cycle for Swordfish vertical migration.

higher lunar illumination. Thus, commercial fishermen altered their fishing methods during different lunar phases according to their own experiences gathered over time.

DISCUSSION

The results of this study indicate that the vertical distribution and habitat use of Swordfish in the western North Atlantic are strongly influenced by diel cycles. Swordfish were typically found in the surface mixed layer at night and deeper in the water column during daytime hours. The maximum daytime depth recorded during this study (1,448 m) represents one of the deepest recorded depths for the species. Variability in depth and temperature were greatest during the crepuscular periods surrounding sunrise and sunset, indicating that vertical movements throughout the water column are greatest during these time periods. These results are consistent with those reported in previous studies of Swordfish in the Atlantic and Pacific oceans as well as the Mediterranean Sea (Carey and Robison 1981; Sedberry and Loefer 2001; Canese et al. 2008; Abascal et al. 2010; Dewar et al. 2011). While prior PAT studies were undertaken in several geographic locations, Dewar et al. (2011) reported similar vertical distribution patterns in seven Swordfish tagged in the western North Atlantic Ocean and Caribbean Sea. Thus, this study increased the number of deployments and data available for this region, and supplements prior studies particularly with respect to habitat use on an hourly basis.

Swordfish behavior was also correlated to lunar illumination. Previous studies throughout the Pacific and Atlantic oceans have documented a significant relationship between depth and lunar illumination (Carey and Robison 1981; Loefer et al. 2007; Abascal et al. 2010; Dewar et al. 2011). Loefer et al. (2007) and Dewar et al. (2011) examined the relationship between depth and lunar illumination in the western North Atlantic Ocean and Caribbean Sea. The results of this study are consistent with these prior studies and indicate that Swordfish depth preference increases with increasing lunar illumination.

We utilized a power spectral density analysis to quantitatively determine the periodicity in Swordfish vertical migration, a novel analysis with PAT data. Previous studies have shown qualitatively, mostly by inspection or by assumption, the diurnal signal in Swordfish behavior (Carey and Robison 1981; Sedberry and Loefer 2001; Canese et al. 2008; Abascal et al. 2010; Dewar et al. 2011). The power spectral density analysis is the maximum likelihood estimator for estimating the period of a harmonic signal in noise and thus is able to show quantitatively that the diurnal signal is the dominant data period in Swordfish behavior. This analysis presents a new method to analyze PAT data and quantitatively determine periodicity in the behavior of electronically tagged marine animals.

While Swordfish typically occupied deep waters during daytime hours, all fish monitored during this study demonstrated basking behavior during the day in tropical and subtropical waters. Daytime basking behavior has been previously documented in the North Atlantic Ocean, the Pacific Ocean, and the Mediterranean Sea (Carey and Robison 1981; NMFS 2006; Canese et al. 2008; Abascal et al. 2010; Sepulveda et al. 2010; Dewar et al. 2011). Sepulveda et al. (2010) reported an average basking time of 17 min for Swordfish tagged off the California coast, similar to the average time spent in the upper 25 m during a basking event recorded during this study (18 min). Dewar et al. (2011) reported a larger range of average time spent at the surface (10 min to 4.7 h); however, data were pooled from tagging locations in both the western North Atlantic and Pacific oceans. Since little information has been previously published on Swordfish basking in the tropical western North Atlantic, this study increases the data reported for this region. In addition, this study provides quantitative evidence linking fish size and basking frequency, which had not been documented in prior studies.

Currently, Swordfish in the Florida Straits are subject to both a directed commercial fishery utilizing buoy gear (NMFS 2006; D.W.K. and Bayse, unpublished report) and a recreational rod-and-reel fishery (Levesque and Kerstetter 2007). While traditionally a nighttime activity, recent advancements in recreational fishing techniques have permitted fishers to pursue Swordfish during the day by fishing baits on the bottom in very deep water (350 m or greater; F. Smith, Southeast Swordfish Club, personal communication). These techniques are currently being expanded to other areas off the U.S. East Coast and the Gulf of Mexico, subjecting Swordfish to exploitation on a 24-h basis in several geographic areas. These new techniques are important factors to consider when estimating fishing mortality values for stock assessment purposes. In addition, accurate data on both the behavior of Swordfish and depth of fishing gear can provide information vital to formulating gear selectivity parameters required for stock assessment purposes. While the Florida Straits (and other areas of the western North Atlantic) remain currently closed to U.S. pelagic longline vessels, analysis of previous data indicated that Swordfish fishers adjusted hook depth based on lunar phase. Changes in Swordfish distribution according to lunar phase observed during this study are consistent with changes made by commercial fishers. In addition, preliminary data on buoy gear depth indicates an overlap between observed hook depths (mean $\pm$ SD length $= 57.3 \pm 19.2$ m) and the nighttime Swordfish distributions observed during the present study (D.W.K. and Bayse, unpublished report).

While Swordfish behavior and vertical habitat use has been well documented via PAT tagging throughout several regions of the world's oceans, relatively few studies have examined these behaviors in the western North Atlantic to date. The results of this study build and expand upon previous studies, and indicate that Swordfish demonstrate a light limited habitat preference in relation to diel and lunar cycles. An exception to this is basking behavior documented within the region by Dewar et al. (2011) and the present study. In addition, the correspondence of vertical movement from these tags' data with that seen by a Florida Straits commercial fishery may also illustrate potential utility for stakeholder data to increase the local understanding of pelagic fish behavior.

Geolocation has proven to be problematic with vertically migrating animals such as Swordfish (Dewar et al. 2011; Evans et al. 2011). Neilson et al. (2009) investigated horizontal movements of Swordfish in the western North Atlantic; however, the authors acknowledge that the scarcity of light data precluded the calculation of precise tracks. However, new technology utilizing GPS has the potential to provide fine-scale data on the horizontal movements of vertically migrating organisms (Evans et al. 2011). A greater understanding of both Swordfish vertical habitat use and horizontal movements will provide insight into behavior, migration patterns, stock structure, and bycatch. Correlating this data with the behavior of both commercial (e.g., buoy gear) and recreational fishing gears will offer data on gear selectivity and help to maintain accurate stock assessments in the future.

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