**Abstract**—With a focus on white marlin (*Tetrapturus albidus*), a concurrent electronic tagging and larval sampling effort was conducted in the vicinity of Mona Passage (off southeast Hispaniola), Dominican Republic, during April and May 2003. Objectives were 1) to characterize the horizontal and vertical movement of adults captured from the area by using pop-up satellite archival tags (PSATs); and 2) by means of larval sampling, to investigate whether fish were reproducing. Trolling from a sportfishing vessel yielded eight adult white marlin and one blue marlin (*Makaira nigricans*); PSAT tags were deployed on all but one of these individuals. The exception was a female white marlin that was unsuitable for tagging because of injury; the reproductive state of its ovaries was examined histologically. Seven of the PSATs reported data summaries for water depth, temperature, and light levels measured every minute for periods ranging from 28 to 40 days. Displacement of marlin from the location of release to the point of tag pop-up ranged from 31.6 to 267.7 nautical miles (nmi) and a mean displacement was 3.4 nmi per day for white marlin. White and blue marlin mean daily displacements appeared constrained compared to the results of other marlin PSAT tagging studies. White marlin ovarian sections contained postovulatory follicles and final maturation-stage oocytes, which indicated recent and imminent spawning. Neuston tows ($n$=23) yielded 18 istiophorid larvae: eight were white marlin, four were blue marlin, and six could not be identified to species. We speculate that the constrained movement patterns of adults may be linked to reproductive activity for both marlin species, and, if true, these movement patterns may have several implications for management. Protection of the potentially important white marlin spawning ground near Mona Passage seems warranted, at least until further studies can be conducted on the temporal and spatial extent of reproduction and associated adult movement.

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# Movements and spawning of white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) off Punta Cana, Dominican Republic

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White marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) are widely distributed throughout the tropical and temperate waters of the Atlantic Ocean and adjacent seas; the former species is endemic only to the Atlantic Ocean (Mather et al., 1975). Genetic analyses and tag recapture data have indicated that each species has a single Atlantic-wide population (ICCAT, 1998). Several stock assessment indicators indicate that the white marlin population has been severely overfished for several decades (ICCAT, 2001, 2002). The Atlantic blue marlin stock is also heavily over-exploited, but to a lesser degree. The main source of adult mortality for both stocks is the multinational offshore longline fisheries that, in the process of targeting tunas (Scombridae) and swordfish (*Xiphias gladius*), land the marlins as bycatch (ICCAT, 2002, 2003).

Despite their economic and ecological value, little is known about the biology and ecology of Atlantic marlins (Prince and Brown, 1991). This is especially true regarding the reproductive biology of white marlin and adult movement patterns in spawning areas (Baglin, 1979; Mather, 1975; White Marlin Status Review Team[1]; SEFSC[2]). Long-term (i.e., >40 years) commercial (Goodyear, 2003) and recreational (i.e., Cabeza de Toro Billfish Tournament, Graves and McDowell, 1995; Casilla[3]) fishing records indicate that, every spring, white marlin are present in relatively high numbers off the southeastern coast of Hispaniola. This observation, coupled with

[1] White Marlin Status Review Team. 2002. Atlantic White Marlin Status Review Document, 49 p. Report to National Marine Fisheries Service, Southeast Regional Office, 263 13th Avenue, St. Petersburg, FL 33701-5511.

[2] SEFSC (Southeast Fisheries Science Center). 2004. Atlantic Billfish Research Plan. National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149-1003.

[3] Casilla, W. 2003. Personal commun. Club Nautico de Santo Domingo, Calle Juan Baron Fajardo #2, Ensanche Iantini, Santo Domingo, Dominican Republic.

anecdotal information about gravid fish, prompted the present examination of adult movements in a potentially important, but as yet unconfirmed, spawning location.

The present study was conducted off Punta Cana, Dominican Republic, during April and May 2003. Objectives were 1) to characterize the horizontal and vertical movement of adult white marlin captured from the area using pop-up satellite archival tags (PSATs) and 2) to investigate by larval sampling, whether marlin were reproducing at this location.

## Materials and methods

Deployment of PSAT tags on adult marlin was conducted from a 17-m charter fishing vessel by using standard trolling gear (9/0 long-shaft J hooks) and dead bait. Wildlife Computers Inc. (Redmond, WA) PAT 3 model tags were used. This tag allows the user to program pop-up date, sampling interval, criteria for premature release, bin demarcations for sampling temperature and pressure (depth), as well as transmission and memory priorities. These tags were programmed to sample depth (pressure), temperature, and light once every minute and the depth and temperature records were summarized into histograms at 3-hour intervals. A pressure-activated mechanical detachment device was also used which severs the monofilament tether at a depth of about 1500 m—well before the 2000 m depth at which the tag is crushed and disabled. This feature helps prevents data loss in the event of fish mortality.

All PSAT tags were rigged similarly according to methods described by Graves et al. (2002). Billfish handling and tagging procedures and associated devices reviewed by Prince et al. (2002a) were also used. The target area for tag placement was about 4 to 5 cm ventral to the dorsal midline, adjacent to the first several dorsal spines. An effort was made to insert the anchor through the dorsal midline, pterygiophores, and connective tissue to a depth just short of the anchor exiting the opposite side of the fish. In addition, a conventional streamer tag (series PS) was placed in the fish well posterior to the PSAT tag, according to standard procedures (Prince et al., 2002a).

Two devices were used during tagging which tend to reduce stress in captured fish and to aid in proper tag placement. The first was a "snooter" (a wire snare housed in a 1.5-m PVC tube), which secures to the upper bill and allows the tagger to maintain control of the fish while its head remains beneath the water during the tagging procedure (Prince et al., 2002a). The second was a small hook "gaff" (a long shaft 9/0 hook with point and barb removed) to manipulate the position of the fish in relation to the tagging vessel. Captured fish were resuscitated for 3 to 15 minutes, depending on their apparent state of exhaustion, by moving the vessel ahead at two to three knots while maintaining control of the fish with the snooter. State of exhaustion was inferred from coloration, fight time, and signs of sluggish movement.

One white marlin died during tagging and was retained for examination of its reproductive status. Whole or quarter transverse sections of ovarian tissue were preserved in 10% formalin. Preparation for histological analysis followed McBride et al. (2002). Histological determination of spawning activity was based on oocyte classification and the presence of postovulatory follicles (Wallace and Selman, 1981; Hunter and Macewicz, 1985; Hunter et al., 1992).

Once adult marlins were located for tagging, neuston sampling was conducted from the same fishing vessel with methods similar to those reported by Serafy et al. (2003). In the present study, ten-minute daytime tows were performed with two neuston nets. Both nets had 1000-$\mu$m mesh and were attached to 1 m × 0.5 m or 2 m × 1 m rectangular aluminum frames. Water volume filtered was measured with a mechanical flow meter; station coordinates and water column depth measurements were obtained by using a hand-held geographical positioning system and depth sounder. Neuston collections were made along a series of transects that covered the general area of the recreational fishery for white marlin at this location (Fig. 1). The neuston samples were initially stored in 150 proof white rum. Upon returning to the laboratory (i.e., within 24–96 hours) they were transferred to 95% ethanol. Billfish larvae were sorted from the samples and measured by using Image Pro image analysis software (Image Pro Plus, version 4.5, Media Cybernetics, Inc. Silver Spring, MD). Larval identification was conducted by using restriction fragment length polymorphism analysis of the nuclear MN32-2 locus following the methods of McDowell and Graves (2002).

## Results

Seven white marlin and one blue marlin were tagged with PSAT tags off Punta Cana, Dominican Republic, between April 23–24 and May 14–17 2003 (Table 1). All but two tags were programmed to pop-up after 30 days; the exceptions were 40-day deployments for one white marlin and one blue marlin. One of eight PSATs (deployed on a white marlin) failed to transmit data and one white marlin died prior to release (see below) from hook-related injuries. The displacements of the six white marlin from the original point of release ranged from 31.7 to 267.7 nmi (58.7 to 495.8 km), whereas the displacement for the blue marlin was 219.3 nmi (406.2 km, Table 1, Fig. 2). Displacements per day for white marlin ranged from 1.1 to 7.2 nmi (average of 3.4 nmi). Corresponding daily displacement for the one blue marlin was 5.48 nmi (Table 1).

The minimum and maximum depth and temperatures monitored for the seven PSAT-tagged marlin during the 30- and 40-day deployments showed that on most days, marlin visited depths ≥100 m (Fig. 3). Minimum temperatures ranged from 16.8° to 20.6°C, whereas the maximum temperatures ranged from 28.2° to 30.0°C. In all cases, the minimum depths for each fish monitored

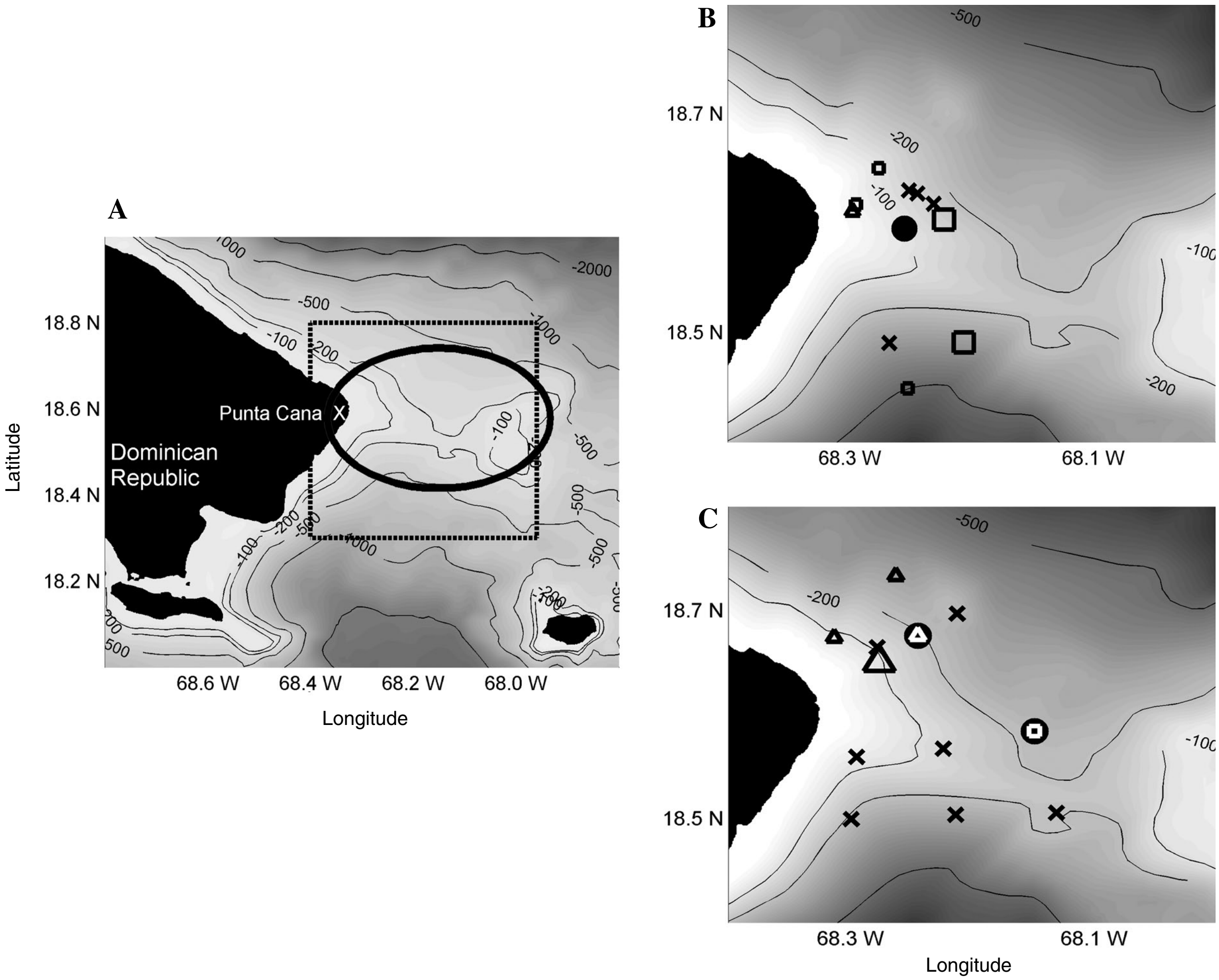


**Figure 1**

(**A**) Western part of Mona Passage off Punta Cana, Dominican Republic, showing the general area of the recreational fishery for white marlin (*Tetrapturus albidus*, rectangle) and larval sampling (oval); (**B**) April 23–24 sampling stations and (**C**) May 13–17 sampling stations. ✕ = stations with no billfish larvae. □ = stations with white marlin larvae, △ = stations with blue marlin (*Makaira nigricans*) larvae, ● = stations with unidentified larval istiophorids. Larger markers indicate two billfish in sample; smaller markers indicate one billfish in sample. Depth contours are in meters.

during April and May were recorded at the surface, whereas maximum depths ranged from 184 to 368 m (Fig. 3). In one case (i.e., PC-WHM01), the minimum and maximum temperatures and depths converged at the surface, indicating constrained vertical movement for this individual. However, in the majority of tracks there was a clear separation of minimum and maximum temperature and depth (e.g., PC-WHM02, Table 1), indicating that active vertical movements were made each day. Only one of the transmitting tags appeared to pop-up prematurely (PC-WHM01, Fig. 3). This tag disengaged from its white marlin host during a deep dive (368 m) after 28 days at large (two days early). Although the fate of this fish cannot be determined, death is a distinct possibility. In general, all marlin spent a high proportion of the time in which they were monitored in the upper 25 m and at temperatures ≥28°C. For example, marlin spent from 50% to 60% of the time in the first depth bin (0 to 25 m) and about 60% to 75% of their time in the 28° to 30°C temperature bin (Fig. 4). Both marlin species made dives down to 100–200 m or more on a fairly consistent basis but generally stayed at these depths less than 10% of the time (Fig. 4).

One female adult white marlin, measuring 157 cm lower jaw fork length, could not be resuscitated during pop-up satellite tagging, presumably because of damage caused by a hook that penetrated the stomach. Based on length-weight conversion equations (Prager et al., 1995), the estimated weight of this fish was 21.6 kg (47.2 pounds). The histologically examined ovaries contained distinct postovulatory follicles, indicating that spawning likely occurred within the previous 24 hours (Fig. 5, upper panel). In addition, imminent spawning (likely within the following 12 hours) was indicated by

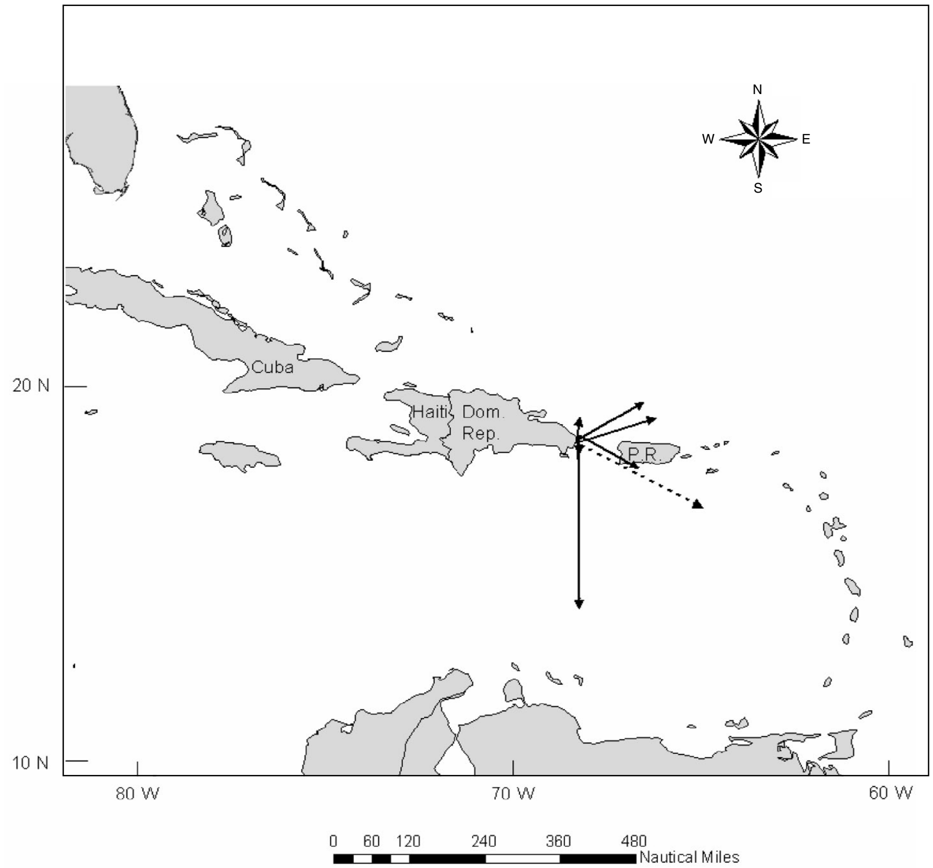


**Figure 2**

Displacement vectors (from point of tag release to point of tag pop-up in nautical miles, nmi) for six white marlin (*Tetrapturus albidus*) (solid lines, 31.7–268 nmi) and one blue marlin (*Makaira nigricans*) (dashed line, 219 nmi) released off Punta Cana, Dominican Republic, bearing pop-up satellite archival tags during April and May 2003. Tags were programmed for either 30- or 40-day deployments.

**Table 1**

Summary of pop-up satellite archival tag information for seven white marlin (*Tetrapturus albidus,* WHM) and one blue marlin (*Makaira nigricans*, BUM) released from recreational gear in the vicinity of Punta Cana, Dominican Republic, April and May 2003. Net displacements are given in nautical miles (nmi) and kilometers (km). Compass direction (in degrees) indicates the bearing from point of tag release to point of first transmission. Dashed line indicates that no value was available.

| Tag number | Days monitored | Estimated weight pounds (kg) | Location of release | Location of first transmission | Compass direction | Net displacement nmi (km) | Displacement per day nmi (km) |
|---|---|---|---|---|---|---|---|
| PC-WHM-01 | 28 | 40 (18.14) | 18.49°N, 68.38°W | 19.17°N, 68.26°W | 9.52° | 41.21 (76.32) | 1.47 (2.72) |
| PC-WHM-02 | 31 | 40 (18.14) | 18.60°N, 68.27°W | 19.56°N, 66.58°W | 58.87° | 111.87 (207.18) | 3.61 (6.69) |
| PC-WHM-03 | 31 | 50 (22.68) | 18.49°N, 68.37°W | 19.14°N, 66.25°W | 71.81° | 126.76 (234.76) | 4.09 (7.57) |
| PC-WHM-04 | 30 | 35 (15.88) | 18.69°N, 68.27°W | 18.16°N, 68.28°W | 181.03° | 31.68 (58.67) | 1.06 (1.96) |
| PC-WHM-05 | 30 | 50 (22.68) | 18.70°N, 68.29°W | 17.81°N, 66.70°W | 120.11° | 105.22 (194.87) | 2.84 (5.26) |
| PC-WHM-06 | 0 | 50 (22.68) | 18.29°N, 68.13°W | — | — | — | — |
| PC-WHM-07 | 37 | 60 (27.22) | 18.60°N, 68.30°W | 14.12°N, 68.38°W | 181.00° | 267.73 (495.84) | 7.24 (13.41) |
| PC-BUM-01 | 40 | 130 (58.97) | 18.49°N, 68.38°W | 16.75°N, 65.01°W | 117.78° | 219.32 (406.18) | 5.48 (10.51) |

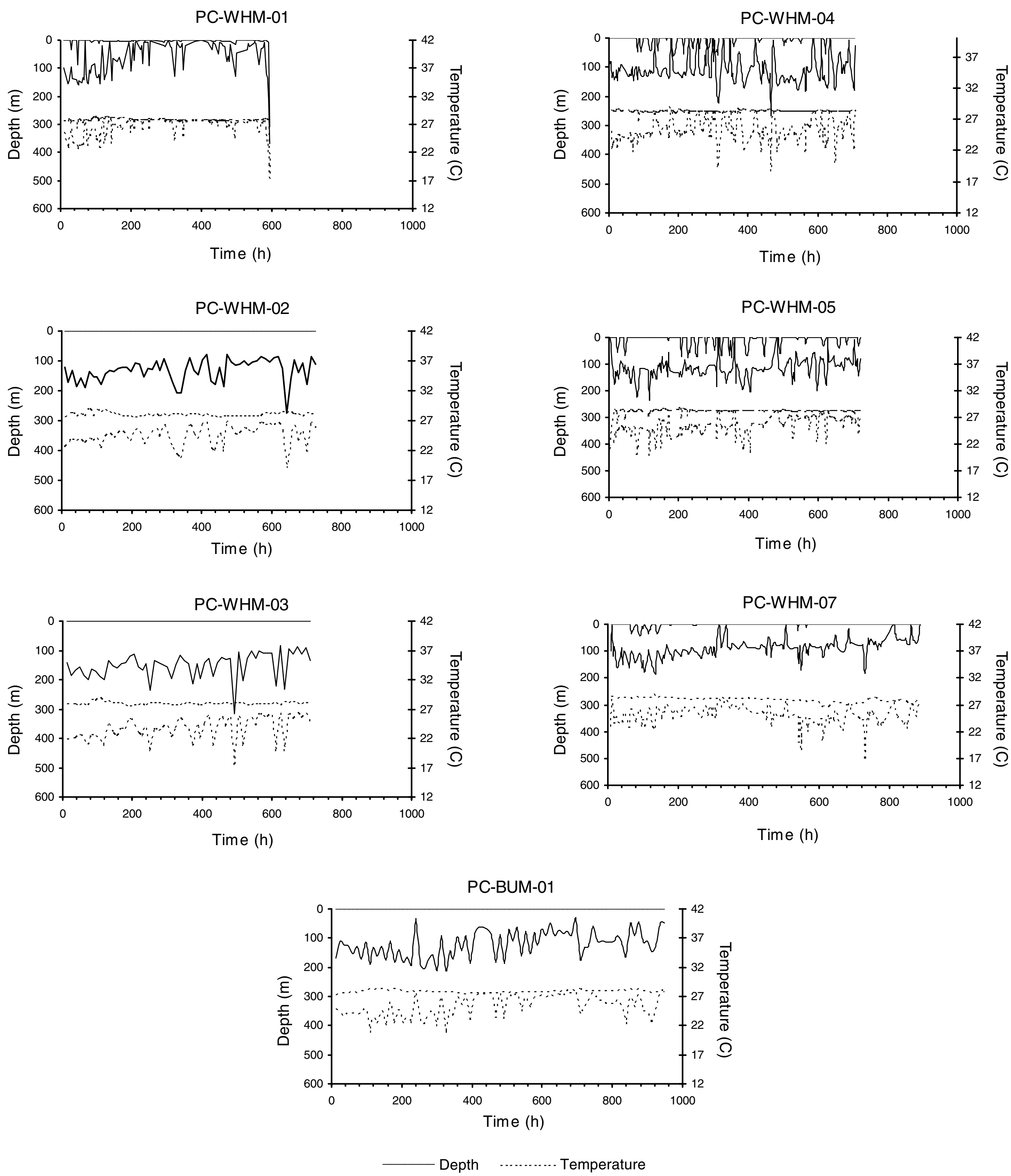


**Figure 3**

Minimum and maximum depth and temperature per 3-hour time intervals for six white marlin (*Tetrapturus albidus*) and one blue marlin (*Makaira nigricans*) monitored with pop-up satellite archival tags. Tags were programmed to deploy for either 30 or 40 days, April and May 2003, in the vicinity of Punta Cana, Dominican Republic. WHM=white marlin, BUM=blue marlin.

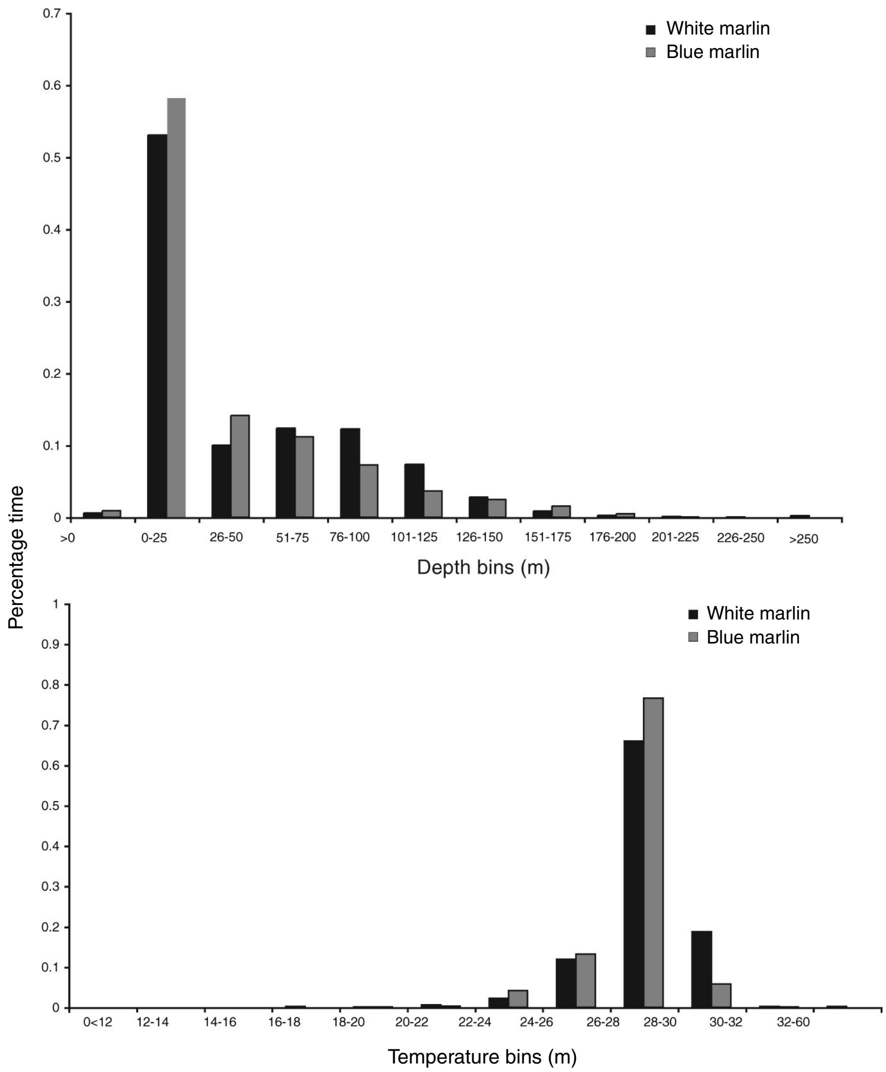


**Figure 4**

Total time at depth (upper panel) and time at temperature (lower panel) for white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) tagged with popup satellite archival tags during April and May 2003. Tags monitored marlin for 30 and 40 days.

some oocytes exhibiting an early state of final oocyte maturation, including migration of the nucleus towards the oocyte periphery and yolk coalescence (Fig. 5, lower panel).

A total of 23 neuston net tows were made in the general area of the recreational fishery from 23 April to 17 May 2003 (Fig. 1). These tows yielded 18 larval billfishes. Molecular identification was successful for 12 larvae: 8 white marlin and 4 blue marlin (Table 2). Half of the white marlin larvae were 3–4 mm standard length (SL), two were 4–5 mm SL, one was 6.2 mm SL, and one was 12.1 mm SL (Fig. 6). The one positively identified blue marlin larva captured in April was 4.6 mm SL; the remainder taken in May were 3.5 mm SL, 5.1 mm SL, and 10.4 mm SL. Sizes of the six unidentified billfish larvae ranged from 3 to 6 mm SL (Fig. 6).

## Discussion

Larval sampling with neuston tows and histological analyses of adult ovaries confirmed spawning activity of white marlin in the vicinity of Punta Cana during April and May (2003). Co-occurrence of larval blue marlin and white marlin in samples indicated that the two species share this spawning location. White and blue marlin spawning activity in the vicinity of Punta Cana, as indicated from the data presented in our study, also coincided in time and space with the fishing activity of the recreational white marlin fishery that has operated each spring at this location for over 40 years. From PSAT tag data, adult white and blue marlin caught at this time and in this area appeared to exhibit similar vertical and horizontal movement patterns in terms of time at depth, time at temperature, average horizontal displacement per day, net horizontal displacement, and direction of dispersion (compass heading).

## Movements

Average displacement per day is one possible measure to characterize daily horizontal movement activity. We examined this metric in other PSAT studies on marlin and compared them with our results (Fig. 7). Graves et al. (2002) monitored eight blue marlin with PSAT tags caught off Bermuda in July 2000 for periods of 5 days each and reported net displacement vectors ranging from 7.8 to 26.4 nmi/day (mean displacement for the eight fish was 17.5 nmi/day). Kerstetter et al. (2003) also monitored blue marlin during the summer months with PSAT tags in the northwest Atlantic (for 5 and 30 days) and found that displacements ranged from 15.1 to 39.2 nmi/day (mean for six fish was 22.9 nmi/day). Net displacement findings (17.5 and 22.9 nmi/day), presumably for blue marlin spawning times (summer months) from these two studies were roughly 5 to 6.5-fold higher than the average displacements for white marlin reported in our present study (about 3.3 nmi/day) and were 3 to 4-fold higher than the average displacement for the one blue marlin monitored in our study (Fig.7). A recent report (Graves and Horodysky[4]) has provided displacement movements of white marlin monitored with PSAT tags for 5 to 10 day periods from three different areas in the Northwest Atlantic during May (Punta Cana, Dominican Republic), August–September (U.S. Mid-Atlantic waters), and November (La Guaira, Venezuela) 2002. Only the work in Punta Cana was conducted during the presumed spawning season for white marlin. Average displacements for these areas were 9.6

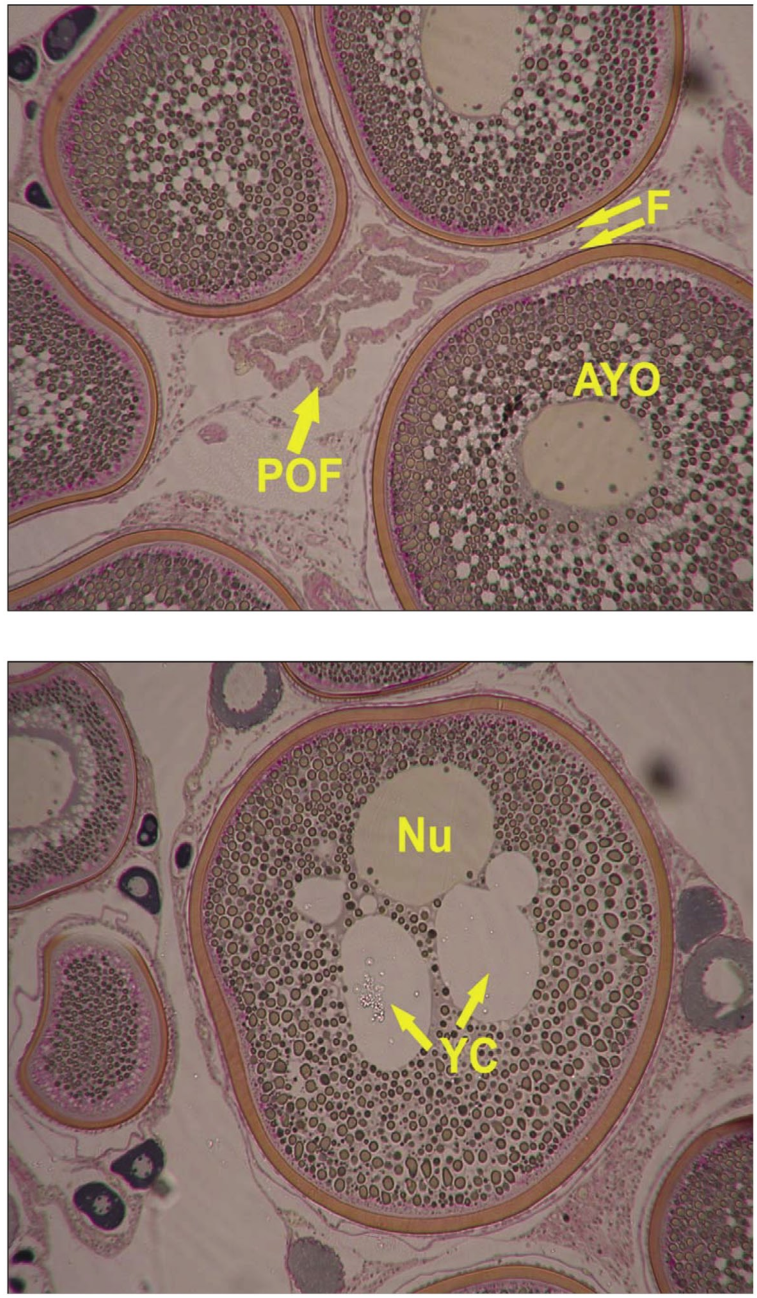


**Figure 5**

**Upper panel.** A postovulatory follicle (POF), advanced yolked oocyte (AYO), and follicle (F) are shown in section of gonad from a female white marlin (*Tetrapturus albidus)* sampled off Punta Cana, Dominican Republic, 16 May 2003. The presence of POFs indicates recent spawning (likely within 24 hours). **Lower panel.** The labeled oocyte has begun final oocyte maturation, as indicated by the migration of the nucleus (Nu) to the periphery and yolk coalescence (YC). Both of these steps are among the series of events initiated hormonally that occur just prior to spawning (likely within 12 hours).

[4] Graves, G. E., and A. Z. Horodysky. 2002. Progress report. Use of pop-up satellite archival tags to study survival and habitat utilization of white marlin released from the recreational fishery, 34 p. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA 23062-1346.

**Table 2**

Summary of neuston tow information for larval collections of istiophorids in the vicinity of Punta Cana, Dominican Republic, April and May 2003. "Unidentified istiophorids" refers to specimens for which molecular identification was unsuccessful.

| 2003 dates | Number of tows | Volume filtered ($m^3$) | Number of positive tows | Number (length range) of white marlin | Number (length range) of blue marlin | Number (length range) of unidentified istiophorids |
|---|---|---|---|---|---|---|
| 23–24 April | 11 | 9400 | 7 | 7 (3.45–12.16 mm) | 1 (4.6 mm) | 2 (3.98–5.28 mm) |
| 13–17 May | 12 | 8413 | 5 | 1 (6.20 mm) | 3 (3.49–10.45 mm) | 4 (3.25–4.4 mm) |
| Total | 23 | 17,813 | 12 | 8 | 4 | 6 |

nmi/day for Punta Cana; 9.4 nmi/day for the U.S. Mid-Atlantic region; and 8.2 nmi/day for La Guaira Bank (Fig. 7). Thus, the average white marlin displacements found by Graves and Horodysky were 2 to 3-fold higher than those reported in the present study. Black marlin (*Makaira indica,* Gunn et al., 2003) and striped marlin (*Tetrapturus audax,* Domeier et al., 2003) monitored mostly outside of spawning times and areas had displacements per day 2 to 4-fold higher than those in the present study. Therefore, reproductively active white marlin and blue marlin monitored in our study (30- or 40-day deployments) appeared to have more constrained average displacements per day than those in other studies where similar PSAT technology was used to monitor marlin in and outside of their respective spawning seasons.

Further PSAT-based research, with extended monitoring durations (i.e. at least ≥3–4 months) on white marlin and other billfish species in their spawning areas, will be necessary to clarify the causative factors for these findings. Interpretation of our findings also needs to be tempered by the fact that the displacement vectors (minimum straight line distances) used to characterize movements in this study were limited to beginning and end points. In theory, daily estimates of light-based geolocation would provide improved resolution of small-scale movement patterns. However, there is little scientific agreement (Musyl et al., 2001; Hill and Braun, 2001) as to the methods and validity of daily tracks generated from highly variable light levels, particularly for wide ranging species near the equator.

Although we present no evidence that the horizontal movement patterns of blue marlin (other than possibly constrained displacements) reported in our study are directly related to spawning activity, the possibility that white marlin could show fidelity to a spawning area cannot be ruled out. For example, Pepperell (1990) examined conventional tagging results off eastern Australia and reported that the periodic peaks in return frequency were possibly indicative of black marlin returning to the spawning ground as part of their annual migration cycle. The multidirectional pattern of blue and white marlin displacements found in the present study was very similar to the pattern reported by Graves et al. (2002) for blue marlin monitored with PSAT tags for five days off Bermuda. The relatively short-term duration of PSAT tags in both studies (5–40 days) generally precludes detection of directed seasonal horizontal movement patterns (including potential annual fidelity to a spawning area) as described by Mather et al. (1975), Pepperell (1990), and Ortiz et al. (2003).

Detailed accounts of temperature and depth preferences of electronically monitored white marlin have been rare and those that do exist are limited to very short (≤ten days) monitoring durations (Block et al., 1990; Horodysky et al., 2003; Graves and Horodysky[4]). We found that white marlin monitored with PSATs for periods of 28–40 days spent the majority of time in the upper 25 m of the water column at temperatures of 28–30°C. Similar findings were found for this species by Graves and Horodysky[4] and Horodysky et al. (2003), as well as for blue marlin, black marlin, and striped marlin reported by Graves et al. (2002); Kerstetter et al. (2003); Gunn et al. (2003); and Domeier et al. (2003). However, we could not directly address the depth at which spawning occurs in our study from PSAT results, other than to note the preference of adults for, and capture of larvae in, surface waters. Empirical data on the depth of spawning for istiophorids are not available, although anecdotal evidence indicates that some species may spawn in surface waters (black marlin observations by Harvey, personal commun.[5]).

## Spawning

Prior studies of gonads have indicated that white marlin spawn in the northwest Atlantic during the spring (Baglin, 1977, 1979; de Sylva and Breder, 1997). Spring aggregations of white marlin have been the target of the Cabeza de Toro billfish tournament off Punta Cana for over 40 years (Casilla[3]), and the sampling of larvae in

[5] Harvey, G. C. McN. 2004. Personal commun. 102 Webster Drive, P.O. Box 10499 APO, Grand Cayman Island, Cayman Islands, British West Indies.

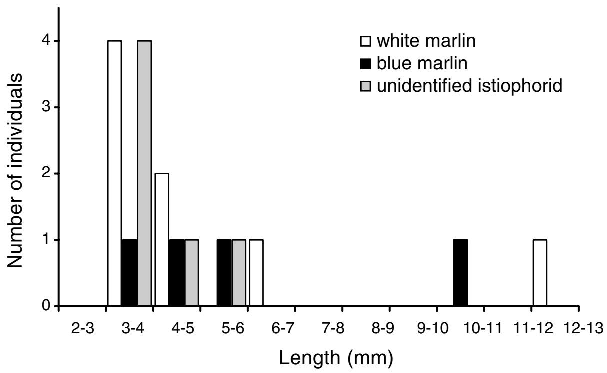


**Figure 6**

Length-frequency distribution for larval white marlin (*Tetrapturus albidus*), blue marlin, (*Makaira nigricans*), and unidentified istiophorids collected in the vicinity of Punta Cana, Dominican Republic, April and May 2003.

the present study is the first to provide direct evidence of springtime spawning activity in this area. Histological assessment of the captured female ovarian tissue is consistent with the premise that the adult white marlins in the aggregation that we located during fishing and PSAT tagging operations participated in spawning activity. This contention is strengthened by the presence of very small, presumably very young, white (and blue) marlin larvae in the same location.

The presence of larvae is the most direct way of documenting that a spawning event has actually occurred. This is particularly relevant to highly mobile species, such as billfishes, that can cover large distances in a short time (Prince and Brown, 1991). Serafy et al. (2003) used a similar approach to identify blue marlin spawning grounds in the area of Exuma Sound, Bahamas. In their neuston collections, 90 blue marlin, no white marlin, and three sailfish larvae were captured. Because Serafy et al., (2003) sampled during the entire month of July, it seems possible that larval sampling in Exuma Sound took place after the majority of white marlin spawning had already occurred. Subsequent neuston sampling of Bahamian waters yielded white marlin larvae in Exuma Sound in April and in the Old Bahama Channel and just east of Long Island in March, but no blue marlin during these months (D. E. Richardson and S. A. Luthy, unpubl. data). Extensive sampling of the Straits of Florida (SOF) over four years resulted in sporadic captures of white marlin larvae in May and June. Blue marlin was the more common larval marlin in the SOF and was captured from June to September (S. A. Luthy, unpubl. data). In the present study, white marlin larvae were twice as abundant in larval samples as blue marlin larvae (which had been captured earlier in Punta Cana) than in other areas where blue marlin larvae had been found. These results are consistent with reports that white marlin is primarily a spring-time spawner but

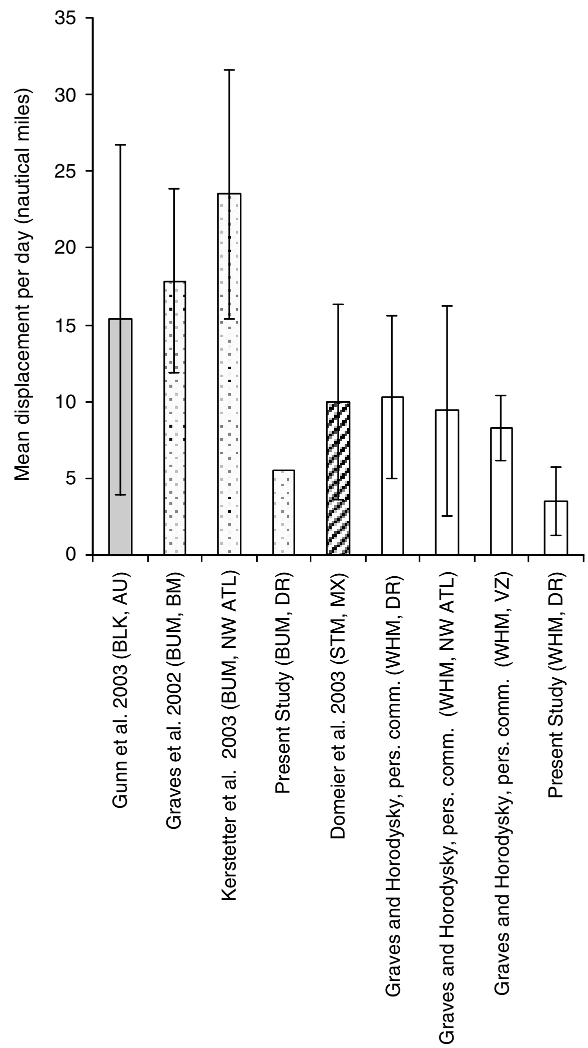


**Figure 7**

Mean displacement per day (in nautical miles) for blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus)*, black marlin (*Makaira indica*), and striped marlin (*Tetrapturus audax*) monitored with pop-up satellite archival tags by Gunn et al. (2003) [Australia], Domeier et al. (2003) [Mexico], Graves et al. (2001) [Bermuda], Kerstetter et al. (2003) [Northwest Atlantic], Graves and Horodysky[4] [Punta Cana, Dominican Republic, La Guaira, Venezuela, U.S. Mid-Atlantic region], and present study. In all studies, displacements were computed from the point of tag release to the point of first transmission from PSAT tags and are not meant to infer tracks taken by the fish. Means are accompanied by ± one standard deviation for each species identified as follows: blue marlin (BUM, stippled bar), white marlin (WHM, empty bar), black marlin (BLK, solid bar), and striped marlin (STM, cross hatched bar).

mark an expansion of the July to October spawning season reported for blue marlin in the North Atlantic by Erdman (1968) and de Sylva and Breder (1997).

For blue marlin larvae <6.2 mm SL, Serafy et al. (2003) found problems with estimating age from size with the larval growth equations reported by Prince et al. (1991). Serafy et al. (2003) suggested an exponential growth curve with an assumed size-at-hatching of 2.5 mm SL yielded more realistic larval age values for this growth stanza (<6.2 mm SL). Application of the Serafy et al. (2003) growth model to the larval blue marlin collected in the present study indicates that larvae 3 mm SL were 2 days old, 4-mm-SL larvae were 5 days old, and 5-mm-SL larvae were over 7 days old. It seems possible that blue and white marlin have similar size-at-hatching and growth rates at this early stage of development. Given this assumption, the fact that half of the white marlin larvae (4 out of 9) and a third of the blue marlin larvae sampled in this study were 3–4 mm long (i.e., only a few days old) indicates that spawning activity was taking place in the same general area where these larvae were captured and where the recreational fishery for these species was being pursued. This statement may not hold true for the larval marlin in our collections over 4 mm SL because increases in size and age add increased uncertainties concerning possible spawning locations. Providing a more precise estimate of spawning location was beyond the scope of our study, although we would expect that the upstream spawning locations (assuming minimal mobility of larvae) of both marlin species to be a function of the prevailing currents and oceanographic features in the Punta Cana area and the elapsed time between the spawning event and sample collection. Future research should focus on a more rigorous and comprehensive estimate of spawning location for all sizes and ages of larvae. This would require both a significant increase in the spatial and temporal larval sampling scheme, as well as direct aging methods for both species and sizes of marlin larvae collected.

### Implications for managment and future research

The current stock status of Atlantic white marlin indicates that biomass is only at about 12% of the level necessary to maintain maximum sustainable yield (MSY) and continues to decline (ICCAT, 2002). The stock has been estimated to be incurring fishing mortality at a rate about eight times higher than the population can sustain to produce MSY (ICCAT, 2002). Although the Atlantic blue marlin stock is also considered to be overexploited, its status is not as precarious as that of white marlin (ICCAT, 2001). The characterization of adult movements and larval distribution in a potentially important spawning area is seen as a necessary "first step" toward improved management and rebuilding of depressed Atlantic billfish stocks, possibly with gear restrictions (e.g., use of circle hooks, Prince et al., 2002b; Horodysky and Graves, 2005). Improved management seems particularly relevant in the area of Punta Cana because the target of the 40-year-old Cabeza de Toro tournament is, and probably always has been, a reproductively active aggregation of white marlin. In light of the ICCAT recommendation to reduce mortality on the overexploited marlins from all Atlantic fisheries (ICCAT, 2002), a shift to catch-and-release requirements for the white marlin recreational fishery off Punta Cana, and the use of circle hooks during the spring months, may be suitable options. In terms of spawning, there is an obvious need for more detailed spatiotemporal information on the distribution of marlin reproduction and on the identification of nursery areas to help managers make informed decisions regarding conservation of the resource. In addition, more fine-scale data on adult movement patterns in relation to horizontal and vertical use of the water column, including identification of spawning depth, are necessary.

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