CHAPTER 2.1.7: WHITE MARLIN	AUTHORS: J. HOOLIGAN	LAST UPDATE: Jan. 14, 2013

2.1.7 Description of White Marlin (WHM)

1. Names

1.a Classification and taxonomy

Species name: *Tetrapturus albidus* (Poey, 1860)
Synonyms in use: *Kajikia albida* (Poey, 1860)
ICCAT species code: WHM
ICCAT names: White marlin (English), Makaire blanc (French), Aguja blanca (Spanish)

Nakamura (1985) classified white marlin as follows:

- Phylum: Chordata
- Subphylum: Vertebrata
- Superclass: Gnathostomata
- Class: Osteichthyes
- Subclass: Actinopterygii
- Order: Perciformes
- Suborder: Xiphioidei
- Family: Istiophoridae

1.b Common names

List of vernacular names in use according to ICCAT and Fishbase (ww.fishbase.org). List is not exhaustive and may exclude some variants of local names.

Azores Islands: Espadim branco
Barbados: White marlin
Benin: Ajètè, Adjètè
Brazil: Agulhão, Agulhão branco, Marlim branco
Canada: White marlin, Makaire blanc
Cape Verde: Espadim-branco do Atlântico
China: 白色四鳍旗鱼（Bái sè sì chi chi-yu)
Côte d'Ivoire: Espadon
Cuba: Aguja blanca
Denmark: Hvid marlin
Dominican Republic: Aguja blanca
Finland: Valkomarliini
France: Makaire blanc
Germany: Weißer Marlin
Greece: Marlinos Atlantikou
Italy: Marlin bianco, Agguhia pilligrina
Japan: Nishimakajiki
Korea: Bag-sae-chi
Martinique: Varé, Makaire blanc
Mexico: Marlin blanco
Morocco: Espadon

Namibia: Weißer Marlin
Netherlands Antilles: Balau Salmou, Balau kora
Norway: Hvit spydfisk
Portugal: Marlim-branco, Espadarte-branco
Puerto Rico: White marlin
Romania: Marlin alb
Russian Fed.: марлин белый, Belyi marlin
Senegal: Marlin blanc
South Africa: White marlin, Wit marlin
Spain: Aguja blanca, Marlin blanco
Trinidad y Tobago: White marlin
Uraguay: Marlin blanco
United Kingdom: Atlantic white marlin
United States of America: White marlin, Skilligalee
Venezuela: Aguja blanca, Palagar

2. Identification

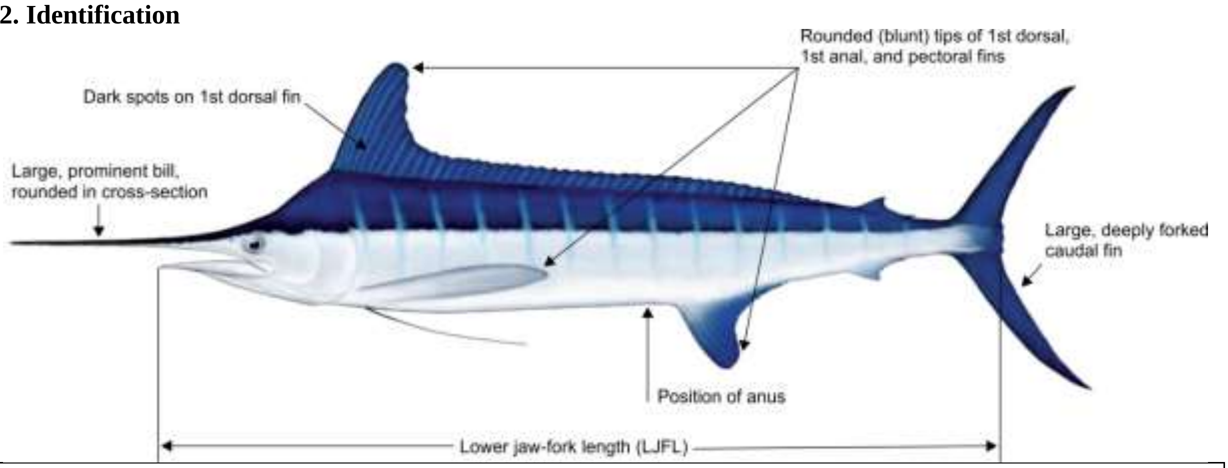


Figure 1. Drawing of adult white marlin by Les Gallagher (Les Gallagher: fishpics), with annotated prominent features.

***Characteristics of* Tetrapturus albidus (see Figure 1)**

Phylogenetic analyses using mitochondrial and nuclear DNA revealed that the white marlin (**Figure 1**) does not cluster closely with the spearfishes (*Tetrapturus* spp.), prompting the suggestion by Collette *et al.* (2006) that that it would be more appropriate revise the nomenclature for the white marlin to *Kajikia albida*; hence the synonym currently in use.

Nakamura (1985) reported a maximum size for white marlin at 280 cm total length, and over 82 kg, placing it mid-size among billfish species. Goodyear *et al.* (2003) examined ICCAT records for white marlin size at catch, and reported common sizes ranging from about 150 to 180 cm lower jaw-fork length (LJFL).

Regarding age, Die and Drew (2008) reported ages up to 13 years based on anal spine analysis from 270+ white marlin samples collected in the western Atlantic. However, most of these fish were 3-8 years of age. The longest time at-liberty documented for a mark-recaptured white marlin is in excess of 15 years (Orbesen *et al.*, 2008; Ortiz *et al.*, 2003).

External

- First dorsal fin rays, 38-46; second dorsal fin rays, 5-6; first anal fin rays, 12-17; ; second anal fin rays, 5-6; pectoral fin rays, 18-21; pelvic fin rays, 2; branchiostegals, 7; vertebrae, 12 precaudal, 12 caudal: gill rakers, 0; adult jaws and palatine exhibit small, file-shaped teeth.
- Body elongated and compressed.
- Upper jaw prolonged into long stout spear (bill), rounded in cross-section.

- Long first dorsal fin, with height of anterior lobe approximately equal to body depth, then abruptly decreasing height posteriorly.
- Tips of first dorsal, first anal, and pectoral fins rounded or blunt.
- Pelvic fins nearly equal in length to pectoral fins.
- Caudal fin large and deeply forked.
- Caudal peduncle with double keels on each side, with a caudal notch on the dorsal and ventral surface.
- Single lateral line visible, arching above pectoral fin, then extending straight towards tail.
- Anus situated near anterior insertion of first anal fin; distance generally less than half the height of first anal fin.
- Mid-lateral scales elongated and pungent, with 1-2 posterior points (**Figure 2**).

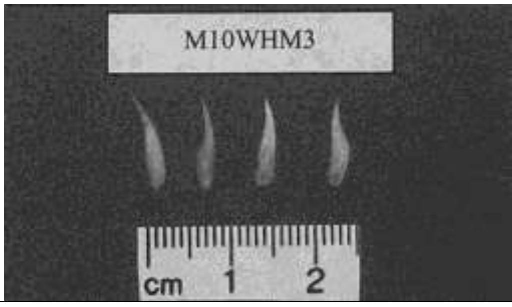


Figure 2. Examples of white marlin mid-lateral scales.

Colour:

- Dark blue dorsally, brownish-silvery-white laterally, and silvery-white ventrally. Usually no lateral barring, although obscure white vertical bars are occasionally observed.
- First dorsal fin membrane bluish-black, with small, dark spots that generally fade after death. Remaining fins are brown to bluish-black.

Internal

- Symmetrical gonads.
- Swimming bladder present, consisting of many small bubble-shaped chambers.

External characteristics of white marlin larvae

- Yolk-sac larvae unknown.
- Based on gross morphology, white marlin larvae <100 mm (SL) are very difficult to distinguish from other similar sized billfish. However, differentiation of larval billfish species < 100 mm (SL) is possible using genetic tools (Luthy *et al.*, 2005).

Misidentification

Gross morphology of white marlin is very similar to the roundscale spearfish, often resulting in mis-identification of roundscale spearfish as white marlin (Arocha and Beerkircher, 2012). Definitive identification is available using genetic tools (Shivji *et al.*, 2006). However, close observation helps to distinguish between subtle morphological differences, which include:

- Position of white marlin anus is closer to anterior insertion of first anal fin, compared to roundscale and longbill spearfishes.
- Compared to roundscale spearfish, white marlin mid-lateral scales are generally stiffer, and have fewer posterior points (1-2 vs. 2-3). Also, the anterior end of mid-lateral scales is broader and rounder in roundscale spearfish.
- White marlin branchiostegal rays (**Figure 3**) do not extend posterior to the degree observed in roundscale spearfish (Beerkircher and Serafy, 2011).

Figure 3. Comparative lengths of branchiostegal rays (black arrows) in white marlin (upper) and roundscale spearfish (lower) relative to posterior edge of operculum (red arrows, *photo courtesy of* Meredith Jones).

3. Biology and population studies

3.a Habitat preferences

Catch records indicate that the geographical range for white marlin extends from approximately 45°N to 45°S in the Atlantic Ocean, along with some accounts reported from the Mediterranean Sea. They generally prefer water >100 m deep with surface temperatures above 22 °C. They often associate themselves with ocean fronts, steep drop offs, submarine canyons, and other features where shoaling of prey species may occur (Nakamura, 1985). Physiological characteristics and habitat preferences of white marlin and other billfish are less understood that those of tunas, primarily because of the difficulty of studying these animal in a laboratory setting. Therefore, much of the known information was gathered from in situ studies using electronic tagging technologies.

Temperature preferences determined from short-term (<40 d) pop-up satellite archival tag (PSAT) deployments (Horodysky *et al.*, 2007; Prince *et al.*, 2005) suggested that white marlin spend most of their time in the epipelagic zone in water 24-29 °C. More recent studies (Hoolihan *et al.*, 2012) using longer deployments (up to 150 d) showed white marlin exploring temperatures ranging 7.8-29.6 °C. However, an analysis of time spent at temperature, relative to the surface temperature, showed these same fish spending 97.2% of darkness hours, and 80.3% of daylight hours in surface temperature waters. So, while they are capable of short duration deeper dives, probably associated with foraging, their preference is to stay in the warmest water available (i.e. surface temperature). In general, istiophorids do not explore waters that are more than ~8 °C below the surface temperature (Goodyear *et al.*, 2008; Hoolihan *et al.*, 2011; Hoolihan *et al.*, 2012), which is most likely an adaptation to cardiac temperature thresholds limiting prolonged excursions into colder waters (Brill *et al.*, 1999).

Depth distributions from PSAT data indicate white marlin spend most of their time in warm near-surface temperatures (<25 m depth) in the western North Atlantic (Horodysky *et al.*, 2007; Prince *et al.*, 2005). These data indicated frequent short-duration descents extending to >300 m depths, although most descents ranged from 100 to 200 m. Horodysky (2007) described two types of diving behavior. The first was a short duration V-shaped dive, characterised as deep descents of 6-83 min duration, in which the fish spent less than 10 min at the maximum depth. The second was a U-shaped dive characterised as those confined to a specific depth range (± 30 m) for a prolonged period (13-1140 min).

Dissolved oxygen requirements for billfishes are poorly understood, partly due to the difficulty in maintaining these animals in a laboratory environment. However, habitat utilization, based on electronic tagging data (Prince and Goodyear, 2006; Prince *et al.*, 2010), suggests that billfishes are limited by a minimal dissolved oxygen concentration requirement of around 3.5 mL L^{-1}, similar to the high demand oxygen requirements and associated metabolic rates exhibited by tropical tunas (Brill, 1996). Studies indicate that billfishes located in the eastern tropical Atlantic oxygen minimum zone (Prince *et al.*, 2010) are restricted to a narrow surface layer of adequate oxygen. This, in turn, increases their susceptibility to capture in surface fishing gears.

3.b Growth

White marlin can reach 280 cm TL and exhibit sexual dimorphism, with females growing to a larger maximum size compared to males (Mather *et al.*, 1972; Nakamura, 1985). Preliminary studies found a significant relationship between LJFL and the radius size and ring count of both otoliths and dorsal fin spines from white marlin (Prince *et al.*, 1984). More recently Drew *et al.* (2006) and Die and Drew (2008) described annual periodicity in the annuli formation of anal fin spines. The estimated age of these fish ranged 1-13 years, though most were aged 3-8 years. These assigned ages were consistent with a subset of mark-recaptured fish sampled. Mark-recapture records suggest that white marlin are capable of living 15+ years (Orbesen *et al.*, 2008; Ortiz *et al.*, 2003).

3.c Length-Weight relationship

ICCAT used sex specific length-weight relationships for white marlin developed by Prince and Lee (1989) up to 1992. After that, the revised data were used by Prager *et al.* (1995) to develop new length-weight and weight-length conversions, as well new equations to estimate LJFL from several length measurements (**Table 1**).

Table 1. Equations currently used by ICCAT for white marlin to convert between LJFL and round weight (RWT, kg).

Equation	*N*	Sex	LJFL range (cm)
$RWT = 1.9556 \times 10^{-5}\ LJFL^{2.7487}$	1719	Male	96.0-195.5
$RWT = 3.9045 \times 10^{-6}\ LJFL^{3.0694}$	3149	Female	91.4-205.0
$RWT = 5.2068 \times 10^{-6}\ LJFL^{3.0120}$	4868	Combined	91.4-205.0

3.d Maturity

Ueyanagi *et al.* (1970) reported that white marlin attain sexual maturity when reaching about 130 cm eye-fork length (153.2 cm LJFL), based on samples obtained in the western South Atlantic. Later, de Sylva and Breder (1997) assumed sexual maturity to occur at 130 cm eye-fork length (153.2 cm LJFL), or about 20 kg in female specimens. Arocha and Marcano (2006) estimated that 50% of female white marlin are mature (L_{50}) at 189.9 cm LJFL, based on macroscopic and microscopic gonad assessment of samples collected between 5°N and 25°N. Further, using samples collected from the equatorial western Atlantic (between 5°N and 5°S), Oliveira *et al.* (2007) estimated the L_{50} of males and females at 139 cm and 149 cm LJFL, respectively. More recently, Arocha and Bárrios (2009) determined the L_{50} for females at 160.46 cm LJFL, based on 1389 samples collected from the western central Atlantic. The available sexual maturity estimates for white marlin are shown in **Table 2**.

Table 2. Available estimates 50% size at maturity (L_{50}) for white marlin in the Atlantic.

Size at Maturity (L_{50})	Reference
189.9 cm LJFL, females	Arocha and Marcano (2006)
149.0 cm LJFL, females	Oliveira *et al.* (2007)
139.0 cm LJFL, males	Oliveira *et al.* (2007)
160.4 cm LJFL, females	Arocha and Bárrios (2009)

3.e Sex ratio

According to de Sylva and Davis (1963),the white marlin male:female sex ratio was not the expected 1:1. Also, similar observations were reported by Baglin (1979). These two studies, conducted in the western North Atlantic, revealed a differential spatial and seasonal sex ratio pattern; and, indicated that females were more prevalent during the periods when the ratio was not 1:1. Arocha (2006) described a seasonal pattern between trimesters for sex ratio at size of females for white marlin sampled in the Caribbean Sea (5°N-25°N). Here, the proportion of females increased with size from 20% at 150 cm LJFL to more than 60% at sizes >180 cm LJFL during all trimesters except the second, when the proportion of females of sizes between 150 and 200 cm LJFL were around 40-50%. On the Atlantic side, north of the Island of Barbados, the proportion of females was around 40% for female sizes between 140 and 170 cm LJFL. While south of the Island of Barbados, the proportion of females was close to 50% for female sizes of 130-170 cm LJFL. In general, as size increased the proportion of females also increased, up to a size (>200 cm LJFL) where no males are found.

3.f Reproduction and first life stages

Similar to other billfishes, white marlin do not exhibit sexually dimorphic color patterns or external morphological characteristics.

Spawning

White marlin are batch spawners, shedding batches of hydrated oocytes in separate spawning events (de Sylva and Breder, 1997).

Documented white marlin spawning areas occur mainly in the tropical western North and South Atlantic, predominantly in the same offshore locations normally inhabited. In the North Atlantic, spawning activity has been reported off eastern Florida (USA), the Windward Passage, and north of Puerto Rico (Baglin, 1979). Seasonal spawning concentrations have been noted northeast of Hispaniola and Puerto Rico (Arocha and Bárrios, 2009; Arocha and Marcano, 2006), and off the east coast of Hispaniola (Prince *et al.*, 2005). Spawning activity has also been reported for the equatorial Atlantic (5°N-5°S) off northeastern Brazil (Oliveira *et al.*, 2007), and in the South Atlantic off southern Brazil (Arfelli *et al.*, 1986; Ueyanagi *et al.*, 1970).

Spawning takes place during austral and boreal spring-summer. In the North Atlantic, reproduction events occur from April to July, with spawning activity peaking around April-May (Arocha and Bárrios, 2009). In the equatorial Atlantic (5°N5°S), spawning occurs during May-June; and in the South Atlantic, reproduction events take place from December to March.

Eggs and larvae

Oliveira *et al.* (2007) estimated batch fecundity to be 771,000-877,000 oocytes per female. More recently, Arocha and Bárrios (2009) estimated 190,000-596,000 fully hydrated oocytes per individual female white marlin that were sized from 152 to 172 cm LJFL, with an average interval of 1.5 d between batch spawning.

White marlin eggs are pelagic, spherical and transparent; whole hydrated oocytes average 1.108 mm diameter (1.000-1.700 mm, *n*=26), and contain an oil globule measuring on average 0.330 mm in diameter(Arocha and Bárrios, 2009). Yolk material is not homogeneous (de Sylva and Breder, 1997).

Recruitment

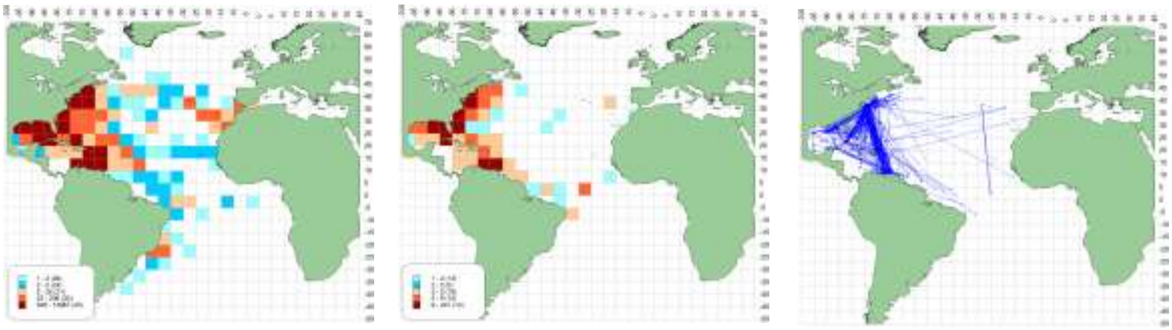
Information on early life stages of billfishes is very scarce. It is assumed that larval period is short due to fast growth during this period (Luthy, 2004; Prince *et al.*, 1991).

Luthy (2004) used ichthyoplankton and neuston nets to capture 4.4 to 14.3 mm SL white marlin larvae in the Straits of Florida. Post larvae, >100 mm SL, are occasionally collected by nightlight using a dip net in *Sargassum* patches (de Sylva, 1963), as well as retrieved from the stomach contents of tunas, and billfishes.

Young (immature) white marlin first appear in the catches when they are around 50 cm LJFL. From this time on, it is easier to know their migratory movements both by observing the fisheries and by tagging experiments.

3.g Migrations

The majority of information on white marlin movements originates from conventional mark-recapture programs, mostly from the western North Atlantic. Locations for release effort, recoveries, and associated vector displacements are shown in **Figure 4** (Anon., 2012); and, indicate a few transatlantic movements, but no transequatorial or transoceanic movements. The longest linear displacement recorded for one of these fish was 6517 km after 474 days at-liberty (Ortiz *et al.*, 2003).



Figures 72 [a-c]

a)-Density of releases. b)-Density of recoveries. c)- Straight displacement between release and recovery locations.

Figure 4. White marlin tag releases and recaptures.

3.h Diet

White marlin are opportunistic apex predators that prey on schooling stocks of flying fishes, small tunas, dolphinfish, and squids. In the southern Caribbean Sea, their diet is composed mainly of the squid, *Illex coindetti*, followed by *Sardinella aurita*, and *Dactylopterus volitans* (Garcia de los Salmones *et al.*, 1989). In the northeastern United States, major prey items include the round herring (*Etrumerus teres*) and the squid (*Doryteuthis pealeii*), as well as *D. volitans* (de Sylva and Davis, 1963). Other prey items include, moon fishes, puffer fishes, pomfret fishes, snake mackarels, and deep water red prawns.

In the North and tropical Atlantic, about 57% of the diet consisted of fish prey, with the remainder composed mostly of cephalopods (42%). Among prey fish, species of the families Bramidae followed by the Gempylidae comprised over 75% in importance (Satoh *et al.*, 2004).

In the western equatorial Atlantic, the most important prey reported for white marlin were the pomfret *Brama brama*, and the squid *Ornithoteuthis antillarum* (Júnior *et al.*, 2004); and, the flying gurnard *Dactylopterus volitans*, and Atlantic bird squid *Ornithoteuthis antillarum* (Pinheiro *et al.*, 2010). The variety and constant presence of prey items have led some authors to suggest that because of the large muscular mass and high active metabolic rates, the space for visceral mass is reduced (including stomach size) forcing the fish to feed constantly, resulting in the regular presence of prey items in their stomachs and constant energy for movements (Júnior *et al.*, 2004).

3.i Physiology

White marlin, like other billfishes and tunas, have anatomical and physiological adaptations for continuous swimming, and cranial endothermy (brain and eyes) which facilitate foraging at different depths. This includes a thermogenic organ situated beneath the brain and close to the eyes that generates and maintains elevated temperatures in the cranial region (Block, 1986). This organ, known as a 'brain heater', facilitates the deep diving behaviour in marlins by permitting ocular and physical functions at low temperatures. Research into the vision of blue marlin *Makaira nigricans* indicates that the eyes are specifically adapted for the low light levels encountered during diving (Fritsches *et al.*, 2003; Kröger *et al.*, 2009).

Regarding swimming speed, the available data come from analysis of minimum straight line distances calculated from PSAT data on adult white marlin (Horodysky *et al.*, 2007). Average displacements were estimated between 7.8 and 14.2 nmi/day (0.3-0.4 nmi/hr) from point of release. Speed estimates for vertical movement events, derived from high resolution pop-up satellite archival data, showed white marlin descending at average rates of 0.02-1.40 m s^{-1}, and ascending at rates ranging 0.02-1.85 m s^{-1} (Hoolihan *et al.*, 2009).

3.j Behaviour

White marlin are not schooling fish. They are mostly solitary, although they are known to sometimes form small groups. Advances in research behaviour of billfishes have been slow due to the difficulty of holding them in captivity and the lack tracking technology for long term monitoring (Holland 2003). However, traditional tags and PSAT information, along with biological information on spawning grounds and season, as well as feeding habit information can help in identify reproductive behaviour patterns.

Areas northeast of Hispaniola and Puerto Rico exhibit aggregating spawning fish during late spring and early summer (Prince *et al.*, 2005). Larvae collections from the spawning grounds and along the pathway to/from spawning grounds (Straits of Florida) help to support the reproductive behaviour of adult fish associated with spawning in the western central Atlantic. However, little is known of the reproductive behaviour in other parts of the Atlantic.

Knowledge about white marlin vertical behaviour has been suggested from PSAT studies (Hoolihan *et al.*, 2012; Horodysky *et al.*, 2007, see 3.a Habitat preferences).

3.k Natural mortality

No reliable estimates of natural mortality rates are available. Tagging data are insufficient for that effort. Estimating M from growth parameters is limited because they have not been estimated. Natural mortality based on the estimated longevity would range from 0.15 to 0.30. However, based upon body size, behaviour, and physiology, estimates of adult fish would likely be fairly low (Anon. 1994, 1998). However, Mather *et al.* (1972) estimated the instantaneous total mortality to be 0.32 (s.e. 0.17), from tag-return data of fish north of 32°N between 1961 and 1965.

3.l Conversion factors

ICCAT's databases and analyses make use of a number of formulae to convert between different types of measurements. In the case of white marlin, relationships are shown in **Table 3** (see section 3.c Length-Weight relationship).

Table 3. Length and weight conversion factors for white marlin.

Equation	Sex	*N*	Length range (cm)	Reference
LJFL = 5.923 + *TL* x 0.731	Female	51	190-245	Prager *et al.* (1995)
LJFL = 18.664 + *TL* x 0.667	Male	65	130-235	
LJFL = -0.720 + *TL* x -0.760	Combined sex	127	130-280	
LJFL = 96.462 + *PAL* x 1.231	Female	105	40-66	
LJFL = 103.501 + *PAL* x 1.100	Male	123	40-85	
LJFL = 108.00 + *PAL* x 1.000	Combined sex	272	35-85	
LJFL = 9.400 + *PFL* x 1.280	Female	188	92-145	
LJFL = 26.000 + *PFL* x 1.133	Male	172	80-180	
LJFL = 13.572 + *PFL* x 1.242	Combined sex	424	80-180	
LJFL = 48.834 + *PDL* x 1.278	Female	127	72-115	
LJFL = 53.316 + *PDL* x 1.211	Male	121	68-110	
LJFL = 39.250 + *PDL* x 1.375	Combined sex	294	65-115	
LJFL = 14.743 + *EOFL* x 1.061	Female	65	128-165	
LJFL = 9.581 + *EOFL* x 1.097	Male	30	115-160	
LJFL = 15.444 + *EOFL* x 1.056	Combined sex	102	115-165	
LJFL = 29.184 + *DFL* x 1.053	Female	75	115-150	
LJFL = 14.539 + *DFL* x 1.154	Male	47	105-150	
LJFL = 13.834 + *DFL* x 1.167	Combined sex	129	105-150	
DWT = 1.20 x *RWT*	Combined sex	-	-	ICCAT Manual 1990

TL: Total length; *PAL*: Pectoral-anus length; *PFL*: Pectoral-fork length; *PDL*: Pectoral-second dorsal length; *EOFL*: Eye orbit-fork length; *DFL*: Dorsal-fork length; *DWT*: Dressed weight.

4. Distribution and exploitation

4.a Geographical distribution

White marlin are widely distributed in subtropical and tropical waters of the Atlantic Ocean, and occasionally in Atlantic temperate waters and in the Mediterranean Sea. Geographical limits are from 55ºN to 45ºS, but they are less abundant in waters of the eastern central Atlantic and the south central Atlantic.

Adults (>150 cm LJFL) appear in temperate, subtropical and tropical waters while juveniles (<100 cm LJFL) are found in tropical waters. In the Atlantic, the larger size classes (>200 cm LJFL) are generally associated with cooler water bodies while smaller individuals tend to prefer warmer strata.

Distribution in the Atlantic Ocean: in the western Atlantic, important concentrations are present along the northeast coast of the United States, the Gulf of Mexico, the northern and eastern areas of the Caribbean Sea, the western equatorial area, and along the Brazilian coast through to the Uruguayan coast. In the eastern North Atlantic, longline bycatch records suggest concentrations around Portugal, Spain, and Western Sahara (García-Cortés *et al.*, 2011).

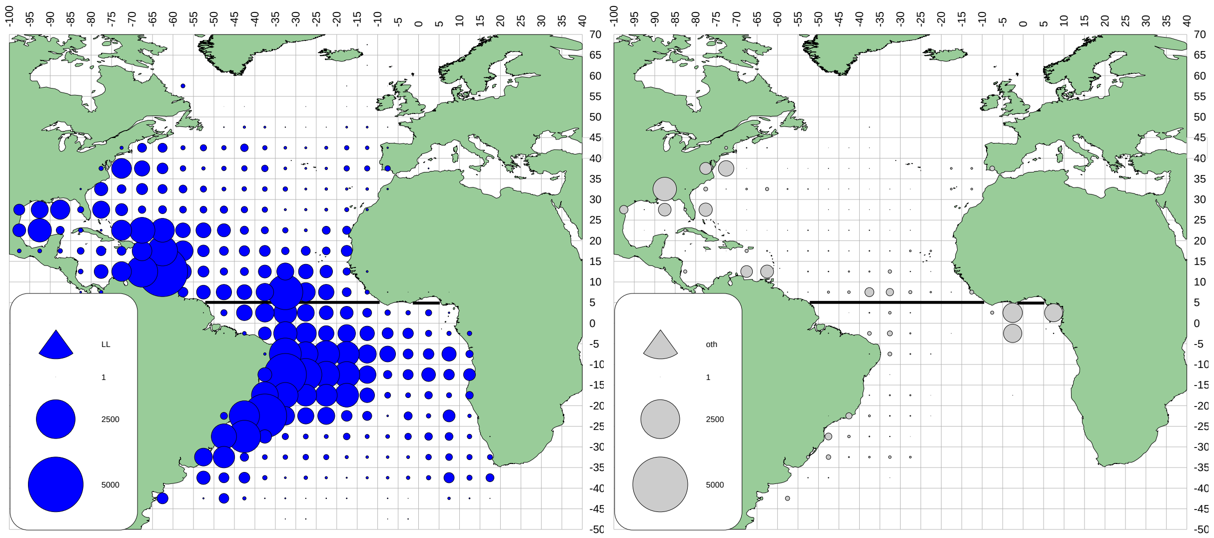
4.b Populations/Stock structure

At one time ICCAT recognized two Atlantic white marlin stocks, separated at the 5°N latitude. This boundary was based on the catch distribution, seasonal displacement of spawning areas north and south of 5°N, and that no fish tagged north of 5°N had been captured south of that latitude. However, genetic comparisons using mitochondrial and nuclear markers, for samples collected north and south of 5°N, revealed no significant heterogeneity (Graves and McDowell, 2001; Graves and McDowell, 2006). Therefore, ICCAT presently recognizes a single Atlantic-wide stock (Anon., 2001).

4.c Description of fisheries: Catches and effort

In developed countries white marlin and other billfishes are primarily targeted by recreational fishers. There are local artisanal fisheries that exploit white marlin mainly for local consumption and in some cases regional trade (Arocha, 2006; N'goran *et al.*, 2001). In the Caribbean Islands and Venezuela, surface drift gillnets and surface longlines attached to FADs are the main fishing gears for marlin (Arocha, 2006; Reynal *et al.*, 2006). There are also artisanal fisheries for billfishes off the west coast of Africa, mainly in the Gulf of Guinea, using drift gill nets that catch white marlin. However, in the Gulf of Guinea, blue marlin and sailfish are the main istiophorids caught, as opposed to the Caribbean and Venezuela fisheries, where white marlin are more common in the artisanal longline catch (Arocha, 2006; Arocha *et al.*, 2006). Sport and recreational fishing effort is concentrated off the eastern coast of the United States, the Caribbean islands, and along the coasts of Venezuela and Brazil. In the eastern Atlantic, recreational fisheries are most prominent along the west coast of Africa, the Canary Islands, and off the Azores (Harvey, 2002). There are no commercial fisheries targeting white marlin, nevertheless as with all billfishes, white marlin are caught as by-catch in the Atlantic Ocean longline fisheries targeting tunas and swordfish.

White marlin catches concentrate mainly in the tropical areas (**Figure 5**), along the Brazilian coast, in the Caribbean Islands, and the eastern coast of the United States (Anon., 2011a). By-catch of white marlin in the tuna longline fleets accounts on average for 90% of the estimated total catch (Anon., 2006a). Total catch of white marlin increased rapidly with the introduction of the longline gear in 1956, peaking at 4900 t in 1965, and declining thereafter (**Figure 6**). By the early 1970’s catches were about 2500 t and continued to decrease, reaching a low of 975 t in 1978 (Anon., 2012).



a. WHM (LL) b. WHM (oth)

Figure 5. Geographical distribution of white marlin catch in tonnes by a) longline, and b) other gears for the period 1960-2009.

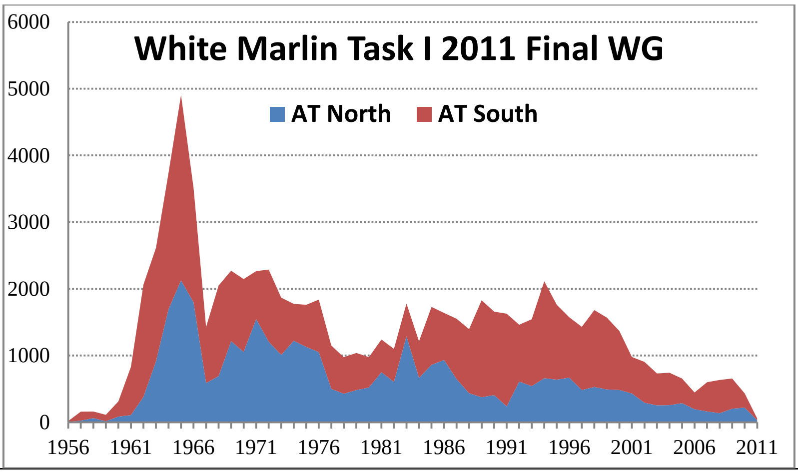


Figure 6. White marlin total catch (including dead discards) by North and South Atlantic for the period 1956-2010.

Catches then oscillated between 1000 and 1500 t until 1993. In 1994 catches increased to 1900 t, and since then, catches have declined below 1000 t (**Figure 6**). As with all by-catch species, estimates of white marlin catch from the longline fisheries are uncertain, even more in recent years because of management regulations that require release or discard of all white marlin caught; and, because of low observer coverage monitoring discards (Anon., 2006b). Sport and recreational catches averaged about 100 t in the mid 1970s, since then, catches have declined to less than 10 t due, in part, to regulations and catch-&-release practices of this fishery. White marlin catch split approximately even between the North and South Atlantic until mid 1980's, when catches in the North Atlantic declined more rapidly.

4.d Catch-at-size

There are no estimates of catch at age for white marlin. Median size of captured fish is 155-165 cm LJFL, with 95% percentile of 120 to 220 cm LJFL, 50% of the catch is between 150 and 165 cm LJFL. Less than 1% of measured white marlin are greater than 300 cm, and these measurements may be due to a different type of measurement (*i.e.*, total length), or misidentified blue marlin. **Figure 7** illustrates relative stability for white marlin size at-catch from combined major fisheries in the Atlantic over the past decade (Anon., 2011b).

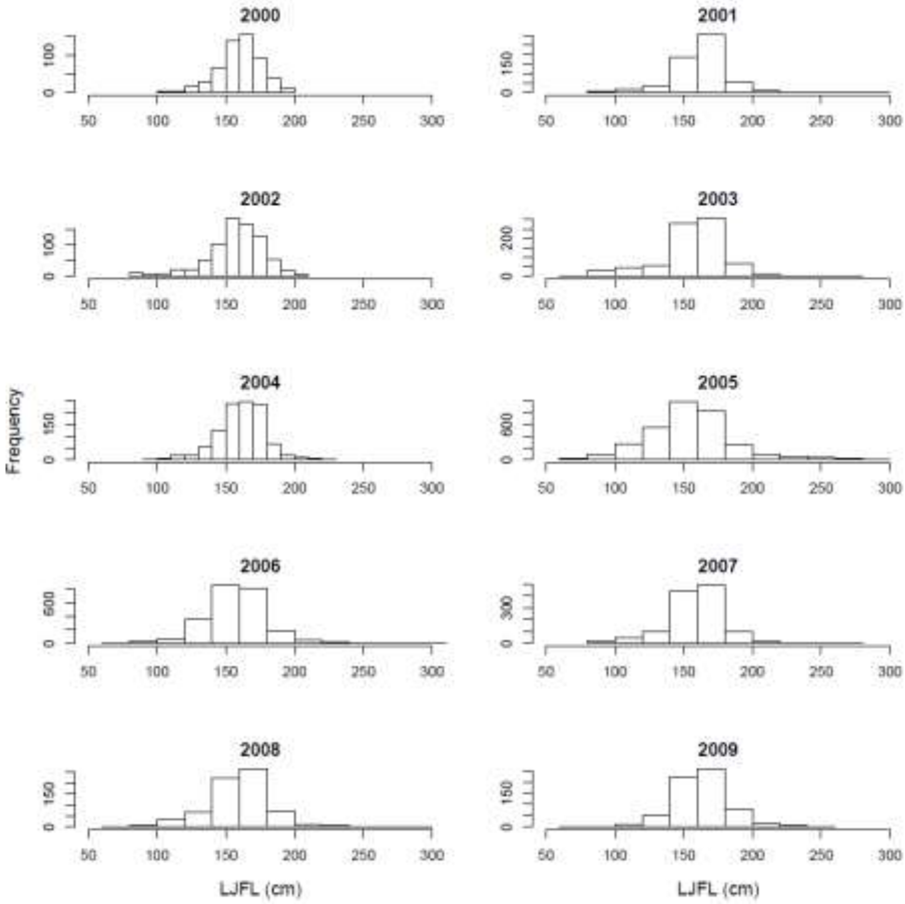


Figure 7. Size frequency histograms of white marlin (LJFL cm), combined across all fisheries for the period 2000-2009.

5. Bibliography

Anon. 2001. Report of the Fourth ICCAT Billfish Workshop. Col.Vol.Sci.Pap. ICCAT. Madrid, 53: 1-130.

Anon. 2006a. Report of the Data Preparatory Meeting for the 2006 Billfish Assessment (Natal-RN, Brazil). ICCAT Col. Vol. Sci. Pap., 59: 1-123.

Anon. 2006b. Report of the 2006 ICCAT Billfish Stock Assessment (Madrid, Spain). ICCAT Col. Vol. Sci. Pap., 60: 1431-1546.

Anon. 2011a. Statistical Bulletin. ICCAT, Madrid. Vol 40 40. 156 pp.

Anon. 2011b. Report of the 2011 Blue Marlin Stock Assessment and White Marlin Data Preparatory Meeting. 25-29 April 2011, Madrid, Spain. ICCAT. 71 pp.

Anon. 2012. Report of the 2012 White Marlin Stock Assessment Meeting. ICCAT. Madrid, Spain. ICCAT. 79 pp.

Arfelli, C. A., De Amorim, A. F. and Galhardo-Amado, J. C. 1986. Analysis of *Tetrapturus albidus* Poey (1861), caught off South and southeast of Brazil (1971-1984). ICCAT Col. Vol. Sci. Pap., 25: 202-217.

Arocha, F. 2006. Los peces de la familia Istiophoridae capturados por las flotas de Venezuela: Aspectos biológicos, pesquerías y gestión pesquera. Trabajo de ascenso para profesor asociado presentado en la Universidad de Oriente, 141 p.

Arocha, F. and Bárrios, A. 2009. Sex ratios, spawning seasonality, sexual maturity, and fecundity of white marlin (*Tetrapturus albidus*) from the western central Atlantic. Fisheries Research, 95: 98-111.

Arocha, F. and Beerkircher, L. 2012. Guide for the identification of Atlantic istiophorids. ICCAT, Madrid, Spain. 4pp.

Arocha, F., Larez, A., Marcano, J., Barrios, A., Gutierrez, X., Debrot, D. and Ortiz, M. 2006. Standardized catch rates for white marlin (*Tetrapturus albidus*) from the Venezuelan artisanal pelagic longline fishery off the Caribbean Sea and adjacent areas: period 1992-2003. ICCAT Col. Vol. Sci. Pap., 59: 315-322.

Arocha, F. and Marcano, L. 2006. Life history characteristics of *Makaira nigricans*, *Tetrapturus albidus*, and *Istiophorus albicans* from the eastern Caribbean Sea and adjacent waters. pp. 587-597. *In* The Fourth World Fisheries Congress: Reconciling Fisheries and Conservation. 2-6 May 2004. Vancouver, B.C., Canada. Ed. by J. NIELSEN, J. DODSON, K. FRIEDLAND, T. HAMON, N. HUGHES, J. MUSICK and E. VERSPOOR. Amer. Fish. Soc. Symp. 49. Bethesda, Maryland.

Baglin, R. E. 1979. Sex composition, length-weight relationship, and reproduction of the white marlin, *Tetrapturus albidus*, in the western North Atlantic Ocean. Fishery Bulletin, 76: 919-926.

Beerkircher, L. R. and Serafy, J. E. 2011. Using head measurements to distinguish white marlin Kajikia albida from roundscale spearfish Tetrapturus georgii in the western North Atlantic. Bulletin of Marine Science, 87: 147-153.

Block, B. A. 1986. Structure of the brain and eye heater tissue in marlins, sailfish, and spearfishes. Journal of Morphology, 190: 169-189.

Brill, R. W. 1996. Selective advantages conferred by the high performance physiology of tunas, billfishes, and dolphin fish. *In* Symposium on Metabolism and Physiology of High Performance Fish, at American Fisheries Society Conference, Vancouver, BC (Canada), July 1994.

Brill, R. W., Block, B. A., Boggs, C. H., Bigelow, K. A., Freund, E. V. and Marcinek, D. J. 1999. Horizontal movements and depth distribution of large adult yellowfin tuna (*Thunnus albacares*) near the Hawaiian Islands, recorded using ultrasonic telemetry: implications for the physiological ecology of pelagic fishes. Marine Biology, 133: 395-408.

Collette, B. B., Mcdowell, J. R. and Graves, J. E. 2006. Phylogeny of recent billfishes (Xiphioidei). Bulletin of Marine Science, 79: 455-468.

Die, D. J. and Drew, K. 2008. An Atlantic-wide study of age and growth of Atlantic marlins. *In* Proceedings from the Atlantic Billfish Research Program Symposium, pp. 67-84. Ed. by D. DONALSON. Gulf States Marine Fisheries Commission, Galveston, Texas.

Drew, K., Die, D. J. and Arocha, F. 2006. Current efforts to develop an age and growth model of blue marlin (*Makaira nigricans*) and white marlin (*Tetrapturus albidus*). ICCAT Col. Vol. Sci. Pap., 59: 274-281.

Fritsches, K. A., Marshall, N. J. and Warrant, E. J. 2003. Retinal specializations in the blue marlin: eyes designed for sensitivity to low light levels. Marine and Freshwater Research, 54: 333-341.

García-Cortés, B., Ramos-Cartelle, A. and Mejuto, J. 2011. Obsevations of the white marlin (*Tetrapturus albidus*) carried out on board of the Spanish surface longline fleet targeting swordfish from 1993-2010. ICCAT Col. Vol. Sci. Pap., SCRS/2011/035: 14.

Garcia De Los Salmones, R., Infante, O. and Alio, J. J. 1989. Reproduccion y alimentacion de los peces de pico, *Istiophorus albicans*, *Tetrapturus albidus* y *Makaira nigrican*, en la costa central de Venezuela. ICCAT Col. Vol. Sci. Pap., 30: 436-439.

Goodyear, C. P., Arocha, F. and Prince, E. D. 2003. Size composition of the white marlin catch. ICCAT Col. Vol. Sci. Pap., 55: 603-612.

Goodyear, C. P., Luo, J., Prince, E. D., Hoolihan, J. P., Snodgrass, D., Orbesen, E. S. and Serafy, J. E. 2008. Vertical habitat use of Atlantic blue marlin (*Makaira nigricans*): interaction with pelagic longline gear. Marine Ecology - Progress Series, 365: 233-245.

Graves, J. E. and Mcdowell, J. R. 2001. A genetic perspective on the stock structures of blue marlin and white marlin in the Atlantic Ocean. ICCAT Col. Vol. Sci. Pap., 53: 180-187.

Graves, J. E. and Mcdowell, J. R. 2006. Genetic analysis of white marlin (Tetrapturus albidus) stock structure. Bulletin of Marine Science, 79: 469-482.

Harvey, G. 2002. Portraits from the Deep, World Publications. 208 pp, Winter Park, FL, (United States).

Hoolihan, J. P., Luo, J., Goodyear, C. P., Orbesen, E. S. and Prince, E. D. 2011. Vertical habitat use of sailfish (*Istiophorus platypterus*) in the Atlantic and eastern Pacific, derived from pop-up satellite archival tag data. Fisheries Oceanography, 20: 192-205.

Hoolihan, J. P., Luo, J. and Prince, E. D. 2012. Preliminary analysis of time spent at temperature relative to the surface temperature for white marlin monitored with pop-up satellite archival tags. ICCAT Col. Vol. Sci. Pap., 68: 1585-1589.

Hoolihan, J. P., Luo, J., Richardson, D. E., Snodgrass, D., Orbesen, E. S. and Prince, E. D. 2009. Vertical movement rate estimates for Atlantic istiophorid billfishes derived from high resolution pop-up satellite archival data. Bulletin of Marine Science, 83: 257-264.

Horodysky, A. Z., Kerstetter, D. W., Latour, R. J. and Graves, J. E. 2007. Habitat utilization and vertical movements of white marlin (*Tetrapturus albidus*) released from commercial and recreational fishing gears in the western North Atlantic Ocean: inferences from shor duration pop-up archival satellite tags. Fisheries Oceanography, 16: 240-256.

Júnior, T. V., Vooren, C. M. and Lessa, R. P. 2004. Feeding habits of four species of Istiophoridae (Pisces: Perciformes) from northeastern Brazil. Environmental Biology of Fishes, 70: 293-304.

Kröger, R. H. H., Fritsches, K. A. and Warrant, E. J. 2009. Lens optical properties in the eyes of large marine predatory teleosts. Journal of Comparative Physiology A, 195: 175-182.

Luthy, S. A. (2004) Billfish larvae of the Straits of Florida. PhD, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 112pp.

Luthy, S. A., Cowen, R. K., Serafy, J. E. and Mcdowell, J. R. 2005. Toward identificaion of larval sailfish (*Istiophorus platypterus*), white marlin (*Tetrapturus albidus*), and blue marlin (*Makaira nigricans*) in the western North Atlantic Ocean. Fishery Bulletin, 103: 588-600.

Mather, F. J., Jones, A. C. and Beardsley, G. L. 1972. Migration and distribution of white marlin and blue marlin in the Atlantic Ocean. Fishery Bulletin, 70: 283-298.

N'goran, Y. N., Amon-Kothias, J. B. and Bard, F. X. 2001. Captures d'Istiophorides (voilier *Istiophorus albicans*, marlin bleu *Makaira nigricans*, marlin blanc *Tetrapturus albidus*) et effort de pêche des filets maillants dérivants operant en Côte d'Ivoire. ICCAT Col. Vol. Sci. Pap., 53: 272-280.

Nakamura, I. 1985. Billfishes of the World: an annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Species Catalogue, Vol. 5. . FAO fisheries synopsis. Rome, 125: 66pp.

Oliveira, I. M., Hazin, F., Travassos, P., Pinheiro, P. and Hazin, H. G. 2007. Preliminary results on the reproductive biology of the white marlin, *Tetrapturus albidus* Poey 1960, in the western equatorial Atlantic Ocean. ICCAT Col. Vol. Sci. Pap., 60: 1738-1745.

Orbesen, E. S., Hoolihan, J. P., Serafy, J. E., Snodgrass, D., Peel, E. M. and Prince, E. D. 2008. Transboundary movement of Atlantic istiophorid billfishes among international and U.S. domestic management areas inferred from mark-recapture studies. Marine Fisheries Review, 70: 14-23.

Ortiz, M., Prince, E. D., Serafy, J. E., Holts, D. B., Davy, K. B., Pepperell, J. G., Lowry, M. B. and Holdsworth, J. C. 2003. Global overview of the major constituent-based billfish tagging programs and their results since 1954. Marine and Freshwater Research, 54: 489-507.

Pinheiro, P., Júnior, T. V., Hazin, G. H. V., Travassos, P., Tolotti, M. T. and Barbosa, T. M. 2010. Diet of the white marlin (*Tetrapturus albidus*) from the southwestern equatorial Atlantic Ocean. ICCAT Col. Vol. Sci. Pap., 65: 1843-1850.

Prager, M. H., Prince, E. D. and Lee, D. W. 1995. Empirical length and weight conversion equations for blue marlin, white marlin, and sailfish from the North Atlantic Ocean. Bulletin of Marine Science, 56: 201-210.

Prince, E. D., Cowen, R. K., Orbesen, E. S., Luthy, S. A., Llopiz, J. K., Richardson, D. E. and Serafy, J. E. 2005. Movements and spawning of white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) off Punta Cana, Dominican Republic. Fishery Bulletin, 103: 659-669.

Prince, E. D. and Goodyear, C. P. 2006. Hypoxia-based habitat compression of tropical pelagic fishes. Fisheries Oceanography, 15: 451-464.

Prince, E. D. and Lee, D. W. 1989. Development of length regressions for Atlantic Istiophoridae. International Commission for the Conservation of Atlantic Tunas. Col. Vol. Sci. Pap., 30: 364-374.

Prince, E. D., Lee, D. W., Wilson, C. A. and Dean, J. M. 1984. Progress in estimating age of blue marlin, *Makaira nigricans*, and white marlin, *Tetrapturus albidus*, from the western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. ICCAT Col. Vol. Sci. Pap., 20: 435-447.

Prince, E. D., Lee, D. W., Zweifel, J. R. and Brothers, E. B. 1991. Estimating age and growth of young Atlantic blue marlin *Makaira nigricans* from otolith microstructure. 107Fishery Bulletin, 89: 441-460.

Prince, E. D., Luo, J., Goodyear, C. P., Hoolihan, J. P., Snodgrass, D., Orbesen, E. S., Serafy, J. E., Ortiz, M. and Schirripa, M. J. 2010. Ocean scale hypoxia-based habitat compression of Atlantic istiophorid billfishes. Fisheries Oceanography, 19: 448-462.

Reynal, L., Monthieux, A., Chantrel, J., Lagin, A., Roivoalen, J. J. and Norbert, M.-H. 2006. Premiers elements sur la biologie et la pêche du marlin bleu (*Makaira nigricans*) autour des DCP ancres en Martinique. ICCAT Col. Vol. Sci. Pap., 59: 303-314.

Satoh, K., Yokawa, K., Saito, H., Matsunaga, H., Okamoto, H. and Uozumi, Y. 2004. Preliminary stomach contents analysis of pelagic fish collected by Shoyo-Maru 2002 research cruise in the Atlantic Ocean. ICCAT Col. Vol. Sci. Pap., 56: 1096-1114.

Shivji, M. S., Magnussen, J. E., Beerkircher, L. R., Hinteregger, G., Lee, D. W., Serafy, J. E. and Prince, E. D. 2006. Validity, identification, and distribution of the roundscale spearfish, *Tetrapturus georgii* (Teleostei: Istiophoridae): Morphological and molecular evidence. Bulletin of Marine Science, 79: 483-491.

de Sylva, D. P. 1963. Postlarva of the white marlin, *Tetraturus albidus*, from the Florida current off the Carolinas. Bulletin of Marine Science of the Gulf and Caribbean, 13: 123-132.

de Sylva, D. P. and Breder, P. R. 1997. Reproduction, gonad histology, and spawning cycles of North Atlantic billfishes (Istiophoridae). Bulletin of Marine Science, 60: 668-697.

de Sylva, D. P. and Davis, W. P. 1963. White marlin, *Tetrapturus albidus*, in the Middle Atlantic Bight, with observations on the hydrography of the fishing grounds. Copeia, 1963: 81-99.

Ueyanagi, S., Kikawa, S., Uto, M. and Nishikawa, Y. 1970. Distribution, Spawning, and Relative Abundance of Billfishes in the Atlantic Ocean. Bull. Far Seas Fish. Res. Lab, 3: 15-55.