# Do Blue Marlin Spawn in the Northern Gulf of Mexico?

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## ABSTRACT

Blue marlin, *Makaira nigricans*, are seasonal residents in pelagic waters of the northern Gulf of Mexico (nGOM) where they support an active catch-and-release and trophy recreational fishery. However, little is known about the biology of the species in the nGOM. We collected ovaries from 62 blue marlin (size range 253.4 – 351.3 cm LJFL) captured during fishing tournaments in the nGOM from 1999-2007 to examine their reproductive condition during the May through September resident period. Gonadosomatic Index was low during all months; mean values never exceeded 0.59 ± 0.07. Histological analysis found no females captured in the nGOM that were spawning capable, although several females captured in July 2006 and September 2007 had regressing ovaries with vitellogenic and/or hydrated oocytes undergoing atresia. Furthermore, a fish captured in June 2007 with early developing ovaries had a mass of hardened, hydrated oocytes interspersed throughout the ovary, suggesting a failed or incomplete spawning event during the 2006 season. While histological evidence suggests blue marlin do not spawn in the nGOM, we have collected blue marlin larvae ≤ 7 d old along the western edge the Loop Current in the nGOM in July/August but not in other regions of the nGOM during the same months. Possibly, the larvae were spawned in the southern GOM or Caribbean Sea and transported to the nGOM by the Loop Current. The status of blue marlin spawning in the nGOM remains uncertain pending additional data collection.

KEY WORDS: Reproduction, pelagic fishes, *Makaira nigricans*

# ¿Desova el Marlin Azul en el Norte del Golfo de México?

El marlin azul, *Makaira nigricans*, son residentes estacionales en aguas pelágicas en el norte del Golfo de México (nGM) donde ellos sostienen una pesquería recreativa activa de cogido y liberación y del peces trofeo. Sin embargo, es sabido poco acerca de la biología de la especie en el nGM. Coleccionamos ovarios de 62 marlin azul (el tamaño recorre 253,4 – 351,3 cm LJFL) capturado durante torneos pesqueros en el nGM de 1999-2007 para examinar su condición reproductora durante el período residente (mayo a septiembre). El Indice de Gonadosomatico fue bajo durante todos meses; la valora medio nunca excedió 0,59 ± 0,07. El análisis histológico no encontró hembras capturadas en el nGM que desovaban capaz, aunque varias hembras capturadas en julio 2006 y septiembre 2007 tenidos ovarios retroceder con ovocitos vitelogénicos y/o hidratados que experimentan atresia. Además, un pez capturó en junio 2007 con ovarios en clase desarrollar temprano tuvieron una masa de endurecido, hidrató ovocitos esparcidos a través del ovario, sugiriendo un desove fallado o incompleto durante la 2006 temporada. Mientras la evidencia histológica sugiere el marlin azul no desova en el nGM, nosotros hemos reunido larvas de marlin azul <7 d vieja cerca de la Corriente del Lazo en el nGM en julio/ agosto pero no en otras regiones del GMn durante los mismos meses. Posiblemente, las larvas fueron desovadas en el GOM meridional o el Mar Caribe y transportados al nGM por la Corriente del Lazo. La posición del desove de marlin azul en el nGM está en duda la recogida de datos adicional pendiente.

PALABRAS CLAVES: Reproducción, peces pelágicos, *Makaira nigricans*

## INTRODUCTION

Blue marlin (*Makaira nigricans*) are widely distributed in the temperate and tropical waters of both the Atlantic and Pacific Oceans, including the Gulf of Mexico (GOM). There is no genetic evidence to indicate that Atlantic and Indo-Pacific blue marlin are separate species (Collette *et al*. 2006). Furthermore, recent studies have determined that blue marlin from the Atlantic Ocean comprise a single genetic stock that includes the western north Atlantic (US mid-Atlantic), the Caribbean Sea, and the western South Atlantic (Brazil) (McDowell *et al*. 2007). Although not specifically examined, it is assumed that blue marlin from the Gulf of Mexico (GOM) are also part of the Atlantic/Caribbean-wide stock.

Current genetic research suggests that Atlantic blue marlin do not exhibit spawning site fidelity in the Atlantic (McDowell *et al*. 2007), although there is ample evidence that blue marlin spawn in the region. Larval blue marlin have been collected from Exuma Sound, Bahamas (Serafy *et al.* 2003, Sponaugle *et al.* 2005), the Florida Straits (Luthy *et al*. 2005; Sponaugle *et al.* 2005), off Punta Cana, Dominican Republic (Prince *et al.* 2005) and in the northwestern Gulf of Mexico (J. Rooker, Texas A&M Galveston Pers. comm.), while juveniles have been reported from Cat Cay, Bahamas (Eschmeyer and Bullis 1968) and Bermuda (Luckhurst *et al.* 2006). The majority of these samples were collected in July (Eschmeyer and Bullis 1968, Serafy *et al.* 2003, Luthy *et al*. 2005, Sponaugle *et al*. 2005, J. Rooker, Texas A&M Galveston, Pers. comm..), or juvenile ages were back-dated to a July spawn (Luckhurst *et al*. 2006). Spawning seasonality of Atlantic blue marlin has also been estimated through gonadal examination. A combination of gonadal weights and histological observations have shown blue marlin spawn during June and July in Bimini, Bahamas (Yeo 1978), in July in Bermuda (Luckhurst *et al*. 2006), and in July through September in the Caribbean around Jamaica, Puerto Rico and the U.S. Virgin Islands (Erdman 1968, Yeo 1978). These data suggest July is a peak blue marlin spawning month throughout the region. However, blue marlin captured during the summer off South Carolina are not reproductive (Cyr 1987).

Four species of billfishes occur in the GOM: blue marlin, sailfish (*Istiophorus platypterus*), white marlin (*Tetrapturus albidus*), and longbill spearfish (*Tetrapturus pfluegeri*). Longbill spearfish is the only istiophorid that is a winter spawner (Richards and Luthy 2006). White marlin is a spring spawner (March – June; Prince *et al*. 2005), while sailfish and blue marlin are reported to spawn during the summer (deSylva and Breder 1997). Although the adults are distinctive and readily recognizable, the identification of larval and small juvenile billfishes remains difficult. Recent advances by Luthy *et al*. (2004) have enabled the identification of some blue marlin and sailfish based on patterns of lower jaw pigment, and the relationships between the ratio of snout length to eye orbit diameter and standard length (SL), while larvae of longbill spearfish are distinct in having pigment on the branchiostegal membranes. The ability to identify larval billfishes greatly aids in determining species-specific reproductive seasonality and spawning areas throughout the GOM.

The northern GOM supports an active recreational fishery for blue marlin from May through September (Brown-Peterson *et al*. 2004); from 1996 – 2000, a total of 1,297 blue marlin were caught during GOM fishing tournaments, although the vast majority of these fish were tagged and released (Avrigian and Venizelos 2003). However, there is virtually no published information on blue marlin biology and life history from the GOM (deSylva *et al*. 2000). Therefore, this project was undertaken to provide information on spawning of blue marlin in the northern GOM through a combination of histological examination of gonadal tissues of tournament-captured blue marlin and collections of billfish larvae during the presumed summer spawning season.

## MATERIALS AND METHODS

### Adult Fish

Blue marlin captured by hook and line were sampled dockside at recreational fishing tournaments in the northern Gulf of Mexico (Panama City, Florida through Venice, Louisiana) during the summer from 1999 – 2007. Fish from these tournaments were captured offshore in 100 to 2500 meters depth. The study area was bounded by 85.5$^o$ to 88.5$^o$ Lat. N, then extending diagonally to 90.5$^o$ Lat N; and 27.5$^o$ and 29.8$^o$ Long. W.

Lower jaw fork length (LJFL, 0.1 cm) and total weight (W, 0.1 lb.) were measured for each fish and ovaries were removed, weighed (GW, 0.02 lb), and a thin mid-section slice was placed in jars in 10% neutral buffered formalin (NBF). Gonadosomatic Index (GSI) was calculated as GSI = [GW/(W-GW)] x 100. In the laboratory, a 1 cm$^3$ sample of preserved ovarian tissue was put into individually labeled cassettes and stored in NBF prior to histological processing. Ovaries of some fish collected during 2002 – 2004 were frozen; these tissues were thawed at 4°C in NBF and a 1 cm$^3$ sample of tissue was placed into cassettes and stored in NBF. Cassettes containing tissues were rinsed overnight in running tap water, dehydrated in a series of graded ethanols and processed through paraffin embedment following standard histological techniques. Tissue was sectioned at 4-µm and stained with hemotoxyin and eosin. Histological classification of reproductive phases followed Brown-Peterson *et al*. (2007).

### Larval Fish Collections

A series of research cruises were taken in the northern GOM during June, July or August in 2000 – 2006 to collect larval billfishes. The general area sampled during these cruises is shown in Figure 1. For all collections, mesh size of the various nets used was 333 µm. From June through August in 2000 – 2003, a total of 163, ten minute collections were taken in the vicinity of *Sargasssum* habitat in the northcentral GOM using surface neuston nets or subsurface bongo nets. The *Sargassum* was often associated with oceanic frontal zones. In June - August 2004 a total of 81 collections were taken along the western edge of the Loop Current by oblique Tucker trawl, surface neuston nets or subsurface bongo nets. In August 2005, 48 ten minute surface neuston collections were taken along the edge of the Loop Current. In August 2006, a total of 46 ten minute surface neuston collections and four subsurface bongo collections were taken along the western edge of Desoto Canyon in the northcentral GOM in the vicinity of fronts with associated *Sargassum*. All collections were immediately preserved in 95% ethanol and returned to the laboratory for subsequent sorting and identification.

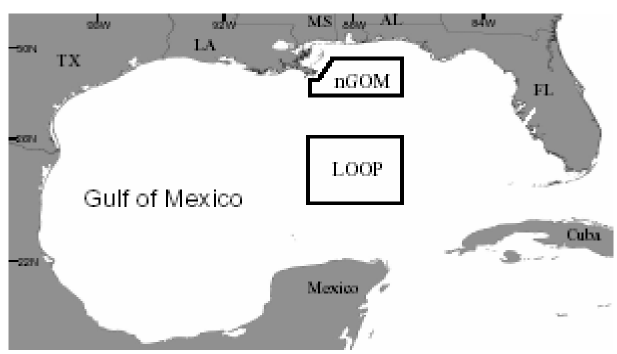


**Figure 1.** Areas in the northern Gulf of Mexico sampled for blue marlin larvae. nGOM: samples collected at pelagic *Sargassum* often in association with oceanic frontal zones from June – August 2000 and 2002, July – August 2001, July 2003 and August 2006. Loop: samples collected June – August 2004 and August 2005 along the boundary of the Loop Current.

## Larval Fish Identification

The initial sorting of all larval fish collections involved separation of billfish larvae. The billfish larvae were then sorted to species using morphological characteristics where possible. Approximately 40% of preflexion or flexing blue marlin larvae are distinct in having one pigment spot on each side of the tip of the lower jaw (Luthy *et al.* 2004). Additionally, about 60% of sailfish larvae (any flexion stage) are distinct in having pigment spots on the posterior 2/3 of the lower jaw (Luthy *et al*. 2004). Blue marlin and sailfish larvae > 8 mm can be separated based on the relationship between the ratio of snout length to eye orbit diameter and SL. These characters allowed separation of known blue marlin and sailfish larvae, the most common billfishes in summer collections. The right eyeball was removed from all remaining larvae, as well as from some known blue marlin and sailfish larvae, for molecular identification.

Total genomic DNA was extracted from 48 preserved larval billfish eyes using a Qiagen DNeasy Tissue Kit (Qiagen, Valencia, CA) according to the manufacturer's directions. After isolation, larvae were identified following the methods of McDowell and Graves (2002). Briefly, a 1200 bp band was amplified using primers for the nuclear locus MN32-2 (Buonaccorsi *et al*. 1999). The resulting band was digested with the restriction endonucleases *Dra* I and *Dde* I, (Invitrogen Corporation, Carlsbad, CA) and larvae were identified based on published restriction profiles of adult billfishes (McDowell and Graves 2002). Digested DNA from adult sailfish, blue marlin, and white marlin were run on each gel as controls. In a few cases, amplification of the 1200 bp band was not possible due to sample degradation. In these cases, an alternate protocol using species-specific multiplex primers developed by J. Magnussen and M. Shivji (Nova Southeastern University Pers. comm.) were used to identify samples. As above, controls consisted of DNA from adults of known identity.

## Adult Fish

Blue marlin were captured in the nGOM at tournaments from mid May through early September, and ranged in size from 253.4 – 351.3 cm LJFL and in weight from 140.4 – 478.8 kg. Ovarian tissue for histological analysis was collected from 76 of the 80 fish captured during 1999 – 2007; ovarian weights were obtained for 56 specimens. The mean GSI was very low during all months and showed a slight decrease from May to September (Figure 2). All fish had GSI values ≤ 1.0. All females captured were sexually mature. Histological inspection of ovarian tissue showed that none of the females captured from the nGOM were spawning capable (Table 1). Furthermore, there were some females in the Regenerating phase, not undergoing ovarian recrudescence, in May, June, July and August. This suggests some female blue marlin may not spawn every year. The mostly commonly observed reproductive phase from May through July was the Early Developing subphase (Figure 3A), characterized by cortical alveolar oocytes and no vitellogenesis. The majority of fish in May and June were in this subphase (Table 1). The most advanced ovarian development seen was the Mid Developing subphase, with oocytes just beginning to sequester vitellogenin (Figure 3B); the highest percentage of fish in this subphase was seen in June (Table 1). Fully grown vitellogenic oocytes not undergoing atresia were not observed in any blue marlin captured from the nGOM. However, evidence that blue marlin captured in the nGOM are capable of fully maturing oocytes comes from a fish in the Regressing phase, captured in early September, 2007. This female had masses of hydrated, but atretic, oocytes, remnants of an incomplete or unsuccessful spawning event earlier in the year (Figure 3C). A fish captured in early June, 2007 in the Early Developing subphase also had a mass of hardened, atretic hydrated oocytes, no doubt left over from a spawning event that occurred during summer 2006. However, it is unclear where these fish may have spawned and if they successfully released hydrated oocytes.

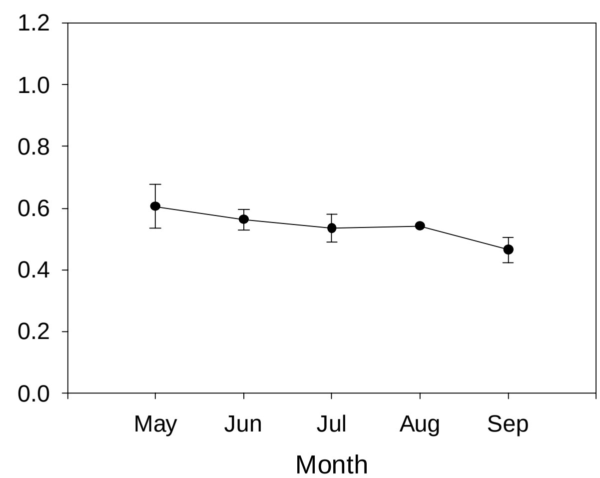


**Figure 2.** Monthly Gonadosomatic Index (GSI, mean ± SE) of female blue marlin sampled from the northern Gulf of Mexico, 1999 – 2007.

By July, 17% of the females were in the Regressing phase, with histological evidence of some atretic vitellogenic oocytes in the ovary (Figure 3D); this percentage increased in August and early September. The presence of females in the Regressing phase suggests spawning had occurred several weeks prior to capture based on lack of post-ovulatory follicles (POF) and the advanced atretic stages of the oocytes in all fish in this phase (Figures 3C, 3D). The greatest percentage of fish in July and August were in the Regenerating phase, indicating cessation of spawning for the season. Thus, histological evidence suggests blue marlin in the nGOM have a relatively short spawning season from late June through August, based on histological assessment of ovarian development. This conclusion is supported by a single report of a female blue marlin in the Actively Spawning phase, with hydrated oocytes, captured west of the Mississippi River in Louisiana in July, 2005 (J. Yurt, Louisiana Department of Fish and Wildlife Pers. comm.). Unfortunately, the ovarian sample collected from this fish was lost during Hurricane Katrina before it could be processed and examined. Interestingly, no fish captured east of the Mississippi River showed any indications of active spawning.

**Table 1**. Ovarian histological maturity phases of blue marlin collected in the northern Gulf of Mexico, 1999-2006. Data represents monthly percentages of females in each phase

| Month | N | Developing—Early* | Developing—Mid* | Spawning Capable | Regressing | Regenerating |
|---|---|---|---|---|---|---|
| May | 8 | 75 | 12 | 0 | 0 | 13 |
| June | 40 | 60 | 18 | 0 | 4 | 18 |
| July | 23 | 35 | 13 | 0 | 17 | 35 |
| August | 3 | 33 | 0 | 0 | 33 | 34 |
| September | 3 | 0 | 0 | 0 | 100 | 0 |

*Ovaries in the early subphase are characterized by cortical alveolar oocytes and no vitellogenesis; ovaries in the mid subphase have oocytes beginning to sequester vitellogenin.

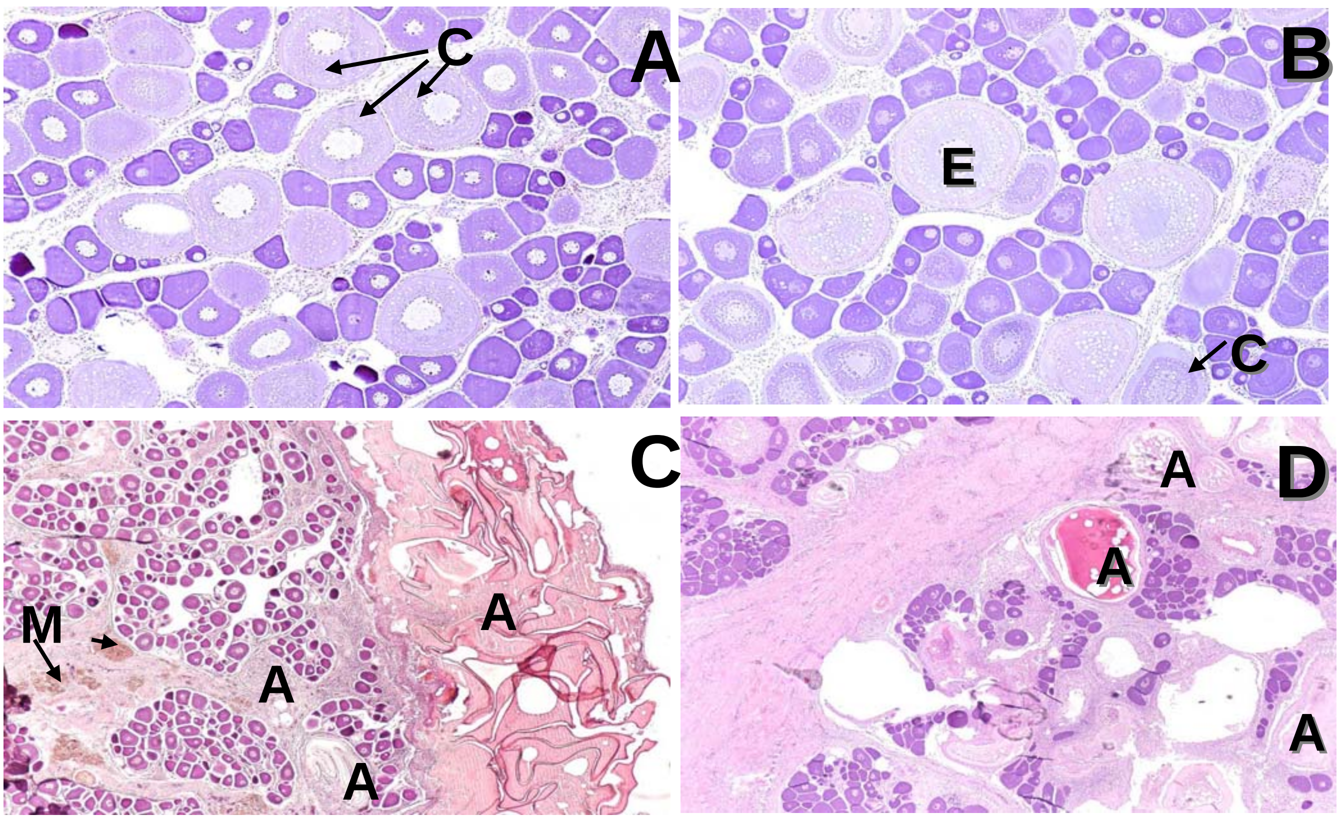


**Figure 3.** Histological photographs of blue marlin ovaries captured in the northern Gulf of Mexico. A. Ovary in the early Developing phase, captured in July 2006. The most advance stage of oocyte development is cortical alveoli. 100X B. Ovary in the Developing phase, captured in July 2005. This individual had the most advanced oocyte stage of any blue marlin examined. 100X. C. Ovary in the Regressing phase captured 1 September 2007. Areas of atretic hydrated oocytes suggest this female was unable to release all hydrated oocytes during the spawning season. 40X. D. Ovary in the Regressing phase captured in July 2006. The presence of atretic vitellogenic oocytes suggests this female spawned earlier in 2006. 40X. Key: A—atretic oocyte; AH—atretic hydrated oocytes; CA—cortical alveolar oocyte; EV—early vitellogenic oocyte; MA—macrophage aggregates.

**Larval Fish**

Larval blue marlin have been identified from the northern GOM (Figure 4), representing the first published record of larvae of this species from this part of the GOM. Of the 48 larvae examined using molecular markers, 27 were identified as sailfish and 11 were identified as blue marlin. Due to the presence of degraded DNA, 10 larvae remained unidentified. Molecular identification confirmed the morphological identification of blue marlin larvae; 100% of the blue marlin identified morphologically were determined to be blue marlin after DNA identification. This finding not only verifies the efficacy of the morphological identifications, but increases the ability of definitively identifying blue marlin larvae with no morphological distinctions from other billfish larvae. Molecular identification of additional billfish collected during 2005 and 2006 is ongoing, and we anticipate confirmation of additional blue marlin larvae from the northern GOM.

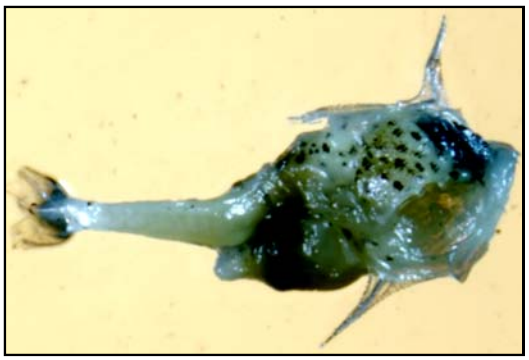

**Figure 4.** Larval blue marlin (9.9 mm SL) collected at the edge of the Loop Current on August 5, 2005. This represents one of the 26 confirmed larval blue marlin collected at the Loop Current in August 2005.

Larval billfishes, and particularly larval blue marlin, were not commonly collected during summer plankton cruises in the northern GOM, despite successful collections of many larval fishes (Table 2). The area with the greatest abundance of larval billfish, and the only area with confirmed blue marlin, was along the edge of the Loop Current. The 2004 collections at the Loop Current netted a total of 60 larval billfishes in 14 of the 81 collections, of which one was positively identified using molecular markers as a blue marlin. All of these billfish were captured in June. The large numbers of larval fish collected in 2004 (16, 363 total) was a result of the capture of schools of clupeids and carangids. A total of 251 billfish larvae were found in 25 of the 48 collections taken along the edge of the Loop Current in August 2005. Of these, 26 were identified as blue marlin based on lower jaw pigment, representing approximately 40% of the blue marlin larvae (Table 2). We anticipate that additional blue marlin larvae will be found in these collections following completion of molecular identification.

Larval billfishes were collected in areas of the nGOM associated with patches of *Sargassum* in 2000, 2001, 2003, and 2006. Few of the collections in each cruise contained billfish, and no blue marlin were identified from these GOM collections based on morphological or molecular characteristics (Table 2). However, molecular methods have successfully identified sailfish larvae from the 2000 - 2003 collections. Two sailfish were morphologically identified from the 2006 collections, and molecular identification of the remaining 17 billfish is ongoing.

## DISCUSSION

Blue marlin are relatively abundant in the northern GOM during the summer, and this study was fortunate to be able to obtain ovarian samples from 76 individuals during the May through September resident period. Furthermore, all blue marlin examined were sexually

**Table 2.** Summary of blue marlin larvae collected as part of summertime plankton collections in the northern Gulf of Mexico from 2000 – 2006.

| Collection Location * | Month and Year of Collection | No. of Larvae | No. of Billfish Larvae | No. of Blue Marlin Larvae |
|---|---|---|---|---|
| nGOM<br>•27 collections, 3 with billfish | June – August 2000 | 2,341 | 29 | 0 |
| nGOM<br>•24 collections, 5 with billfish | July – August 2001 | 4, 687 | 11 | 0 |
| nGOM<br>•47 collections, 0 with billfish | June – August 2002 | 8,180 | 0 | 0 |
| nGOM<br>•15 collections, 1 with billfish | July 2003 | 1,934 | 3 | 0 |
| LOOP<br>•81 collections, 14 with billfish | June – August 2004 | 16,363 | 60 | 1 |
| LOOP<br>•48 collections, 25 with billfish | August 2005 | 8,234 | 251 | 26 |
| nGOM<br>•50 collections, 6 with billfish | August 2006 | 4,132 | 19 | 0 |
| **TOTAL** | | 45,871 | 373 | 27 |

*Northern Gulf of Mexico (nGOM) samples were collected at pelagic *Sargassum*, often in association with oceanic frontal zones. Loop Current (LOOP) samples were collected along the boundary of the Loop Current in the northern and central Gulf of Mexico.

mature; weight at sexual maturity for female blue marlin has been reported to range from 61.3 to 120 kg (Yeo 1978, Hopper 1990, de Sylva and Breder 1997), well below the size of the smallest female captured in this study. Thus, all fish captured in this study were certainly capable of spawning. Previous reports of blue marlin reproduction have indicated that females with GSI values > 3 are reproductively active (Hopper 1990, Luckhurst *et al.* 2006). However, all of the females sampled from the northeastern Gulf of Mexico had GSI values $\leq$ 1, suggesting no spawning activity occurred in the area. Similarly low GSI values have been found in tournament-captured blue marlin from South Carolina (Cyr 1987) and Cabo San Lucas, Mexico (Ortega-García *et al.* 2006); fish from these areas were also considered reproductively inactive based on GSI values.

The relatively high percentages of mature blue marlin showing no ovarian development during May, June, and July suggests some individuals may skip spawning seasons. The phenomena of skip spawning has been documented in Gulf of Mexico groupers (Collins *et al.* 2002, Fitzhugh *et al*. 2006) as well as Atlantic cod (Rideout et al. 2005; Jorgensen *et al.* 2006), and may occur more frequently in large species than originally suspected. The possibility that blue marlin use this reproductive strategy needs additional investigation, and may suggest an explanation for the large numbers of reproductively inactive blue marlin captured in the northeastern GOM.

Histological examination of ovarian tissue indicates that blue marlin captured in the northeastern Gulf of Mexico from May through September are not spawning. However, ovarian recrudescence was occurring in the majority of blue marlin captured in May, June, and July during the course of this study, although no non-atretic oocytes more advanced than early vitellogenesis were seen. Thus, while blue marlin from this section of the GOM do exhibit some ovarian growth and maturation, it appears that spawning is not likely to occur in GOM waters east of the Mississippi River during summer. In contrast, blue marlin have been reported to spawn from May through August from a number of locations based on histological inspections (Bahamas, Yeo 1978, Bermuda, Luckhurst *et al.* 2006, Caribbean, Erdman 1968, Hawaii, Hopper 1990). The lack of spawning capable and actively spawning blue marlin in our collections during the reported reproductive season despite a sizeable sample size is surprising.

Larval blue marlin were collected in June and August from the northern GOM only in areas associated with the boundary of the Loop Current. The Loop Current may be a potential blue marlin spawning site; there has been speculation that blue marlin preferentially spawn near cyclonic eddies in Hawaii (Seki *et al.* 2002). The Loop Current is characterized by convergences, upwellings and strong flow (current speed characteristically 50 cm/s) along its outer boundary. Thus, planktonic organisms, including larvae of Caribbean and southern GOM origins, can become entrained and transported into the northern GOM by the Loop Current (Johnson *et al.* 1992, Gasca *et al.* 2001). Blue marlin larvae have been collected in the Straits of Florida and Exuma Sound, Bahamas during July (Serafy *et al*. 2003; Luthy *et al*. 2005; Sponaugle *et al*. 2006), and these larvae may have become entrained in the Loop Current and transported to our northern GOM capture locations. The relatively low densities of blue marlin larvae found suggests transport, rather than concentration of larvae from a nearby spawning event. The entrainment of larvae spawned outside the GOM becomes a more likely explanation for the observed northern GOM larvae when combined with the lack of blue marlin larvae from other, non-Loop Current/eddy sites in the northern GOM during July and August. This suggests spawning is not occurring in the northern GOM. There is no genetic distinction among blue marlin from Florida, the Caribbean or the GOM (McDowell *et al.* 2007), and thus, it is impossible to determine the origin of the larvae we collected at the Loop Current.

Examination of female adult blue marlin suggests the species does not spawn in the northern Gulf of Mexico east of the Mississippi River. The lack of larvae in the same section of the GOM, with the exception of those found at the Loop Current, supports this speculation. However, there is strong anecdotal evidence suggesting that blue marlin do spawn in some areas of the northern GOM during the summer. Evidence of previous spawning, in the form of hydrated, but atretic, oocytes in females with regressing ovaries was seen in July, August, and early September, indicating spawning occurred several weeks prior to capture. While blue marlin are a highly migratory species, it seems doubtful that these fish spawned in the Caribbean or Straits of Florida and immediately returned to the GOM. Satellite tagging data supports the premise that blue marlin remain in the northern Gulf of Mexico during June and July (J. Rooker, Texas A&M University, Galveston, Pers. comm.). Additionally, one female blue marlin with hydrated oocytes was captured in Louisiana west of the Mississippi River in July 2005 (J. Yurt, Louisiana Department of Fish and Wildlife Pers. comm.), and numerous small blue marlin larvae have been captured in the northwestern GOM during June and July (J. Rooker, Texas A&M University, Galveston Pers. comm.; http://www.tamug.edu/pelagic/billfish_life_ecology.htm). Unfortunately, ovarian tissue of blue marlin from the northwestern GOM has not been examined, and thus the reproductive status of adults in the area is undocumented. The available data suggest blue marlin may indeed spawn in the northern GOM west of the Mississippi River; additional coordinated collections of both adults and larvae from this region are necessary to provide definitive data.

In summary, the status of blue marlin spawning in the northern Gulf of Mexico remains unclear. There is strong histological evidence to support the lack of spawning in the northern Gulf of Mexico east of the Mississippi River, which is augmented by the failure to capture blue marlin larvae in areas not associated with the Loop Current. The presence of young blue marlin larvae along the boundary of the Loop Current may be a result of transport from Carribbean/Straits of Florida spawning events. The likelihood of blue marlin spawning at the Loop Current in the northeastern GOM is slim, since no spawning capable adults have been captured from the region. However, the northwestern GOM may be a spawning site for blue marlin, as it is for bluefin tuna (J. Rooker, Texas A&M University, Galveston Pers. comm.), based on collections of larval blue marlin from that region. Unfortunately, confirmatory data of spawning capable or actively spawning adult fish is lacking from the northwestern GOM. Therefore, in order to determine the spawning status of this prized recreational species in the Gulf of Mexico, additional research is necessary.

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## LITERATURE CITED

Avrigian, A.M and A. Venizelos. 2003. Big game fishing in the northern Gulf of Mexico during 1996 - 2000. *NOAA Technical Memorandum*. **NMFS-SEFSC-495**. 15 pp.

Brown-Peterson, N.J., J.S. Franks, B.H. Comyns, L.A. Hendon, E.R. Hoffmayer, J.R. Hendon, and R.S. Waller. 2004. Aspects of the reproduction of large pelagic fishes in the northern Gulf of Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:1016-1017.

Brown-Peterson, N.J., S.K. Lowerre-Barbieri, B.J. Macewicz, F. Saborido-Rey, J. Tomkiewicz and D.M. Wyanski. 2007. An Improved and Simplified Terminology for Reproductive Classification in Fishes. http://www.usm.edu/gcrl/research/gonadal_terminology.php.

Buonaccorsi, V.P., K.S. Reece, L.W. Morgan, and J.E. Graves. 1999. Geographic distribution of molecular variance within the blue marlin (*Makaira nigricans*): a hierarchical analysis of allozyme, single-copy nuclear DNA, and mitochondrial DNA markers. *Evolution* **53**:568–579.

Collette, B.B., J.R. McDowell, and J.E. Graves. 2006. Phylogeny of recent billfishes (Xiphiodei). *Bulletin of Marine Science* **79**(3):455-468.

Collins, L.A., G.R. Fitzhugh, L.A. Lombardi-Carlson, H.M. Lyon, W.T. Waling, and D.W. Oliver. [2002]. Characterization of red grouper (Serranidae: *Epinephelus morio*) reproduction from the eastern Gulf of Mexico. NOAA Fisheries, Panama City Laboratory Contribution Series 2002-07. Unpubl. Ms.

Cyr, E.D. 1987. Age, growth and reproduction of blue marlin, *Makaira nigricns*, from South Carolina billfish tournament collections. M.S. Thesis. University of South Carolina, Colombia, South Carolina USA. 41 pp.

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

de Sylva D.P, W.J. Richards, T.R. Campo, and J.E. Serafy. 2000. Potential effects of human activities on billfishes (Istiophoridae and Xiphiidae) in the Western Atlantic Ocean. *Bulletin of Marine Science* **66**:187-198.

Erdman, D.S. 1968. Spawning cycle, sex ratio, and weights of blue marlin off Puerto Rico and the Virgin Islands. *Transactions of the American Fisheries Society* **97**:131-137.

Eschmeyer, W.N. and H.R. Bullis, Jr. 1968. Four advanced larval specimens of the blue marlin, *Makaira nigricans*, form the western Atlantic Ocean. *Copeia* **1968**(2):414-417.

Fitzhugh, G.R., H.M. Lyon, L.A. Collins, W.T. Walling, and L. Lombardi-Carlson. [2006]. Update of gag (*Mycteroperca microlepis*) reproductive parameters: Eastern Gulf of Mexico. SEDAR 10 Working Paper DW03. NOAA Fisheries Panama City Laboratory Contribution 05-06. Unpubl. Ms.

Gasca, R., I. Castellanos, and D.C. Biggs. 2001. Euphausiids (Crustacea, Euphausiacea) and summer mesoscale features in the Gulf of Mexico. *Bulletin of Marine Science* **68:**397-408.

Johnson, D.R., J.D. Thompson, and J.D. Hawkins. 1992. Circulation in the Gulf of Mexico from Geosat altimetry during 1985-1986. *Journal of Geophysical Research* **97**:2201-2214.

Jorgensen, C., B. Ernande, O,. Flksen, and V. Dieckmann., 2006. The logic of skipped spawning in fish. *Canadian Journal of Fisheries and Aquatic Science* **63**:200-211.

Luckhurst, B.E., E.D. Prince, J.K. Llopiz, D. Snodgrass, and E.B. Brothers. 2006. Evidence of blue marline (*Makaira nigricans*) spawning in Bermuda waters and elevated mercury levels in large specimens. *Bulletin of Marine Science* **79**(3): 691-704.

Luthy, S.A, R.K. Cowen, J.E. Serafy, and J.R. McDowell. 2005. Toward identification of larval sailfish, white marlin, and blue marlin in the western North Atlantic Ocean. *Fishery Bulletin* **103**:588-600.

McDowell, J.R. and J.E.Graves. 2002. Nuclear and mitochondrial DNA markers for specific identification of istiophorid and xiphiid billfishes. *Fishery Bulletin* **100**:537–544.

McDowell, J.R., J. E.L. Carlsson, and J.E. Graves. 2007. Genetic analysis of blue marline (*Makaira nigricans*) stock structure in the Atlantic Ocean. *Gulf and Caribbean Research* **19**(2):75-82.

Ortega-García, S., A. Klett-Traulsen and R. Rodríguez-Sánchez. 2006. Some biological aspects of blue marlin (*Makaira nigricans*) in the recreational fishery at Cabo San Lucas, Baja California Sur, Mexico. *Bulletin of Marine Science* **79**:739-746.

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

Richards, W.J. and S.A. Luthy. 2006. Istiophoridae:billfishes. Pages 2231-2240 in: W.J. Richards (ed.) *Early Stages of Atlantic Fishes—an Identification Guide for the Western Central North Atlantic.* CRC Press, Boca Raton, Florida USA.

Rideout, R.M., G.A. Rose, and M.P.M. Burton. 2005. Skipped spawning in female iteroparous fishes. *Fish and Fisheries* **6**:50-72.

Seki, M.P., R. Lumpkin, and P. Flament. 2002. Hawaii cyclonic eddies and blue marlin catches: the case study of the 1995 Hawaiian International Billfish Tournament. *Journal of Oceanography* **58**:739-745.

Serafy, J.E., R.K. Cowen, C.B. Paris, T.R. Capo, and S.A. Luthy. 2003. Evidence of blue marlin, *Makaira nigricans*, spawning in the vicinity of Exuma Sound, Bahamas. *Marine and Freshwater Research* **54**:299-306.

Sponagugle, S., K.L. Denit, S.A. Luthy, J.E. Serafy, and R.K. Cowen. 2005. Growth variation in larval *Maakaira nigricans*. *Journal of Fish Biology* **66**: 822-835.

Yeo, R.N. 1978. Fecundity, reproductive biology and some aspects of growth in the Atlantic blue marlin *Makaira nigricans* Lacepede 1802. M.S. Thesis. University of Miami, Coral Gables, Florida USA. 257 pp.