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ASPECTS OF THE MIGRATION, SEASONALITY AND HABITAT USE OF TWO MID-TROPHIC LEVEL PREDATORS, DOLPHINFISH (*CORYPHAENA HIPPURUS*) AND WAHOO (*ACANTHOCYBIUM SOLANDRI*), IN THE PELAGIC ECOSYSTEM OF THE WESTERN ATLANTIC INCLUDING THE SARGASSO SEA

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SUMMARY

This paper provides information on aspects of the ecology of two mid-trophic level predators, dolphinfish Coryphaena hippurus *and wahoo,* Acanthocybium solandri *in the western Atlantic including the Sargasso Sea. Both species are included in the ICCAT Small Tunas category and are taken principally as by-catch species by longline fisheries. However, they support important commercial and recreational line fisheries in the western Atlantic. Both species play an important role in the pelagic ecosystem of the western Atlantic and studies show that there is a linkage between oceanography and the seasonality of fisheries landings. Data from Bermuda, in the central Sargasso Sea, are provided as an example. Electronic (PSAT) tagging data has provided evidence of possible migration routes and lengthy residence times of dolphinfish in the Sargasso Sea. These PSAT data also provide important insights into habitat use and diel patterns of feeding in the water column. The evidence presented here shows both the importance of these two species in the overall ecosystem and the need to incorporate such species into any ecosystem-based fisheries management system.*

RÉSUMÉ

Le présent document fournit des informations sur les aspects de l'écologie de deux prédateurs de niveau trophique intermédiaire, la coryphène commune (Coryphaena hippurus) et le thazard bâtard (Acanthocybium solandri) dans l'Atlantique Ouest, y compris la mer des Sargasses. Les deux espèces sont incluses dans la catégorie des thonidés mineurs de l'ICCAT et sont capturées principalement comme espèces accessoires par les pêcheries palangrières. Cependant, elles soutiennent d'importantes pêcheries commerciales et récréatives opérant à la ligne dans l'Atlantique Ouest. Les deux espèces jouent un rôle important dans l'écosystème pélagique de l'Atlantique Ouest et les études montrent qu'il existe un lien entre l'océanographie et la saisonnalité des débarquements de pêche. Des données provenant des Bermudes, dans la mer centrale des Sargasses, sont fournies à titre d'exemple. Les données de marquage électronique (PSAT) ont fourni des preuves d'éventuelles routes migratoires et de séjour prolongé de la coryphène commune dans la mer des Sargasses. Ces données PSAT fournissent également des informations importantes sur l'utilisation de l'habitat et les modes d'alimentation nycthéméraux dans la colonne d'eau. La preuve présentée ici montre l'importance de ces deux espèces dans l'écosystème global et la nécessité d'incorporer ces espèces dans n'importe quel système écosystémique de gestion des pêches.

RESUMEN

Este documento proporciona información sobre aspectos relacionados con la ecología de dos depredadores de los niveles tróficos medios, el dorado, Coryphaena hippurus, y el peto, Acanthocybium solandri, en el Atlántico occidental, incluido el mar de los Sargazos. Ambas especies están incluidas en la categoría de pequeños túnidos de ICCAT y se capturan principalmente de forma fortuita en las pesquerías de palangre. Sin embargo, respaldan importantes pesquerías comerciales y recreativas de liña en el Atlántico occidental. Ambas especies desempeñan un importante papel en el ecosistema pelágico del Atlántico occidental y los estudios demuestran que existe un vínculo entre la oceanografía y la estacionalidad de los

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desembarques. Como ejemplo, se presentan los datos de Bermudas, en el mar de los Sargazos central. Los datos de marcado electrónico (PSAT) han aportado pruebas de posibles rutas de migración y de largos periodos de residencia del dorado en el mar de los Sargazos. Estos datos PSAT también han proporcionado importante información sobre el uso del hábitat y sobre patrones nictimerales de alimentación en la columna de agua. La evidencia presentada en este documento muestra tanto la importancia de estas dos especies en el ecosistema en general como la necesidad de incorporar dichas especies a cualquier sistema de ordenación pesquera basada en el ecosistema.

KEYWORDS

Pelagic ecosystem, dolphinfish, wahoo, tagging, migration, oceanography, feeding, Sargasso Sea

Introduction

Trophic webs are central to understanding the functioning of pelagic ecosystems. A growing body of scientific literature acknowledges the role of top-down trophic processes in defining the composition and structure of pelagic marine communities and how marine fisheries may be triggering changes in these dynamics (Crespo *et al.* 2016). The removal of apex predators such as tunas and swordfish, which are the target of longline fisheries, may lead to the release of mesopredator populations leading to changes in community structure. Mid-trophic level predators such as dolphinfish, *Coryphaena hippurus* and wahoo, *Acanthocybium solandri* are important components of pelagic ecosystems but they are generally less well studied as opposed to commercially targeted species e.g. tunas, as they are taken principally as by-catch species in longline fisheries. Studies have demonstrated how tuna fishing in the Eastern and Central North Pacific Ocean led to trophic imbalances in the biological communities where these fisheries operated, reducing the abundance of higher trophic level species which led to increases in the abundance of mid-level trophic level species, such as skipjack tuna, due to partial predatory release (Olson and Watters 2003; Hinke *et al.* 2004). However, both dolphinfish and wahoo are the targets of important recreational fisheries in the western Atlantic and knowledge of their biology has been recently enhanced as the result of tagging programs. This paper seeks to better define the role of these two species in the pelagic ecosystem of the western Atlantic including the Sargasso Sea by revealing aspects of their migrations, seasonality and habitat use.

Results and Discussion

Dolphinfish

Fisheries and oceanography

Dolphinfish are taken as a by-catch species in the longline fisheries of the western Atlantic but because they are not targeted by these commercial fisheries, it is difficult to assess their abundance and seasonality of occurrence in the western Atlantic. Farrell *et al.* (2014) analyzed temporal and spatial catch per unit effort (CPUE) of dolphinfish along the U.S. east coast using U.S. pelagic longline logbook data (1999–2007). A negative binomial model was fitted using a variety of oceanographic variables to better understand distribution and abundance. The two most important dynamic oceanographic variables were sea surface temperature (SST) and chlorophyll-*a* concentration. They also used catch and release locations of dolphinfish caught by recreational fishermen (2002–2007) to compare conditions between datasets. For the longline dataset, dolphinfish CPUE was highest at 22°–25°C with a peak at 24°C, while recreational dolphinfish were only caught in waters >19°C with peak catches occurring at 27°C (Farrell *et al.* 2014). Dolphinfish CPUE was highest when chlorophyll-*a* concentration was generally low (<0.2 mg m^{-3}) and the majority of recreational dolphinfish were captured in waters with a chlorophyll-*a* concentration of <0.1 mg m^{-3}. Farrell *et al.* (2014) also found that a majority (73.3%) of recreational dolphinfish were caught in association with *Sargassum* spp.

As Bermuda is in the western-central part of the Sargasso Sea, it is reasonable to use local fisheries landings data as a proxy for the larger Sargasso Sea. Luckhurst and Trott (2000) analyzed quarterly fisheries landings data of dolphinfish and wahoo from Bermuda's commercial pelagic troll fishery from 1987- 1997 to determine if there was a seasonal pattern of landings. They reported that landings of dolphinfish showed a high level of seasonality with third quarter (July-September) landings comprising 45-60% of annual landings over this 11 year period.

The third quarter is the period with the highest SST in Bermuda (Luckhurst, 2007). A highly seasonal landings pattern is deemed to be consistent with a highly migratory species (Oxenford and Hunte 1986). More recently, a quarterly analysis of Bermuda dolphinfish landings from 2011-2015 (**Table 1**) shows a somewhat different pattern to the earlier study with the second quarter often exhibiting higher landings than the rest of the year. But as before, the first quarter consistently had the lowest level of annual landings (> 10%) (Table 1) which is the period when the SST is at a minimum (about 18° C). This is below the preferred minimum temperature of 20° C. for dolphinfish (Luckhurst 2014).

In the tropical waters of Venezuela, the seasonality of dolphinfish appears to be made up of two different size groups (Arocha *et al.* 1999). The first group arrives at the end of the first quarter (March) comprised of large mature individuals that will spawn in May. The second group arrives at the beginning of the third quarter (July) and is comprised of smaller specimens that will spawn in October-November (Arocha *et al.* 1999). Thus it appears that this seasonality is linked to a spawning cycle and migration pattern rather than to changing oceanographic conditions.

Migration

In an early paper, Palko *et al.* (1982) reported that there was little direct evidence of dolphinfish movements in the western central Atlantic. They believed that migrations and movements were likely to be affected by the movement of drifting objects (including mats of *Sargassum*) in oceanic waters with which dolphinfish were associated. Oxenford and Hunte (1986) proposed two migration circuits of dolphinfish in the northeast and southeast Caribbean, based largely on seasonality of fisheries by location and mean size-at-capture. They suggested a northeastern migration circuit incorporating the northern Caribbean islands, the southeastern US and Bermuda, and a southeast circuit incorporating the southeastern Caribbean islands and the north coast of Brazil.

Over the past 15 years, the Dolphinfish Research Program has tagged over 20,000 dolphinfish with conventional tags and more than 500 tags have been recovered (Hammond, pers. com.). This program has also deployed 20 satellite tags (PSAT) on dolphinfish in this same time period and much has been learned about dolphinfish biology and migrations (Hammond 2014). Using conventional tag recapture data (n = 306), Merten *et al.* (2014) examined both small and large scale dispersal and movement patterns of dolphinfish along the U.S. east coast. Movement rates were dependent upon region, latitude, and the distance from shore at which fish were released. The highest observed movement rates were from Florida to the South-Atlantic Bight (SAB) (44.67± 39.53 km/d) and from Florida to northeastern North Carolina (MAB) (44.62 ±15.31 km/d). Movements within the SAB were the slowest (11.80 ± 27.94 km/d). Regional movement headings varied with latitude, with dolphinfish released from the Florida Keys to Central Florida displaying the most directional variability. Only a small number (3.5%) conducted southerly movements and the majority of these occurred during fall (Merten *et al.* 2014). The maximum straightline dispersal rate was 238.3 km/d and the greatest displacement distance was 1915 km observed in 51 days between the Florida Keys and Long Island, New York (Merten *et al.* 2014). Understanding the movements of dolphinfish along the U.S. east coast is a necessary pre-requisite for describing the spatial and temporal movement patterns in the northwestern Atlantic including the Sargasso Sea, the Bahamas and the Caribbean Sea.

An illustrative migratory track was obtained from a PSAT-tagged male dolphinfish released off South Carolina in June, 2014 (Hammond 2014). This fish remained at liberty for 6 months and spent the majority of its time in the northern Sargasso Sea (**Fig. 1**), apparently remaining in preferred oceanographic conditions for weeks at a time. As the SST cooled in November, the fish moved rapidly south to Puerto Rico covering approximately 2,680 km (Hammond 2015) in a month (**Fig. 1**). The total distance travelled by this fish for the six month period was calculated to be almost 13,000 km (Hammond 2015) demonstrating the extensive movement range of dolphinfish. A combination of this same PSAT movement track with a conventional tag recovery movement vector indicates a possible migration route (**Fig. 2**) in the northwestern Atlantic. Oxenford and Hunte (1986) proposed two migration circuits of dolphinfish in the central western Atlantic, based largely on seasonality of landings and size-at-capture. They proposed a northeastern migration circuit showing dolphinfish migrating through the Sargasso Sea and then moving south on their return to the Caribbean and a southeastern circuit (**Fig. 3**). The migration pathway passing through the Sargasso Sea (**Fig. 2**) generally conforms well to that proposed for the northeastern circuit (**Fig. 3**) by Oxenford and Hunte (1986) which was generated without the benefit of any tagging data.

Habitat use and Feeding

Merten *et al.* (2014) deployed a total of six single-point pop-up satellite archival tags (PSAT) from 2005 to 2011 in the western central Atlantic on adult male dolphinfish. They ranged in size from 95–120 cm estimated fork length (FL). An analysis of the vertical movement patterns from these six fish revealed a diel activity pattern within the mixed surface layer with dives below the thermocline. This suggested that temperature was not a barrier to vertical movements for short periods of time. Dolphinfish were tracked for periods of 5–30 days (total = 83 days), reaching depths >200 m, and in temperatures ranging from 16.2 to 30.9 °C. (Merten *et al.* 2014). The data from these tags permitted comprehensive vertical movement analyses by time of day and duration at depth. The longest (>60 min), deepest (>30 m), and most extensive vertical movement patterns were nocturnal while the majority of daylight hours were spent near the surface (Merten *et al.* 2014). Dolphinfish spent 66 % of their time in the surface layer (top 10 m) and this is consistent with their feeding habit of the active pursuit of primary prey species e.g. flyingfishes (Oxenford and Hunte 1999) in the surface layer. Only one of the six tagged fish spent part of the monitoring period (about 8 %) diving to a depth where the temperature was >8 °C from the maximum surface temperature recorded during tracking. Two tags were analyzed based on lunar phase and revealed contrasting relationships between vertical movements during new and full phases thus precluding any definitive conclusions about the effect of lunar phase.

Dolphinfish are attracted to floating objects of all kinds including windrows or mats of *Sargassum* around which they frequently congregate and feed (Luckhurst 2014). They are not known to orient to any particular oceanographic features but they appear to be significantly influenced by SST (Farrell *et al.* 2014). Small dolphinfish often travel together in schools ranging from several individuals up to 50 fish. Larger adult fish are normally solitary or in pairs (Luckhurst 2014). In studying the effects of mat morphology on large *Sargassum*-associated fishes using video recordings, Moser et al (1998) found that fish diversity increased with the amount of continuous *Sargassum* habitat: four taxa were observed when no *Sargassum* was present, 12 taxa were found under clumps and 19 taxa were found under mats (>10 m diameter). Farrell et al (2014) determined that a majority of recreationally-caught dolphinfish were taken in association with *Sargassum*, but that larger dolphinfish (>82 cm FL) were caught more frequently away from *Sargassum* mats. Oxenford and Hunte (1999) found that larger male dolphinfishes appeared to be more active predators on prey species like flyingfish than smaller females. In a study of trophic niche overlap of dolphinfish and two tuna species in the southern New England region of the western North Atlantic, Teffer et al (2015) found that shortfin squid (*Illex illecebrosus*) and small pelagic crustaceans were the principal prey of dolphinfish and yellowfin tuna (*Thunnus albacares*). This is consistent with the finding that squid play an important role in the trophic web of the Sargasso Sea (Luckhurst 2015). A wide variety of *Sargassum*-associated fishes were also important to dolphinfish and yellowfin tuna diets (Teffer *et al.* 2015) and dolphinfish consumed the greatest range of prey sizes. The apparent shift from flyingfishes as principal prey of dolphinfish in the tropics to squid near the northern extent of their range (Teffer *et al.* 2015) where flyingfishes appear to be less abundant, provides a good example of their ability to change their feeding habits to prey species which are abundant in their environment. Shifts in diets on a seasonal or regional basis appear to be common amongst larger pelagic predators (Luckhurst 2015).

From an analysis of the vertical movement patterns of PSAT-tagged dolphinfish, Merten *et al.* (2014) concluded that they vertically shift between the surface mixed layer during the day and feeding at depth at night to exploit aggregating epipelagic and mesopelagic prey species. This shift in feeding behavior leads to predictable diel vertical movements in the water column but the feeding at depth at night is different from the feeding pattern of a number of other highly migratory species including tunas and billfishes which often feed at depth during the day but usually in short dives (Luckhurst 2014). In a preliminary pelagic food web of the Sargasso Sea, Luckhurst (2015) suggested that dolphinfish are an important component of this ecosystem as they function in the capacity of first prey and then predator in relatively quick succession because they are such a fast-growing species (Oxenford 1999) as well as having a short life span (Mahon and Oxenford 1999). Thus, their ecological role is dynamic and changes rapidly. They were placed at a trophic position (TP) of 4.3 based on a stable isotope analysis (Luckhurst 2015) and they were shown to have many links in this food web. Oxenford and Hunte (1999) indicated that dolphinfish diet varies with predator size – smaller dolphinfish eat fewer flyingfish and more squid than larger dolphinfish. They are a primary prey species for apex predators (Oxenford and Hunte 1999) when juvenile, but with growth they become a predator of some importance on lower trophic level species such as flyingfishes and juvenile scombrids. In conducting a stomach contents analysis of longline-caught fish in the western Atlantic, Satoh *et al.* (2004) found that dolphinfish were almost entirely piscivorous with flyingfishes and dolphinfish being the principal prey groups. This suggested to the authors that there was a degree of cannibalism in dolphinfish with large fish feeding on smaller specimens. Oxenford and Hunte (1999) also suggested that there was some degree of cannibalism but that it was not selective.

WAHOO

Fisheries and oceanography

Wahoo is an epipelagic, oceanic species which is frequently solitary but which may form small loose aggregations (Collette and Nauen 1983). Like dolphinfish, wahoo are taken as a by-catch species in the longline fisheries of the western North Atlantic but they are an important source of income and food for the coastal populations of the western Atlantic as well as being a significant target species for recreational fisheries particularly in the USA (Anon. 2016). An Ecological Risk Assessment (ERA) carried out for nine species of small tunas in the North and South Atlantic Oceans, classified wahoo as being at moderate risk from longline fisheries in the North Atlantic and at high risk in the South Atlantic (Lucena-Frédou *et al.* 2016). Much of the data on wahoo landings is cumulated in the ICCAT Task 1 database making it difficult to resolve regional patterns and trends.

Using Bermuda as a proxy for the Sargasso Sea, it is possible to analyze landings patterns in more detail. Wahoo comprise the single most important species in Bermuda's pelagic fishery (Luckhurst and Trott 2000) with annual landings ranging up to 124 t over the past 20 years (Trott, pers. com.). In Bermuda, wahoo landings have a strong seasonal pattern with 60–70% of the annual landings consistently occurring in the second (April–June) and third (July -September) quarters of the year during the period of highest SST (Luckhurst and Trott 2000). Historically, there are Spring (April–May) and Fall (August–September) runs of wahoo in Bermuda with the Spring run typically being the larger. However, these runs vary inter-annually in magnitude and to a lesser degree in timing (Luckhurst and Trott 2000). Wahoo landings are consistently lowest (generally >10 % of annual landings) in the first quarter (January – March) which coincides with the lowest annual SST (about 18°C).

A more recent analysis (2011 – 2015) of quarterly landings of wahoo in Bermuda indicates that the same general pattern of seasonality of landings has been maintained (**Table 2**) with the second and third quarters having the largest landings. However, there are inter-annual changes in the pattern of landings, e.g. in 2011, the fourth quarter had the largest landings (**Table 2**). This may be due to changing oceanographic conditions which can affect the seasonality of occurrence and abundance. Uchiyama and Boggs (2006) postulated that migration related to reproduction may explain some of the seasonality in catch rates of wahoo near the Hawaiian Islands but there are insufficient data to address this possibility as an explanation for the seasonality observed in Bermuda. However, wahoo are known to actively spawn in Bermuda waters during the summer period (Oxenford *et al.* 2003) and it is possible that the seasonal pattern observed may be related to spawning.

Migration

Relatively little is still known about wahoo movement patterns and migration in the western Atlantic and there has been very limited success using conventional tags to define migration patterns (Oxenford *et al.* 2003). In Bermuda, a small scale wahoo tagging program in 1998 succeeded in tagging only 15 wahoo before the program was forced to conclude. However, one of these tagged wahoo was recaptured 10 months later, 64 km away from the point of release (Oxenford *et al.* 2003). It is not possible to know if it remained in Bermuda waters during its time at liberty or returned to the Bermuda Seamount after a seasonal migration. The seasonality of landings described above is another form of evidence suggesting an annual migration pattern in the Sargasso Sea by this important pelagic species.

With the advent of PSAT tagging of wahoo in recent years, important insights into movements and migration patterns have come to light (Luckhurst 2007). PSAT tags deployed on four wahoo in the western North Atlantic indicated that straight-line distances moved (deployment to pop-up) ranged from 162.5 to 1,960 km (Thiesen and Baldwin 2012). The movement patterns of these tagged fish appeared to be largely north-south movements in relation to the Gulf Stream.

Habitat use and feeding

Thiesen and Baldwin (2012) collected data over a total of 198 days from the PSAT tag study described above. Wahoo spent >90% of their time in water less than 200m depth and > 90% of their time was spent in water temperatures ranging from 17.5 to 27.5°C. Three of the four fish made regular dives to depths greater than 200m (Thiesen and Baldwin 2012). All four fish displayed significant differences in mean depth in daylight (50.7m) and during darkness (29.7m).

Franks *et al.* (2008) reported that the wahoo stomach contents which they examined contained pelagic/epipelagic fishes and squid, including evidence of species associated with pelagic *Sargassum*. The dominant fish families in the diet were Carangidae, Coryphaenidae, Scombridae and Exocoetidae. A moderate ontogenetic shift in the diet was observed among three size classes of wahoo. The data suggested that small wahoo fed on smaller, presumably easier-to-catch flying fishes and small jacks, while larger wahoo appeared to feed mainly on larger prey such as *Caranx crysos*, dolphinfish and scombrids (Franks *et al.* 2008). Satoh *et al.* (2004) conducted stomach contents analysis of longline-caught fish in the western Atlantic and found that wahoo were largely piscivorous with cephalopods being the second most important prey group.

Luckhurst (2015) indicated that wahoo are an important component of the pelagic ecosystem in a preliminary pelagic food web of the Sargasso Sea. They were placed at a trophic position (TP) of (4.4) similar to dolphinfish (TP = 4.3) based on a stable isotope analysis (Luckhurst 2015) and they were shown to have a number of links in this food web similar to dolphinfish.

Conclusions

The results presented here make a contribution towards greater understanding of the pelagic ecosystem of the western Atlantic including fisheries landings data from Bermuda in the Sargasso Sea which demonstrate aspects of seasonality related to migration patterns. Both dolphinfish and wahoo play an important role in this ecosystem and, as they are by-catch species in ICCAT longline fisheries, a greater understanding of their biology and ecology is desirable to evaluate the impact of these fisheries on the respective populations. The quantification of dolphinfish trophic interactions in the northwestern Atlantic near the northern extent of their geographical range demonstrates that there is food competition between dolphinfish and commercially important tuna species such as yellowfin and albacore tuna and that these three species occupy equivalent trophic positions (Teffer *et al.* 2015). In a preliminary food web of the Sargasso Sea, Luckhurst (2015) also found that dolphinfish, yellowfin and albacore (as well as wahoo) occupied similar trophic positions. These findings are relevant for ecosystem-based fisheries management of the pelagic guild of fishes subject to fishing pressure in the context of changing stock abundances and the impact of ecological and climate changes.

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Table 1. Reported landings (kg) by quarter of dolphinfish by the Bermuda commercial line fishery from 2011-2015.

Year	***Quarter***	***Landings (Kg)***	***% of Annual total***
2015	1st	348.6	7.6%
	2nd	2563.5	56.2%
	3rd	1124.2	24.6%
	4th	527.2	11.6%
	Total	4563.5	
2014	1st	187.2	4.3%
	2nd	1678.6	38.1%
	3rd	1523.6	34.6%
	4th	1013.1	23.0%
	Total	4402.5	
2013	1st	169.5	5.0%
	2nd	1730.7	50.7%
	3rd	932.0	27.3%
	4th	582.0	17.0%
	Total	3414.3	
2012	1st	326.8	9.3%
	2nd	809.6	23.1%
	3rd	1428.4	40.8%
	4th	935.6	26.7%
	Total	3500.5	
2011	1st	85.2	2.1%
	2nd	514.1	12.6%
	3rd	1398.9	34.3%
	4th	2074.8	50.9%
	Total	**4073.0**	

Table 2. Reported landings (kg) by quarter of wahoo by the Bermuda commercial line fishery from 2011-2015.

Year	***Quarter***	***Landings (Kg)***	***% of Annual total***
2015	1st	9149.1	10.6%
	2nd	38228.5	44.5%
	3rd	23602.9	27.5%
	4th	14959.7	17.4%
	Total	85940.2	
2014	1st	8527.2	11.2%
	2nd	41882.1	54.8%
	3rd	19116.5	25.0%
	4th	6883.0	9.0%
	Total	76408.9	
2013	1st	7543.5	10.1%
	2nd	34516.8	46.0%
	3rd	20250.2	27.0%
	4th	12650.5	16.9%
	Total	74961.0	
2012	1st	6331.8	7.3%
	2nd	30654.6	35.4%
	3rd	26146.4	30.2%
	4th	23437.9	27.1%
	Total	86570.7	
2011	1st	9704.9	9.9%
	2nd	26951.0	27.5%
	3rd	28601.5	29.2%
	4th	32654.6	33.4%
	Total	**97912.1**	

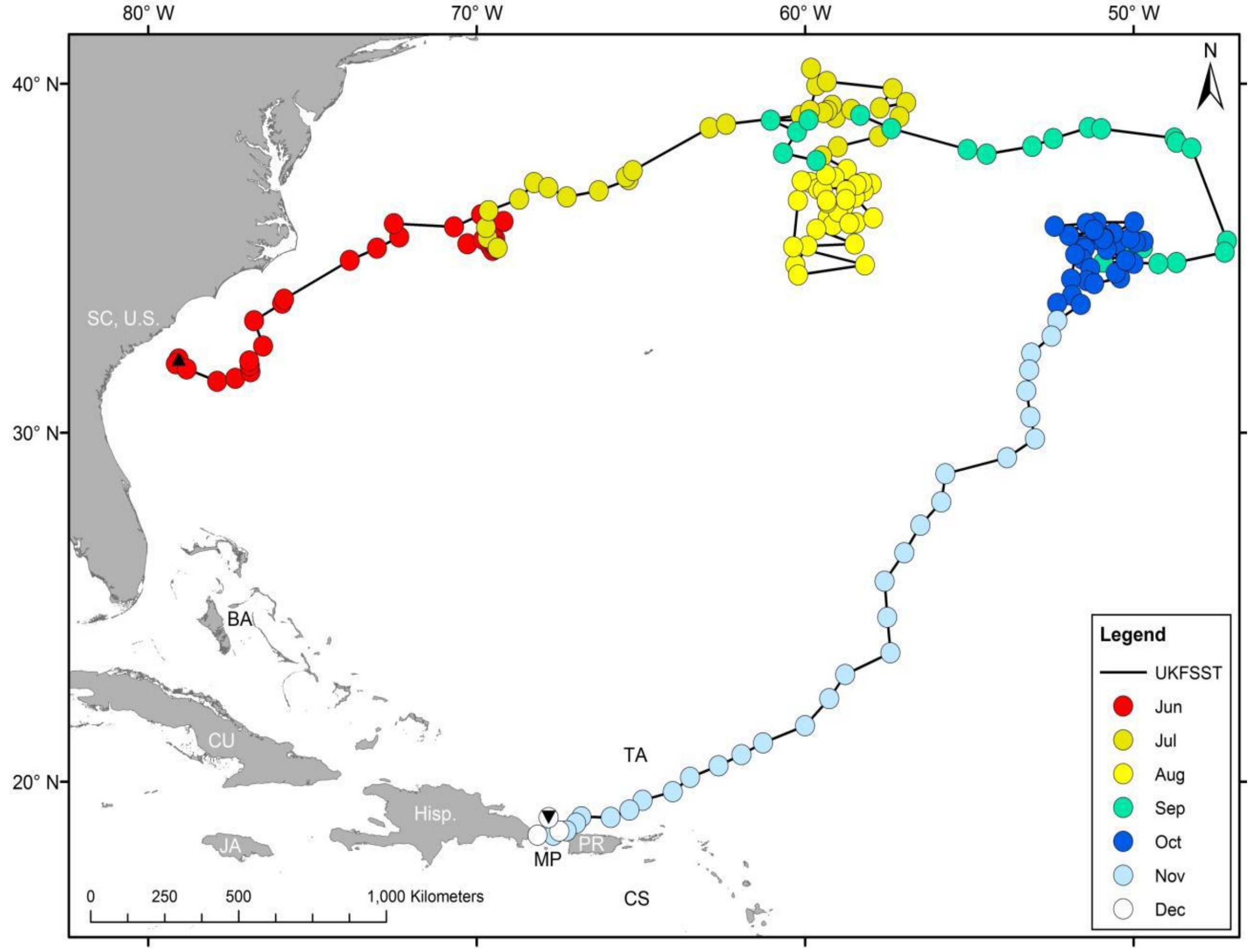

Figure 1. Circumnavigation of the Sargasso Sea by a PSAT-tagged dolphinfish in 2014. Figure from Hammond (2015) Dolphinfish Research Program Newsletter, April 2015. Figure produced by Wessely Merten, Dolphinfish Research Program, Cooperative Science Services LLC, 961 Anchor Rd. Charleston, SC 29412, USA.

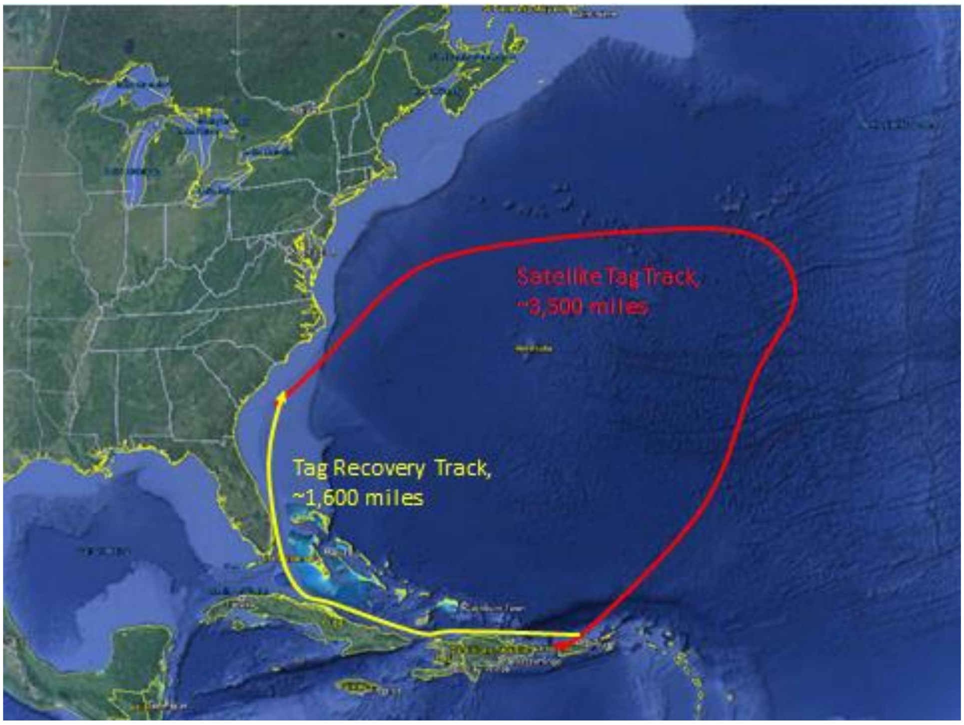

Figure 2. Combining the track of the PSAT-tagged dolphinfish in Figure 1 with that of a conventional tag recovery movement indicates a probable migratory pathway which covers a distance of about 8,000 Km. Figure from Hammond (2015), Dolphinfish Research Program Newsletter, April 2015.

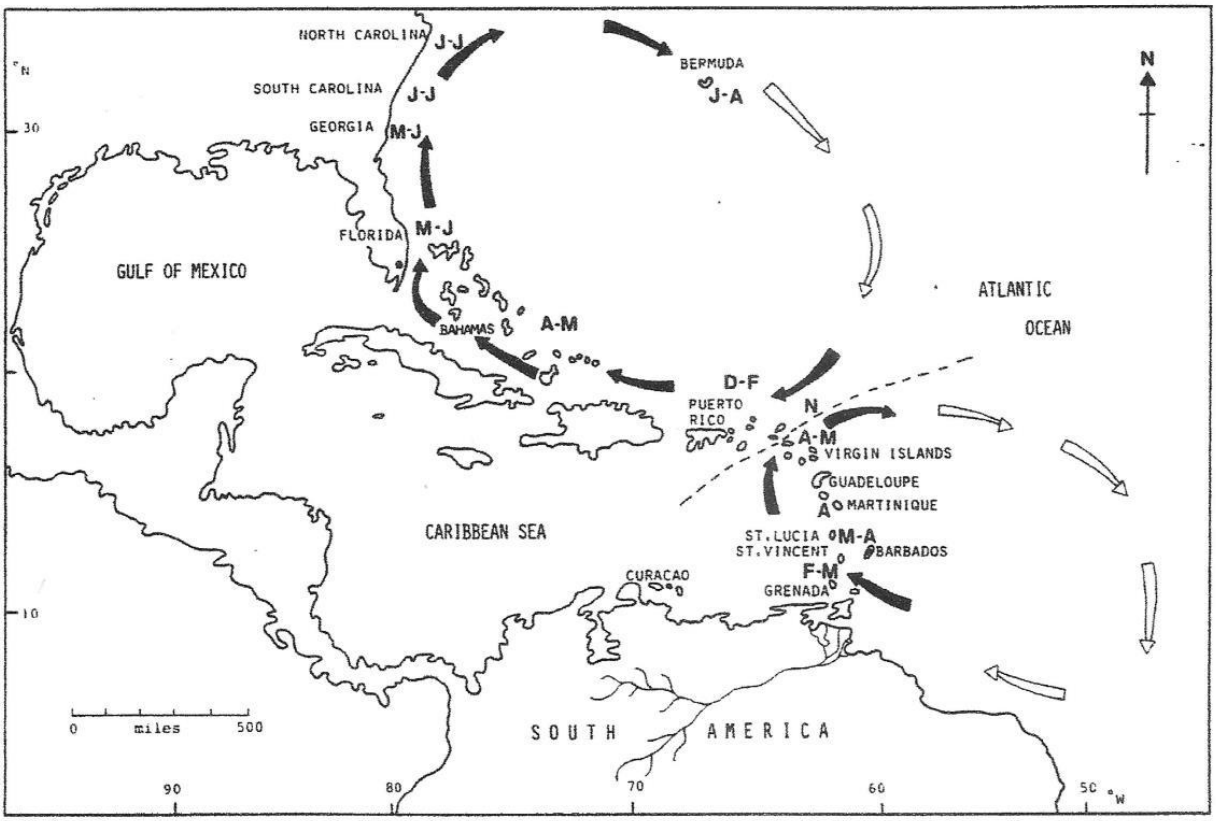

Figure 3. Proposed stock structure with migration pathways of the dolphin, *Coryphaena hippurus*, in the western central Atlantic (from Oxenford and Hunte 1986).