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NOTE

COLLECTION OF LARVAL BLUEFIN TUNA (*THUNNUS THYNNUS*) OUTSIDE DOCUMENTED WESTERN ATLANTIC SPAWNING GROUNDS

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ABSTRACT

Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758), are highly migratory and capable of traversing large distances throughout the North Atlantic Ocean. However, the majority of spawning activity has only been reported from the Mediterranean Sea and Gulf of Mexico. In early April 2009, low numbers of very small larval bluefin tuna were collected within and south of the Yucatán Channel, and along the western boundary of the Loop Current, northeast of Campeche Bank. In situ current velocity measurements showed that these larvae were collected in moderate to strong northward flow regimes, suggesting that they were spawned outside of the Gulf of Mexico. Here we describe the location and oceanographic environment of these larval bluefin tuna collections, and compare the 2009 data with some historical collections in the area.

Despite a wide-ranging distribution throughout the Atlantic, the vast majority of spawning activity for Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758), has been recorded in subtropical waters of the Mediterranean Sea and Gulf of Mexico (Richards 1976, Scott et al. 1993). In the western North Atlantic, adult fish generally forage in cool waters off the northern United States and Canada during the summer and migrate southward to the Gulf of Mexico between winter and early spring (Stokesbury et al. 2004, Block et al. 2005), before spawning between April and June. However, tagging data suggest that not all sexually mature fish make this migration annually (Lutcavage et al. 1999, Block et al. 2001, Galuardi et al. 2010). This may be because bluefin tuna do not spawn every year, or that other spawning grounds exist elsewhere (McGowan and Richards 1989, Lutcavage et al. 1999, Wilson et al. 2005).

Spawning is generally initiated by water temperatures of around 24 °C, and adult bluefin tuna are physiologically limited to waters of < ~30 °C (Blank et al. 2004). Some parts of the western Caribbean therefore may be suitable for bluefin tuna spawning during early spring, before the Gulf of Mexico warms to a sufficient temperature. However, although some error is associated with positions of tagged animals, bluefin tuna tagged in the western North Atlantic generally enter the Gulf of Mexico through the Straits of Florida (Block et al. 2005, Galuardi et al. 2010), and do not commonly appear to travel to areas farther south.

An annual spring plankton survey has been conducted across the United States Exclusive Economic Zone in the northern Gulf of Mexico since 1977 (Scott et al. 1993). Larval bluefin tuna abundances from this survey are formulated into an index, which is used to "tune," or calibrate, the adult stock assessments (Ingram et al. 2010). However, sampling in the southern Gulf of Mexico and western Caribbean historically has been sparse, and thus the occurrence and extent of spawning activity outside the northern Gulf of Mexico is not currently well known. Here we describe the collection of a small number of larval bluefin tuna outside of generally accepted spawning grounds. Due to the dynamic oceanography of the western Caribbean and Gulf of Mexico, the origin of these larvae is not entirely clear. However, confirmation of the presence of bluefin tuna spawning activity outside of the currently known Gulf of Mexico spawning grounds is significant for understanding the ecology of this species and important for effective stock assessment and management.

Methods

In early April 2009, as part of a joint NOAA Fisheries/Instituto Nacional de Pesca (INAPESCA) exploratory cruise, five larval bluefin tuna were collected within and south of the Yucatán Channel, and along the western boundary of the Loop Current, northeast of Campeche Bank, between 3 and 8 April, 2009 (Fig. 1). Forty sampling stations in the region were selected using satellite sea surface temperature imagery and were situated across the western front of the Loop Current. Temperature data were obtained from the infrared sensors on the NOAA (*NOAA 15, 16, 17, 18*), NASA (*Aqua* and *Terra*), and European (*MetOp-A*) satellites, downloaded from the NOAA Comprehensive Large Array-data Stewardship System (CLASS), and the University of South Florida's Institute for Marine Remote Sensing. Plankton collections were made from the NOAA ship RV Gordon Gunter using bongo and neuston nets. Bongo nets were fitted with 333 μm mesh on two 61-cm diam round frames, and towed obliquely to 200 m depth, or to within 10 m of the seafloor, and neuston nets were fitted with 0.95 mm mesh on a 1 × 2 m frame, and were towed at the surface, as described in Scott et al. (1993). Larval fish from the right bongo net and the neuston net were identified to the lowest possible taxa at the Southeast Fisheries Science Center in Miami, Florida (SEFSC).

To evaluate the oceanographic environment in which the larvae were collected, upper-ocean currents were continuously monitored throughout the survey using a 75 kHz hull-mounted acoustic Doppler current profiler (SADCP). SADCP data were processed using the University of Hawaii's Common Ocean Data Access System (CODAS3) software providing 5-min average current velocity profiles. In addition, sea surface temperature data were obtained from the satellites listed above for dates of larval bluefin tuna collection (3–8 April, 2009), and were rectified and calibrated using buoy data from National Data Buoy Center, and flowthrough temperature data recorded on the ship. A warm water composite was then created, using satellite passes completed between 00:00 and 15:00 hrs (GMT), to reduce the effects of cloud cover. Image brightness and contrast were optimized to enable visualization of water masses and frontal boundaries.

Identifications of larvae provisionally identified as bluefin tuna were verified using genetic techniques. Briefly, the Polymerase Chain Reaction (PCR) was used to amplify the ATCO region of the mitochondrial DNA genome using primers designed from an alignment of ATCO sequences from Chow et al. (2003) plus homologous regions gathered from GenBank. This primer set allowed for more consistent amplifications of a 649 basepair product from a broader phylogenetic spectrum of fish taxa but maintained an appreciable amount of among group variation (J Quattro, unpubl data):

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ATCOF1-1093: 5′ — CCC AAC ACC AAC ATC CCG ATG ACT — 3′
ATCOR1-1094: 5′ — GGG GTC AAC TAT GTG GTA TGC GTG — 3′
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Sequences have been deposited in the GenBank sequence repository (HQ846658-HQ846662). We used the Characteristic Attribute Organization System (CAOS; Sarkar et al. 2002, Kelly et al. 2007) algorithm to extract diagnostic characters (e.g., individual species-specific base substitutions) for all tuna sequences presented in Chow et al. (2003). These diagnostic characters were used to produce descriptive rules sets for all tuna species and the five

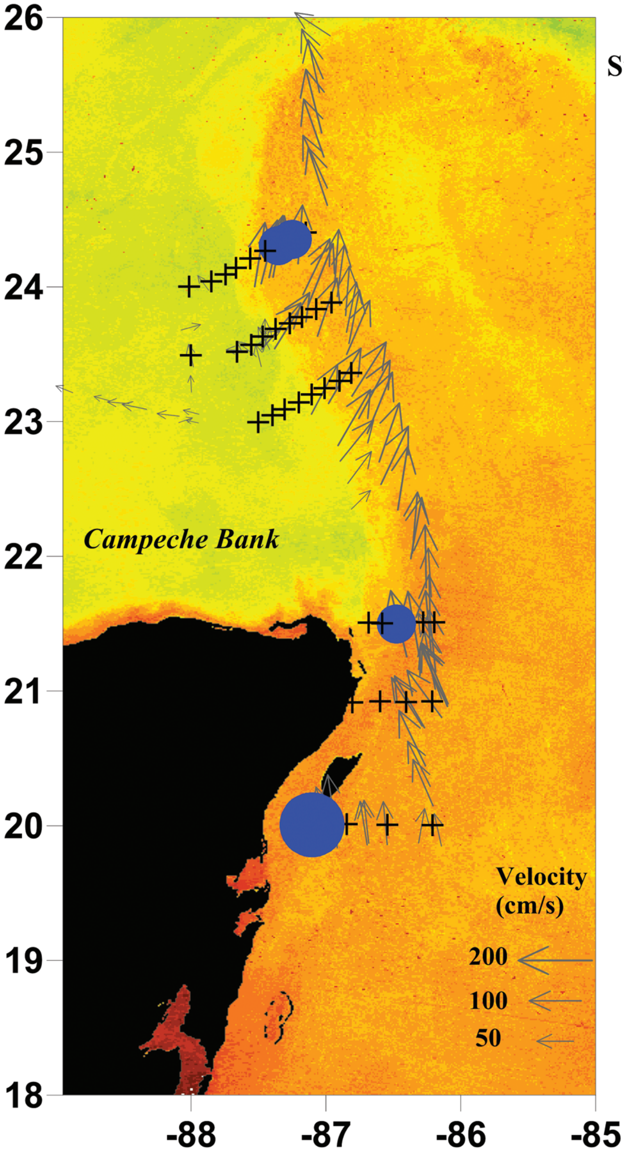

Figure 1. Location of larval bluefin tuna collected from 3 to 8 April, 2009. Current vectors from shipboard ADCP measurements are also shown, as are six-day composite sea surface temperatures from satellite imagery (3–8 April, 2009). The black line on the temperature scale denotes 24 °C.

putative bluefin tuna sequences were subsequently aligned to this rules dataset. To compare our collection of five individuals to previous collections, data on larval collections in the vicinity of the Yucatán Peninsula were compiled from historic databases and via reference to the literature.

Table 1. Station locations and sizes of larval bluefin tuna collected on April 2009 research cruise.

Longitude	Latitude	Date	Bluefin tuna larval length (mm SL)	Extracted sea surface temperature (°C)
−87.10	20.01	3 April, 2009	1.58	26.3
−87.10	20.01	3 April, 2009	3.64	26.3
−86.48	21.50	4 April, 2009	2.12	25.2
−87.25	24.35	8 April, 2009	2.35	25.1
−87.35	24.31	8 April, 2009	1.92	25.5

Results

All five putative bluefin tuna individuals were separately placed in the most diagnosable cluster of individuals, which contained all Atlantic bluefin tuna assayed by Chow et al. (2003) to the exclusion of all other *Thunnus* included in their analysis. A combination of the remotely sensed and shipboard-collected oceanographic data showed that bluefin tuna larvae were collected in regions of moderate to strong northward flow, on the western boundary of the Loop Current (Fig.1). Extracted sea surface temperatures at catch locations were between 25.1 and 26.3 °C. The larvae collected were very small, between 1.58 and 3.64 mm SL (Table 1), and although size-at-age is highly variable for larval bluefin tuna, this would correspond to larvae of ~3–7 d in age (Brothers et al. 1983, Scott et al. 1993).

Data from other historic sampling efforts in the region are sparse, but some collections during spring and summer were made by United States vessels in 1977, 1978, and 1981, and by Mexican vessels in 1982 and 1983 (Olvera Limas et al. 1988). These cruises collected small numbers of bluefin tuna east and north of the Yucatán Peninsula (Fig. 2).

Discussion

Although limited data were available, they confirm that at least some bluefin tuna spawning takes place outside of the Gulf of Mexico. Given the small size of the larvae collected, bluefin tuna were likely to have been spawned in the Western Caribbean. Whether this spawning activity was a result of a small number of individuals from the western northern Atlantic population, or a remnant of some past sub-population is not clear. A previous subpopulation off Brazil supported a brief fishery; however, this collapsed in the 1950–60s (Mather et al. 1995, Fonteneau 2009). Mature adult bluefin tuna have previously been recorded in low numbers in the northern Caribbean, especially the Windward Passage east of Cuba, but sampling in the Western Caribbean historically has been scarce (Mather et al. 1995).

Larval bluefin tuna have previously been collected in the Florida Straits and Gulf Stream regions (McGowan and Richards 1989), and in the Yucatán Channel (Olvera Limas et al. 1988). However, the present study represents the first (to our knowledge) record of genetically confirmed larval bluefin tuna that were almost definitely spawned outside of the Gulf of Mexico. The larvae collected were within a northward flowing current, and had likely been advected some distance from their spawning location. In addition, sea surface temperatures at collection locations were well within assumed favorable ranges for spawning (Muhling et al. 2010).

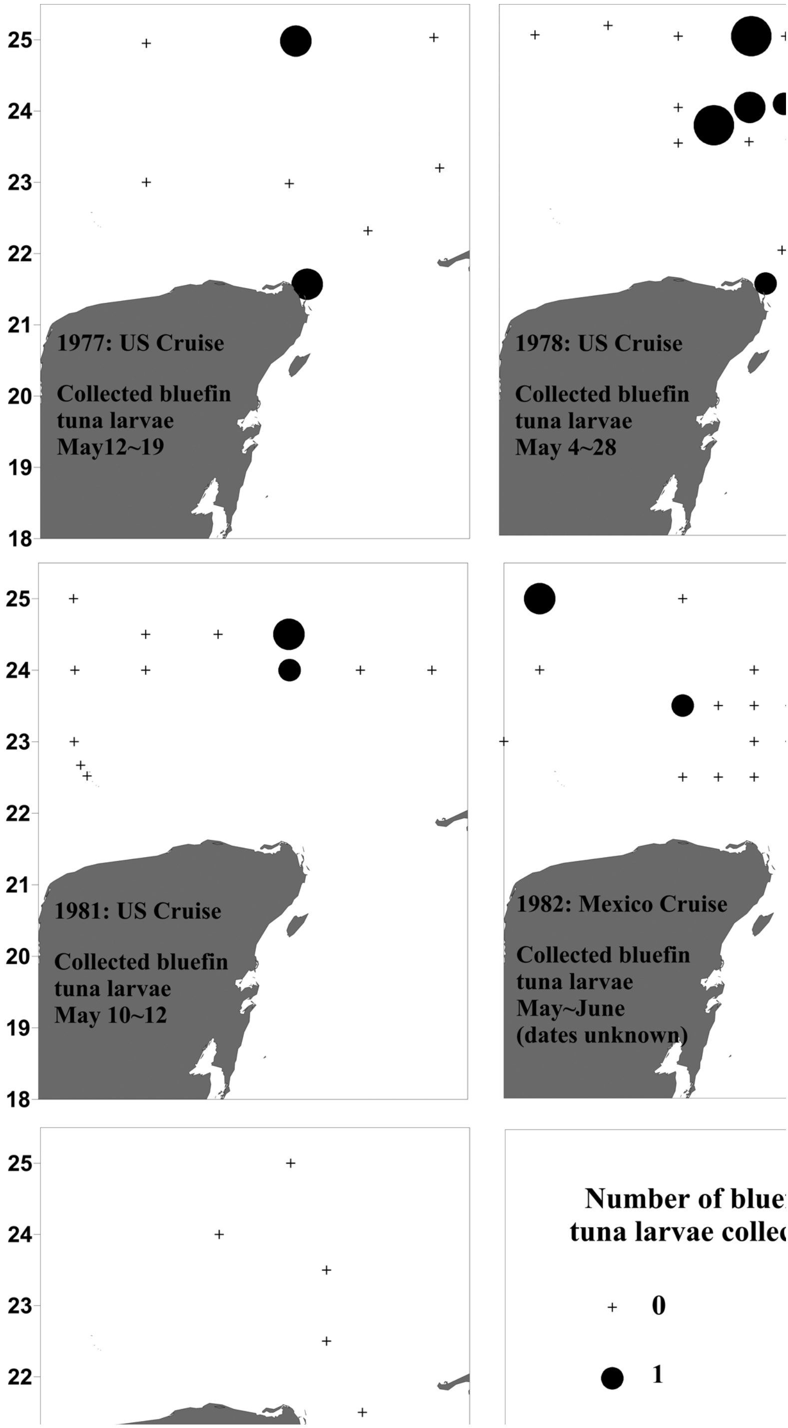

Figure 2: Distribution of larval bluefin tuna in the Yucatán Channel and Campeche Bank regions from historical cruises completed between 1977 and 1983. 1982 and 1983 cruise data are reproduced from Olvera-Limas et al. (1988).

Larval abundances recorded here were low, with only a few bluefin tuna larvae collected per plankton tow. Abundances from the annual NOAA-NMFS cruise in the northern Gulf of Mexico are similarly sparse and patchy (Muhling et al. 2010), although this may be due in part to gear selectivity (NOAA-NMFS, unpubl data). Further sampling is required to quantify the contribution of Caribbean spawning to population recruitment and to assess the effects of this on the accuracy of the larval abundance index currently in use (Ingram et al. 2010).

Historically, bluefin tuna stocks have been heavily exploited, and they are currently considered to be undergoing overfishing (McAllister and Caruthers 2007). If spawning activity outside of the Gulf of Mexico is significant, this is likely to be an important consideration for understanding reproductive biology and managing this species effectively. An extended survey is planned for 2011 in the western Caribbean to investigate the extent of spawning activity outside of the Gulf of Mexico and to evaluate current assumptions that all western Atlantic bluefin tuna constitute one spawning stock.

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