MOVEMENTS OF ATLANTIC BLUEFIN TUNA FROM THE GULF OF ST. LAWRENCE, CANADA TO THEIR SPAWNING GROUNDS

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SUMMARY

Pop-up satellite archival tags were attached to Atlantic bluefin tuna in the southern Gulf of St. Lawrence in September and October of 2007 and 2008, and datasets were obtained from 14 tagged fish of durations ranging from 45-232 days. Eight of the tagged bluefin entered the Gulf of Mexico spawning ground between mid-January and late-March. These bluefin showed occupation of known spawning areas along the slope waters in the western and eastern Gulf of Mexico. A single bluefin entered the Mediterranean Sea in late May indicating a potential connection between the Canadian foraging ground in the Gulf of St. Lawrence and the eastern spawning ground. Five of these bluefin did not visit the Gulf of Mexico or Mediterranean Sea spawning grounds: on two fish the tags popped-up prior to the beginning of the breeding season; one bluefin was located in the central Atlantic Ocean, and two inhabited waters to the northeast of the Bahamas during the breeding season. The latter three fish were some of the smallest in our dataset (244 to 255 cm CFL when tagged).

KEYWORDS

Bluefin tuna, Thunnus thynnus, electronic tagging, Gulf of St. Lawrence, spawning grounds

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1. Introduction

Atlantic bluefin tuna (*Thunnus thynnus*) aggregate to feed in waters of the southern Gulf of St. Lawrence (GSL) from July through November. During this time, they are targeted by a commercial rod and reel fishery that caught approximately 227.6 tonnes in 2009. Most of these fish are of spawning size with over 75% of landed bluefin > 250 cm (CFL) (Neilson et al. 2007). Bluefin catch per unit effort (CPUE) in the southern GSL has increased in recent years while declining at other inshore foraging grounds in the Western Atlantic Ocean (Neilson et al. 2007, Paul et al. 2008, ICCAT 2008, 2009). This trend may result from ontogenetic niche expansion by the large cohort of medium sized bluefin observed in US coastal waters during the late 1990s and early 2000s (Block et al. unpublished data and McAllister et al. 2008). As bluefin increase in size they tolerate colder ambient temperatures and thereby expand their geographic range into cooler northern latitudes. Alternative hypotheses include a warming of ocean temperatures associated with global climate change and a decline in the forage base on other feeding grounds (McAllister et al. 2008).

Atlantic bluefin are managed as two populations: a western population that spawns in the Gulf of Mexico (GoM) and an eastern population that spawns in several regions in the Mediterranean Sea. Both spawning populations are significantly overexploited and in decline (ICCAT 2008, 2009). Tagging, genetics and microconstituent analyses of otoliths indicate that the two populations mix when foraging along the eastern seaboard of North America, with a significant component of adolescent bluefin off North Carolina being of eastern origin (Block et al. 2005, Carlsson et al. 2007, Boustany et al. 2008, Rooker et al. 2008, Schloesser et al. 2010). The bluefin inhabiting the southern GSL are hypothesized to be almost exclusively of western origin (Rooker et al. 2008, Schloesser et al. 2010). Natal homing is thought to maintain the population structure within Atlantic bluefin tuna populations (Block et al. 2005, Teo et al. 2007, Rooker et al. 2008). Additional spawning activity outside the two major spawning grounds has also been proposed (Lutcavage et al. 1999, Block et al. 2001, Boustany et al. 2008).

To better understand the relationship between the GSL population and other foraging populations and to increase the sample size of bluefin showing visitation to the GoM, we undertook directed efforts to tag large bluefin in this region.

2. Methods

**Tagging.** We attached 29 pop-up satellite archival tags (Model: MK10, Wildlife Computers, USA) to Atlantic bluefin tuna in the southern GSL in 2007 (n=18) and 2008 (n=11). One tagging vessel and several fishing vessels, operating out of Port Hood, Nova Scotia, were used to deploy the tags off the southwestern coast of Cape Breton Island (Fig. 1). The fish were caught on rod and reel, and in all cases tuna were tagged onboard the designated tagging boat, measured, and released. The satellite tags were attached externally at the base of the second dorsal fins with a titanium dart and monofilament leader that penetrated to a depth of 14 cm (Block et al. 1998a). To improve tag retention, one or two monofilament loops were used to secure the tags (with nylon darts) to the bluefin’s body. The tags were programmed to detach and transmit daily summaries of light-level, depth and external temperature information after periods of 240 to 300 days (Table 1). Also included in this study are data from an archival tag (Model LTD2310, Lotek Wireless, Canada) implanted in a 191 cm bluefin tuna off North Carolina on January 9, 2004 and recovered from a Japanese fish market (recapture date and location unknown). This fish visited the southern GSL in September and October of 2004, and the tag provided a
1-min resolution time series record of light-level, depth and external temperature data for that period. This tag had been surgically implanted into the peritoneal cavity of the fish using procedures previously described (Block et al. 1998b).

**Analysis.** Light-level data from the tags were processed using software provided by the tag manufacturer to provide daily longitude estimates based on the time of local noon or midnight. Daily latitude estimates were calculated by matching tag SSTs with remotely sensed SSTs using a modified algorithm developed in Teo et al. (2004).

**3. Results and Discussion**

Of the 29 pop-up satellite archival tags deployed in the southern GSL in 2007 and 2008, datasets were obtained from 14 tags of durations 45-232 days (Table 1). Shorter data sets are not discussed in this paper. Large fish put significant drag forces on pop-up satellite archival tags, particularly during periods of deep diving on entry and exit from the GoM, and in all cases the tags reported prematurely (Table 1). One tag was recovered after premature release in Bahamian waters, and a 1-min resolution time series record of light-level, depth and external temperature data was retrieved. Bluefin tagged in the first year occupied waters of the western Atlantic Ocean for the entire period that their tags remained attached (Fig. 2a). They ranged as far south as the GoM and occupied offshore habitats but did not cross the 45°W meridian separating eastern and western stocks. Bluefin tagged in the second year occupied a similar range remaining in the western Atlantic, with the exception of one fish that migrated from the Gulf of St. Lawrence release area to the Mediterranean Sea (Fig 2b). SSTs recorded on the tags ranged from 6.1-27.9°C (Fig. 3).

**Gulf of St. Lawrence.** Habitats occupied by bluefin in the southern GSL spatially overlap with traditional Atlantic herring and Atlantic mackerel fishing grounds (Fig. 1). SSTs recorded by the tags in the GSL ranged from 8.2-13.2°C and averaged 11.0°C on their day of departure (Fig. 3). Two types of dive behavior were evident in the high resolution archival data recovered from a bluefin tagged in North Carolina that visited the southern GSL. In the first pattern (Fig. 4a), the bluefin spent daylight hours moving between the bottom of the warm surface layer (WSL) and the cold intermediate layer (CIL) and the night in the WSL. This is consistent with daytime foraging on Atlantic herring, a species that ascends into the WSL at night and descends into the CIL during the day (Darbyson et al. 2003). In the second pattern (Fig. 4b), the bluefin remained in the WSL throughout the day and night. Atlantic mackerel are not known to vertically migrate and are thermally bound to the WSL (Darbyson et al. 2003). Fishermen report that bluefin feed on Atlantic herring deep in the water column on “The Ridge” in late summer and then switch to Atlantic mackerel inhabiting surface waters along the coasts of Cape Breton and Prince Edward Islands in the fall (Fig. 1). Body temperatures generally increased during the daytime and declined at night. Thermal excesses (body temperature – ambient water temperature) of up to 12.4°C were recorded in bluefin inhabiting the southern GSL (Fig. 4b).

**Gulf of Mexico.** Eight of the tagged bluefin (mean curved fork length = 277 cm) subsequently entered the GoM spawning ground between mid-January and late-March (Fig. 5a, b). SSTs recorded on the tags ranged from 20.7-27.9°C while in the GoM (Fig. 3). Bluefin that were headed to the GoM occupied warmer SSTs after departing the southern GSL than the four bluefin that occupied waters of the central Atlantic Ocean and to the northeast of the Bahamas during the breeding season (Fig. 6). The three fish tagged in the first year that visited the GoM spawning grounds all occupied waters of the western GoM
(e.g. Fig. 5a) that have been well established as GoM spawning regions (Block et al. 2005, Teo et al. 2007a,b, Teo and Block 2010). In the second year, one fish occupied the western GoM, two fish occupied the eastern GoM (e.g. Fig. 5b) and one fish visited both areas. Four tags remained attached until the fish departed the GoM in late-May and early June (Table 1). Those four fish had GoM residency periods of 62-137 days.

Mediterranean Sea. One of the tagged bluefin entered the Mediterranean Sea spawning ground (Fig. 5d). After leaving the southern GSL, the fish initially moved to North Carolina waters and then spent the winter months in waters off the Bahamas. Departing Bahaman waters in mid-February, the bluefin entered the Mediterranean Sea in late May, and its tag popped up in mid June in the vicinity of the known spawning grounds between Sicily and Sardinia. While in the Mediterranean Sea, the fish inhabited surface waters ranging from 17.9-21.7°C (Fig. 3).

Atlantic Ocean. When migrating southwards from Canadian waters, some bluefin took offshore routes while others followed the shelf break (Fig. 5a, b). Three fish spent extended periods on foraging grounds off North Carolina from mid-November to early February in SSTs between 14.4-24.6°C. Ten of the bluefin visited Bahaman waters between early December and late April where SSTs ranged from 20.9-26.4°C.

Five fish did not visit the GoM or Mediterranean Sea spawning grounds. Two of their tags popped-up prior to the beginning of the breeding season. Of the remaining three fish, one bluefin (246 cm CFL when tagged) was located in the central Atlantic Ocean when its tag detached in early April and two (244 and 255 cm CFL when tagged) inhabited waters to the northeast of the Bahamas prior to tag detachment in May/June (Fig. 5c). These were some of the smallest fish in our dataset and may not yet have reached the size of western maturity for Gulf of Mexico fish. Alternatively, they could have spawned in waters to the northeast of the Bahamas or entered the GoM or Mediterranean Sea spawning grounds after their tags had detached. SSTs occupied by bluefin in the northern Bahamas during the western spawning period were similar to those occupied by bluefin on their GoM spawning grounds (Fig. 3).

4. Acknowledgements

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5. References


Neilson JD, Paul SD, Ortiz M (2007) Indices of stock status obtained from the Canadian bluefin tuna fishery. ICCAT Collective Volume of Scientific Papers 60:976-1000


Schloesser RW, Neilson JD, Secor DH, Rooker JR (2010) Natal origin of Atlantic bluefin tuna (Thunnus thynnus) from Canadian waters based on otolith δ13C and δ18O. Canadian Journal of Fisheries and Aquatic Sciences 67:563-569


Teo SLH, Block BA (2010) Comparative influence of ocean conditions on yellowfin and Atlantic bluefin tuna catch from longlines in the Gulf of Mexico. PLoS ONE 5: e10756. doi:10.1371/journal.pone.0010756
Table 1. Deployment and pop-up metadata from 14 Atlantic bluefin tuna tagged in the southern GSL in 2007 and 2008.

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Figure 1. Traditional fishing areas for Atlantic bluefin tuna, Atlantic mackerel and Atlantic herring in the southern GSL (Jacques Whitford Environment Limited 2001). All tagging was done in the vicinity of Port Hood.
Figure 2. Pooled geolocations from the a) 2007 and b) 2008 tag deployments. Tagging (squares) and pop-up locations (triangles) are also shown.
Figure 3. Pooled daily SST records from 14 bluefin tuna tagged in the southern GSL.
Figure 4. Depth (black), ambient temperature (blue) and body temperature (red) from an archival tag implanted internally in a bluefin tuna off North Carolina showing putative foraging behavior in the southern GSL on a) Atlantic herring and b) Atlantic mackerel. Grey shaded area indicates night.
Figure 5. Bluefin tuna that a, b) moved to the GoM spawning ground; c) did not visit the GoM or Mediterranean Sea spawning grounds; and d) moved to the Mediterranean Sea spawning ground. Tagging (squares) and pop-up (triangles) locations are also shown.
Figure 6. Mean weekly SST (± SE) of eight bluefin that visited the GoM during the spawning season (red) versus four bluefin that occupied waters of the central Atlantic Ocean and to the northeast of the Bahamas and during the breeding season (blue).