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Movement patterns of summer flounder near an artificial reef: Effects of fish size and environmental cues

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ABSTRACT

Summer flounder have a well-documented seasonal migration pattern, but the influences of environmental conditions on small-scale (100 s of meters) movements are not well understood. We used passive acoustic telemetry to monitor the distribution and movements of summer flounder at an artificial reef during their summer residency in Chesapeake Bay. Larger fish (>425 mm) primarily occupied deeper waters in close proximity to the reef, whereas smaller fish occupied shallower waters on the periphery of the reef. Mean residency was 54 days, but fish were observed leaving the reef for a brief period during a strong storm. Residency at the reef was sufficient to relate fish (n = 42) movements to a spectrum of tidal stages, diurnal period, lunar phases, and temperatures using a generalized linear mixed model. A repeated measures model was used to account for the autocorrelation inherent in observations of individuals through time. Smaller fish were more likely to move than larger fish, especially during the quarter moons. Movement relative to lunar phase was most apparent at night. Movements peaked at 24 °C and were least likely at the lowest (<22 °C) and highest (>27 °C) temperatures. We hypothesize that while resident at structured habitats, summer flounder move in response to their physiological demands and the behavior of their prey.

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1. Introduction

Understanding habitat use and behavior of individual fish is becoming increasingly important as researchers recognize the connection between these characteristics and a population's vital rates (e.g., recruitment, mortality, and emigration; Sutherland, 1996). Linkages between habitat, fish movements, and population dynamics have been investigated using individual-based models, but such models often suffer from a lack of information on the behavior of individual fish relative to environmental conditions (Lomnicki, 1999; Humston et al., 2004; Hayes et al., 2009). Artificial reefs are ideal locations to study such behaviors because many species are attracted to these complex habitats and can remain resident for long durations (Lowe and Bray, 2006; Topping and Szedlmayer, 2011). Furthermore, relatively few studies have observed fish behavior in these habitats even though they are commonly used as fisheries management tools throughout North America (Baine, 2001). We focused our study on the behavior of summer flounder (*Paralichthys dentatus*) near an artificial reef in Chesapeake Bay.

Summer flounder exhibit a seasonal migration pattern during which they use both offshore and nearshore, coastal habitats (Morse, 1981; Kraus and Musick, 2001). They support a popular recreational fishery and are one of the most targeted and commercially valuable fish species on the US Atlantic coast (Terceiro, 2011). The recreational fishery targets adult summer flounder in the spring and summer when they migrate into coastal and estuarine waters to feed, grow, and prepare for spawning. In Chesapeake Bay, adult and juvenile summer flounder inhabit the estuary from March through November (Desfosse, 1995; Fabrizio et al., 2007; Latour et al., 2008). Adult fish migrate towards the continental shelf break from October through December to spawn off the coast of New Jersey, Virginia, North Carolina, or south of Cape Hatteras (Desfosse, 1995; Kraus and Musick, 2001).

Although the seasonal migration of summer flounder is well documented, their behavior while resident in inshore waters is not as well understood. Conventional mark-recapture studies have indicated that summer flounder may use structured habitats in coastal areas for up to 150 days (Lucy and Bain, 2007), but these data do not provide any indication of the behavior of these fish during residency. In contrast, acoustic telemetry provides a mean to continuously observe fish behavior and relate these behaviors to environmental conditions (Childs et al., 2008).

In recent years, acoustic telemetry studies have provided information on summer flounder habitat preferences, site fidelity, and behavior (Szedlmayer and Able, 1993; Sackett et al., 2007, 2008;

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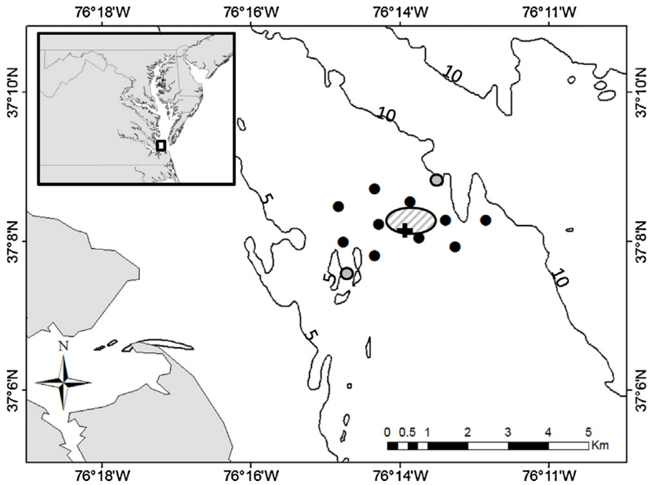

Fig. 1. Location of Back River artificial reef (hashed ellipse) and acoustic receivers (circles) in lower Chesapeake Bay (inset). Also depicted are two receivers lost during the study (gray circles), the release location (+), and water depth in meters (contour lines).

Capossela et al., 2013). These studies have shown that adult summer flounder remain resident in coastal bays and lagoons from 40 to 130 days (Sackett et al., 2007; Capossela et al., 2013), and prefer habitats with relatively high temperatures (>19 °C) and dissolved oxygen levels (Szedlmayer and Able, 1993; Sackett et al., 2008). Although suggestive, previous studies were designed primarily to observe dispersal patterns, occupancy within large (10 s of km^2) regions, and individual behaviors over brief time periods (24–48 h.). As a result, these studies do not provide insight into the small-scale (100 s of meters) movements of summer flounder during their inshore residency. We were interested in how environmental conditions influence the small-scale movements of these fish while they resided in their summer feeding habitats.

In this study, we use passive acoustic telemetry to observe the distribution and behavior of summer flounder near an artificial reef in lower Chesapeake Bay. We document the length of time that fish remained resident at the reef and use a generalized linear model to relate fish behavior to environmental conditions. Observing the behavior of these fish while resident at the artificial reef provides further understanding of how they utilize these types of habitats.

2. Methods

2.1. Study site

Our study site was Back River artificial reef in lower Chesapeake Bay, where summer flounder are present throughout the summer (J. Lucy, personal observation). The reef is 3 nautical miles east of Virginia's western shore of the Chesapeake Bay and consists of over 2250 metric tons of debris spread over an area of approximately 49 hec (Fig. 1). The mean tidal range observed at the site throughout this study was 67 cm, which is typical of mid-Atlantic estuaries.

The maximum distance at which an *in situ* acoustic transmitter could be detected was determined by a range test. Range tests were conducted from a small vessel using a single moored VR2 (VEMCO) receiver equipped with an omnidirectional hydrophone. We placed an acoustic transmitter (V9-2L-R256, transmitting at 69 kHz; VEMCO) near the bottom of the water column in successive 100 m increments from the receiver and remained stationary at each distance for 5 min. We then calculated the proportion of transmitted acoustic signals detected. The optimal detection range was decided a priori to be the distance where at least 50% of the acoustic signals were detected, which was 400 m.

On 13 June, 2006 we deployed 12 acoustic receivers near the artificial reef ensuring that the detection range of adjacent receivers overlapped slightly (Fig. 1). The mean distance between adjacent receivers was 791 m. Each receiver was placed approximately 3 m from the seafloor and tethered to a 91 kg mushroom anchor. We also placed temperature loggers directly above the receivers at the corners of the array. Data from the acoustic receivers were downloaded on two occasions: 22 August, 2006 and 27 March, 2007. All receivers were recovered in August, but we were unable to recover five receivers during the March retrieval due to missing surface buoys. Scuba divers retrieved three of the missing receivers in June 2007, but two receivers were never recovered (Fig. 1).

2.2. Tagging

Forty summer flounder were implanted with acoustic transmitters between 15 June and 10 July, 2006. The mean total length (TL) of tagged fish was 437 mm (range: 258–612 mm). To identify individual fish, each acoustic transmitter emitted a unique acoustic code every 60–180 s. Transmitters were implanted using surgical procedures previously established for summer flounder (Fabrizio and Pessutti, 2007). Briefly, fish were anesthetized with 60 mg L^{-1} AQUI-S (a clove oil derivative approved for use as an anesthetic in Australia and New Zealand), a small incision was made on the non-pigmented side of the fish, a beeswax- coated transmitter (9 mm × 30 mm; V9-2L-R256, VEMCO) was inserted into the peritoneal cavity, and the incision was stitched using non-absorbable sutures in an interrupted pattern. While the fish remained under anesthesia, size and weight measurements were collected, and an individually numbered T-bar anchor tag (Hallprint tags) was inserted into the dorsal musculature near the tail. Fish were then resuscitated using ram ventilation and released near the center of the acoustic array (Fig. 1).

2.3. Data processing

Detections downloaded from acoustic receivers were examined to remove false detections after correcting for the receiver's temporal drift using the procedure described in Heupel et al. (2005). Examples of false detections include those that were: (1) recorded prior to implantation and release of the transmitter, (2) recorded following angler harvest of the fish carrying the transmitter, and (3) not validated by a second detection of the same transmitter at the same receiver within 1 h. These false detections were probably the result of acoustic noise or simultaneous detections of multiple pings. We also removed all detections from one transmitter because it was detected only at a single receiver throughout the study. This anomaly indicated the fish either succumbed to tagging-related mortality or shed the transmitter shortly after release.

2.4. Residency and distribution

We used simple statistics to calculate residency duration at the artificial reef and describe spatial distributions of fish within the acoustic array. We define residency as the number of days an individual was detected at Back River reef, without an absence of more than one week. We used linear regression to determine the effect of fish length on residency duration. To examine the distribution of summer flounder near the artificial reef, we calculated the number of detections per individual recorded by each acoustic receiver. Size-related distribution around Back River reef was examined using a weighted mean length for fish detected by each

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