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The importance of newly-opened tidal inlets as spawning corridors for adult Red Drum (*Sciaenops ocellatus*)

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ABSTRACT

The ability to emigrate from estuarine nursery areas to spawning grounds is essential for the persistence of estuarine dependent species such as Red Drum, (*Sciaenops ocellatus*). Typically in this region, tidal inlets are the only mechanism for this transfer. Cedar Bayou, a natural tidal inlet, was deliberately closed in 1979 but was recently dredged and reopened. The inlet allows for direct water exchange between the Gulf of Mexico and Mesquite Bay, Texas, USA, and represents a unique opportunity to study estuarine dependent species' migration processes. Adult Red Drum were implanted with acoustic transmitters that allowed us to track their movement patterns before and after the reopening of Cedar Bayou. The goals of this study were to: 1) determine if Red Drum choose migration routes opportunistically in Texas waters; and 2) elucidate general movement patterns and residency estimates for Red Drum in Texas bays. Red Drum showed relatively little movement during the pre-opening period and summer, even after the inlet was restored. Once open, fish actively traversed through Cedar Bayou during the months commonly associated with spawning migrations and coincident with a drop in water temperature. These results demonstrate that Red Drum choose migration corridors opportunistically, thus opening tidal inlets such as Cedar Bayou can provide maturing Red Drum with greater connectivity between estuaries and spawning grounds in the open Gulf of Mexico.

1. Introduction

Barrier islands separate most Texas estuaries and bays from the Gulf of Mexico, and tidal inlets connecting these two habitats serve as essential migration corridors for certain estuarine-dependent species. This connectivity is essential for adults to migrate from estuaries to offshore spawning grounds to reproduce and complete their life cycles (Reese et al., 2008). Anthropogenic factors have led to numerous inlet closures along the Texas coastline (Kraus, 2007), often to the detriment to local ecosystems (Hall et al., 2016).

Cedar Bayou provides a direct link between the Mesquite Bay region's abundant seagrass nurseries and the Gulf of Mexico. The inlet was intentionally closed in 1979 to prevent contaminants from the Ixtoc I oil spill from reaching the Texas mainland. Concern from local fishermen and other organizations led to a multi-million dollar dredging effort that restored Cedar Bayou's connection to the Gulf of Mexico on September 25, 2014. Closure of any inlet along the Texas coast drastically increases the distance individuals must migrate to spawning grounds, making it necessary to understand how reopening inlets may influence spawning migrations for estuarine-dependent species.

Red Drum (*Sciaenops ocellatus*) are an iconic species that have a classic estuarine-dependent life cycle. Findings from Red Drum movement studies are somewhat mixed, with some indicating adult movement is limited (Collins et al., 2002; Dresser and Kneib, 2007; Reyier et al., 2011; Moulton et al., 2016), while others found that much broader movements occur and are subject to age (Bachelor et al., 2009). This has led to speculation regarding the preferred spawning locations of Red Drum, and there are numerous reports indicating spawning behavior can occur over a wide range of conditions (Carr and Smith, 1977; Holt et al., 1989; Matlock, 1990; Johnson and Funicelli, 1991; Reyier et al., 2011). Some research has even suggested that adult Red Drum display high spawning site fidelity and even natal homing in certain portions of their range (Collins et al., 2002; Patterson et al., 2004; Rooker et al., 2010). Should Red Drum return to specific areas to spawn, the need to protect those areas would be paramount for sustainable management.

In Texas waters, larval abundance studies clearly suggest that spawning most frequently occurs just offshore of open tidal inlets between October and January. It is the prevailing thought that schools of newly matured Red Drum form in Texas' estuaries and migrate through tidal inlets, where they join adult stocks to spawn in nearshore areas (Holt and Arnold, 1982; Hall et al., 2016). With very little evidence to

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support natal homing in Texas waters, we would expect mature Red Drum to opportunistically use a newly opened inlet as a direct path to spawning areas. However, should no migration take place through the inlet, further study would be needed to determine if other factors such as natal homing influence Red Drum spawning migrations.

Acoustic telemetry has become an increasingly reliable research tool for tracking large-scale movements of fish. Passive acoustic telemetry systems have become popular as they require minimal equipment maintenance while providing constant data recording capabilities. Most passive acoustic telemetry systems use an array of stationary receivers that detect acoustic signals from fish implanted with uniquely coded transmitters (Heupel et al., 2006). By using combinations of various array layouts, coverage of multiple animals can be established to elucidate fine- to landscape-scale movements with relatively few receivers. In addition, study animals do not have to be recaptured to recover movement data. Acoustic data can be used in a variety of ways including “presence/absence” applications, which can be adjusted to determine the timing of major movements such as a migration event (Heupel et al., 2006; Moulton et al., 2016).

The goals of this study were to: 1) determine if Red Drum choose migration routes opportunistically in Texas waters, and 2) elucidate general movement patterns and residency estimates for Red Drum in Texas bays. Specifically, we predicted that Red Drum would choose migration routes opportunistically in Texas waters and would travel through the reopened Cedar Bayou inlet during favorable spawning conditions. Understanding how Red Drum choose migration routes is critical to managing the species and ensuring that suitable migration corridors exist.

2. Methods

2.1. Study area

The San Antonio Bay estuary complex encompasses Mesquite Bay (Armstrong, 1987; Britton and Morton, 1989), which is bordered to the northeast by San Antonio Bay and to the southwest by the Aransas Bay complex. Mesquite Bay is isolated from the Gulf of Mexico when Cedar Bayou is closed, the nearest inlet being Aransas Pass approximately 32 km to the south. The region contains essential fish habitat including numerous seagrass beds (primarily *Halodule wrightii*), salt marshes (*Spartina alterniflora*) and oyster reefs (*Crassostrea virginica*). Shallow, subtidal and intertidal oyster reefs are prevalent along the perimeter of Mesquite Bay, with few deep channels allowing connectivity to surrounding bays. This sufficiently bottlenecks access to Mesquite Bay through these deep channels. We strategically utilized these natural bottlenecks when designing our acoustic array, as there is a high probability that Red Drum are funneled through these corridors when transiting across this bay system.

2.2. Acoustic equipment

An acoustic array of eight Vemco VR2W receivers was deployed in the Mesquite Bay/Cedar Bayou region in May 2014 to examine fish movement prior to the dredging and opening of Cedar Bayou. Receivers were strategically placed in Cedar Bayou, the perimeter of Mesquite Bay, and at suspected “bottlenecks” to capture as much movement information as possible (Payne, 2011) (Fig. 1). The Mesquite Bay receiver array was an addition to the Texas Acoustic Array Network (TexAAN), a large-scale hydrophone network that encompasses the Aransas/Corpus Christi Bay systems and the Laguna Madre, including other tidal inlets. While not specifically part of the Mesquite Bay/Cedar Bayou bay-scale movement project, the TexAAN allowed for the potential to detect regional movements if they occurred. Based on other shallow water acoustic array designs, each receiver was positioned just off the bottom to ensure sound detection even during the lowest tide events (Heupel and Hueter, 2001; Payne, 2011; Reyier et al., 2011). Ultrasonic coded acoustic transmitters (Vemco V13-1 L) were implanted in 11 Red Drum within the Mesquite Bay complex between April and July 2014. Each acoustic transmitter weighed 6 g in water (11 g in air) and was 36-mm in length. The transmitters were programmed to randomly send a uniquely coded acoustic “ping” every 60–180 seconds at a frequency of 69 kHz. Randomized ping timing minimized the probability of signal collisions when numerous tagged animals were simultaneously within the detection range of a single receiver (Payne, 2011). The estimated battery life of each transmitter was 658 days. Receivers in the array were cleaned and data downloaded (Vemco VUE 1.6.5) every 4–6 months after deployment.

The detection range for each receiver is dependent on environmental conditions, such as turbidity, wave energy, water depth, and other background noise (Heupel et al., 2008). Under ideal conditions, each receiver is capable of detecting 69 kHz transmitters within a 1000 m radius (Payne, 2011; Reyier et al., 2011). To test the actual range for receivers in Mesquite Bay, a sentinel transmitter (sending a ping every ten seconds) was deployed on a weighted, vertical mainline 0.6 m from the bottom. The sentinel transmitter was submerged for five minutes (for a total of 30 potential pings per time interval) at 0, 100, 200, 300, 400, and 500 m from three randomly selected stationary receivers (Receivers 1, 5, and 8). This process was then repeated along randomly selected cardinal compass directions where practical (i.e., no land interference or shallow water) for two additional transects for each receiver. These transects included signal obstructions such as oyster reef, varying depths, and sand or seagrass bottom. Thus, these are likely conservative range estimates. A Vemco VR-100 hydrophone unit was used to ensure there were 30 pings from the sentinel transmitter every five minutes (Topping and Szedlmayer, 2011). The receivers were then downloaded to examine detections at each distance. The number of detections for each receiver at each distance was divided by the total number of pings at the 0 m station (used as a control). The mean detection percentage of the three receivers was plotted at each distance and an overlaid sigmoidal regression line was calculated to determine detection rates at any distance (Kessel et al., 2013) (Fig. 2).

2.3. Surgical implantation of transmitters

Red Drum captured ranged from 508 to 711 mm. This size was chosen as growth curves suggest these individuals would be sexually mature and able to take part in spawning migrations by the end of the study. Additionally, previous studies have found that surgically implanted acoustic transmitters should not exceed 2% of the animal’s total body weight, (Winter, 1992; Jepsen et al., 2002; Bradshaw, 2006), indicating that Red Drum used in this study should be no less than 300 g or approximately 306 mm (TL) (Matlock, 1985a,b). Thus, all fish used in this study were well below the 2% body-weight recommendations for transmitter implantation.

The surgical implantation of the transmitters combined procedural elements originally developed by Reyier et al. (2011), Reese-Robillard et al. (2015), and Moulton et al. (2016). Red Drum were collected in Mesquite Bay using hook-and-line and artificial lures to minimize deep-hooking. Post collection, fish were measured (mm TL) and transferred to an oxygenated holding tank. Fish were monitored for approximately 20 min to ensure normal behavior post-capture. All fish were hooked in/near mouth and did not exhibit any type of behavior indicative of post-release fishing mortality. Fish weight was not measured to reduce physical stress to the animal prior to surgery, but weight was estimated using length-weight keys. Red Drum were not anesthetized for surgery to minimize stress and behavioral changes due to prolonged handling and anesthesia recovery time (IACUC 23-12, Texas A&M University-Corpus Christi) (Reese-Robillard et al., 2015). Fish were placed dorso-ventrally in a cradle that allowed the gills to remain in oxygenated seawater (Reese-Robillard et al., 2015). Using a scalpel, scales were removed from the incision site and an approximate 25-mm incision was made parallel to the ventral midline approximately 3 cm anterior to the

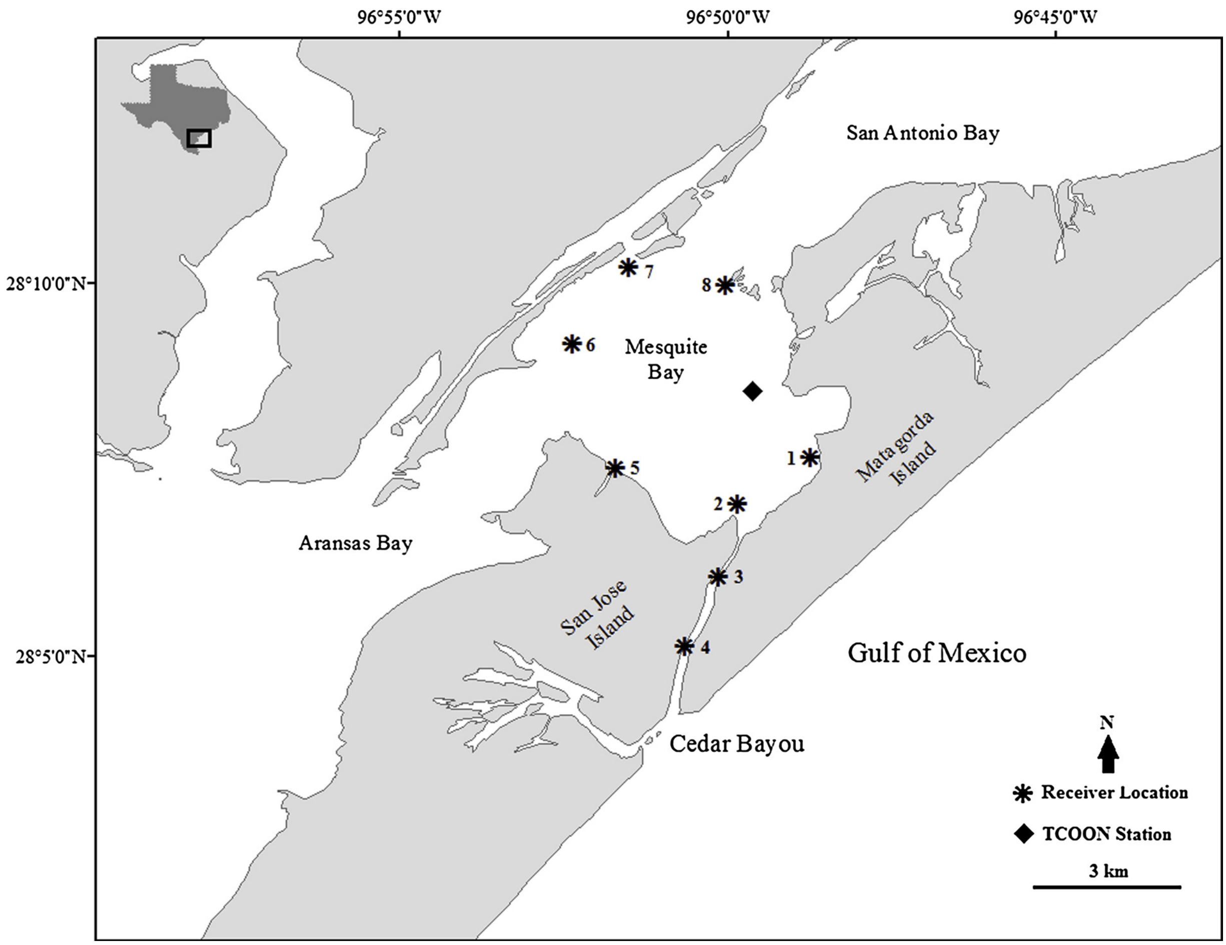

Fig. 1. Map of the study area depicting Vemco VR2W receiver locations (*1-8) within the Mesquite Bay/Cedar Bayou complex. Shallow, subtidal and intertidal oyster reefs are prevalent along the perimeter of Mesquite Bay, with few deep channels allowing connectivity to surrounding bays. This sufficiently bottlenecks access to Mesquite Bay through these deep channels. We took advantage of these natural bottlenecks when designing our acoustic array, as there is a high probability that Red Drum are funneled through these corridors when transiting across this bay system.

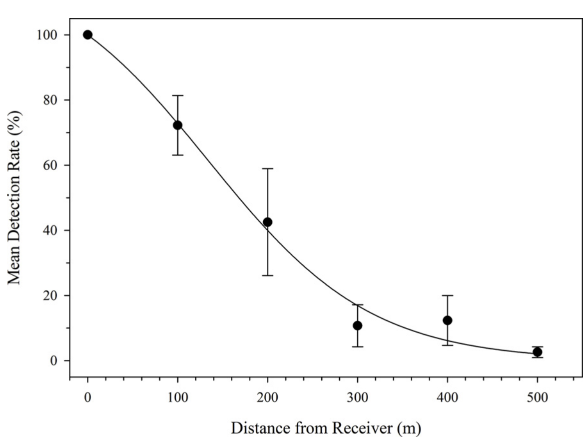

Fig. 2. Mean detection rate (%) with standard error for three receivers in the Mesquite Bay array. A sigmoidal curve was fit to the data indicating a 50% detection rate at 170 m (Adj. R^2 = 0.9819). The furthest recorded detections were at 500 m. These detection ranges reflect those of other studies in similar environments.

anus (Reyier et al., 2011). Transmitters were disinfected using a 12.9% solution of benzalkonium chloride and rinsed in sterile water prior to insertion into the peritoneal cavity (Mulcahy, 2003; Reese-Robillard et al., 2015). The incision was closed using two Vicryl absorbable sutures held with a surgeon knot (Vicryl, 2-0 reverse cutting PSL, Ethicon, Inc., Somerville, New Jersey) (Cooke and Wagner, 2004). Distinctly numbered dart tags were inserted lateral of the dorsal fin for individual identification as well as a phone number for recapture information (Reyier et al., 2011; Reese-Robillard et al., 2015). Post-surgery, fish were monitored for 20 min prior to release at the location of capture.

2.4. Residency index calculation

Residence indices were calculated by dividing the number of days detected by the number of days at liberty. A residency index value of 1.00 indicates that an individual was detected at least once every day of the study. Chin et al. (2013) recommended that two actual detections were made within a 24-hour period before being classified as a “day detected.” Given that some of the fish in this study moved through the entire Cedar Bayou array in a very short period of time (often less than 24 h), all detections were used to qualify as a day detected. Any fish that was not detected during the study was excluded from the mean residency index calculation.

3. Results

3.1. Range testing

Mean detection rate in the Mesquite Bay acoustic array decreased as distance from the receiver increased (Fig. 2). Based on a 100% detection rate at 0 m, the mean detection percentage was 72.2% ± 9.2 (SE) at 100 m, 42.5% ± 16.4 at 200 m, 10.7% ± 6.5 at 300 m, 12.3% ± 7.6

Table 1
Summary data for the eleven Red Drum tagged in Mesquite Bay. Total detections represent the total number of times an individual fish was detected over the array. The stations visited represents the number of individual stations where an individual was detected. Days at liberty were the number of days between an individual's release and the last date detected. The number of days detected represents the number of individual days a fish was detected by any receiver in the array. Residency index calculated by the number of days detected divided by the number of days at liberty. A residency index value of 1.00 indicates that an individual was detected at least once every day of the study.

Fish #	Release Date	TL (mm)	Total Detections	Stations Visited	Days at Liberty	#Days Detected	Residency Index
1	05/17/14	551	1724	5	386	183	0.474
2	05/17/14	526	10228	4	386	175	0.453
3	05/17/14	611	69	2	386	6	0.016
4	06/11/14	521	0	0	361	0	NA
5	06/11/14	525	27	3	361	2	0.006
6	06/11/14	525	7	4	361	6	0.017
7	07/23/14	656	0	0	319	0	NA
8	07/23/14	708	72	2	319	5	0.016
9	08/15/14	618	3408	3	296	71	0.240
10	08/15/14	565	1243	5	296	33	0.111
11	08/15/14	580	0	0	296	0	NA
	Mean =	**581**	**1525**	**3**	**342**	**44**	**0.167**

at 400 m, 2.6% ± 1.7 at 500 m. Range tests in the Mesquite Bay array indicate a 50% detection rate at approximately 170 m. The furthest recorded detections were at 500 m. These detection ranges are typical for estuarine systems (Payne, 2011).

3.2. Residency index

Eight of eleven fish were detected in the array. The mean number of detections per fish was 1525 ± 930 SD, and the number of detections per fish ranged from 0 to 10,228. Overall, each fish that we detected showed a moderate level of movement, with fish moving among three receivers on average throughout the course of the study (Table 1). Movement intensity and frequency varied greatly between individuals. Fish 1 was found to have the highest residency index (0.474) while fishes 4, 7, and 11 were never detected after release (Table 1). Receiver 1 recorded the highest number of detections (16,052 detections) while receivers 7 and 8 recorded no detections (Fig. 3, Table 2). Receivers 2 (bay entrance to Cedar Bayou), 3, and 4 (both located in Cedar Bayou) only provided 4.19% (703 detections) of the total detections (Table 2).

Table 2
Total number of detections and percentage of total detections for each receiver between May 17, 2014 and June 6, 2015. Receivers 2, 3, and 4 (located in Cedar Bayou) only made up 4.19% of the total detections.

Receiver	Detections Before	Detections After	Total	% Before	% After	% Total
1	12,117	3935	16052	75.49	24.51	95.67
2	10	86	96	10.42	89.58	0.57
3	0	129	129	0	100	0.77
4	1	477	478	0.21	99.79	2.85
5	0	17	17	0	100	0.10
6	6	0	6	100	0	0.04
7	0	0	0	NA	NA	0
8	0	0	0	NA	NA	0
Total	**12,134**	**4644**	**16778**			**100**

3.3. Cedar bayou detections

Detections on other receivers throughout Mesquite Bay varied. Fish presence near Receiver 1 was consistent throughout the year (Fig. 3).

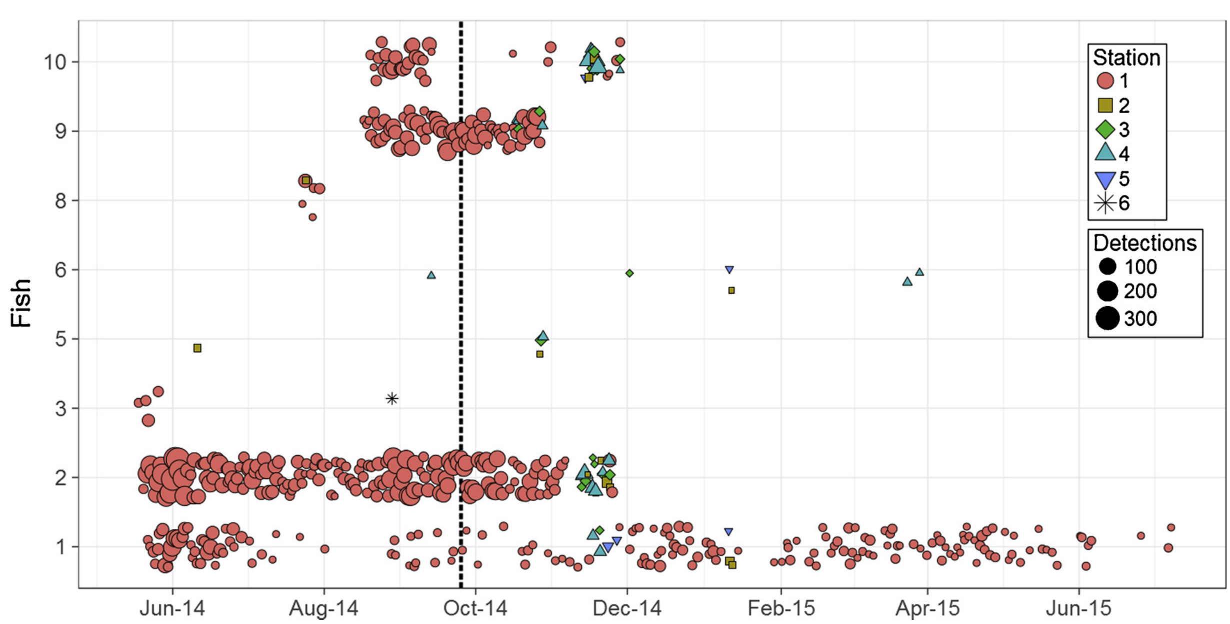

Fig. 3. Jitter plot of total acoustic detections for each fish over the entire study period (May 19, 2014 through July 8, 2015). The majority of detections for the Cedar Bayou receivers (receivers 2, 3, and 4) seemed to occur within a relatively short period of time during fall 2015. The dashed vertical line represents reopening date. Fish 4, 7, and 11 were not detected after release. Receivers 7 and 8 did not record any detections during this study and are thus not represented on this graph.

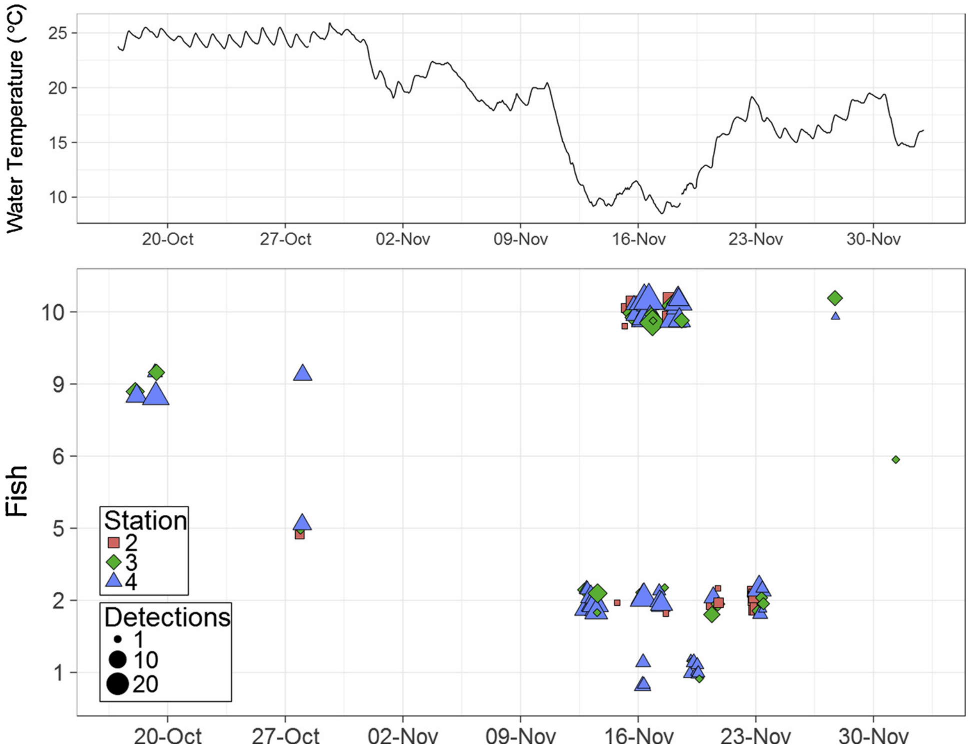

Fig. 4. Water surface temperature (°C) and acoustic detections within Cedar Bayou (stations 2, 3, and 4 only) between October 15, 2014 and December 4, 2014. Point sizes are proportional to the number of hourly acoustic detections. Water temperature data were obtained from the Mission Aransas National Estuarine Research Reserve's remote data station in Mesquite Bay. Mean surface water temperature was found to be 18.1 °C + 5.56 (SD) between October 18, 2014 and November 28, 2014 (temperatures ranged from 9.5 to 25.5 °C). Of the 703 total detections made within Cedar Bayou, 95.6% were made during the spawning season between October 18, 2014 and November 28, 2014, representing a total of six individual fish. Five of these six fish were last detected by receiver 4, the receiver located closest to the Gulf of Mexico.

Receiver 5 was visited for short periods by fish 1, 6, and 10 in December and January. Receiver 6 made only six detections during the study period, which occurred on August 28, 2014 by fish 3 (Fig. 3). Receivers 7 and 8 did not make any detections throughout the study period. Review of these receiver units proved that they were working as multiple background pings were recorded, most likely from boat traffic in the area.

Only one fish was detected in Cedar Bayou prior to reopening, with all of those detections being recorded within the same 24 h period. After-opening, Cedar Bayou receivers (receivers 2, 3, and 4) had numerous detections during a short period of time between the fall and winter of 2014-15 (Figs. 3 and 4, Table 2), showing these fish were more actively using the inlet post-opening. Of the 703 total detections made within Cedar Bayou, 95.6% were made during the spawning season between October 18, 2014 and November 28, 2014, representing a total of six individual fish (Fig. 4). Five of these six fish were last detected by receiver 4, the receiver located closest to the Gulf of Mexico (Fig. 4). Detections from the Cedar Bayou receivers were plotted against surface water temperature data for Mesquite Bay between October 15, 2014 and December 4, 2014 (Fig. 4). Water temperature data were obtained from the Mission Aransas National Estuarine Research Reserve's (MANERR) remote data station in Mesquite Bay (accessed via the Texas Coastal Ocean Observation Network, Conrad Blucher Institute) and mean surface water temperature was found to be 18.1 °C ± 5.56 (SD) between October 18, 2014 and November 28, 2014 (temperatures ranged from 9.5 to 25.5 °C) (Fig. 4). Most detections within Cedar Bayou occurred immediately following a drop in water surface temperature, which is known to elicit spawning behavior for Red Drum (McEachron et al., 1993). Other environmental variable data collected during this time remained relatively stable throughout the study period (Fig. 5).

4. Discussion

4.1. Overview

We examined migration patterns of acoustically tagged Red Drum near a recently opened tidal inlet. Despite the relatively small sample size in our study, the overwhelming majority of detections made in Cedar Bayou occurred during months that are well-established as the Red Drum spawning and migration season. Given that extensive use of Cedar Bayou occurred specifically and with the most frequency during the established spawning season post-opening for the inlet, and that exceptionally high abundances of early juvenile Red Drum were found in Mesquite Bay shortly thereafter (Hall et al., 2016), we concluded that Red Drum were likely using the newly dredged Cedar Bayou inlet as a spawning migration corridor to access the Gulf of Mexico. This use occurred rapidly, during the first spawning season after the inlet was reopened. We are now confident that Red Drum choose migration corridors opportunistically in Texas waters. Given the limited estuary-to-offshore access along the Texas coast, other estuarine-dependent species such as Blue Crab, (*Callinectes sapidus*), and Penaeid shrimp species may also display this opportunistic migration strategy. Additional research on the effects of natural inlet restoration on these invertebrates is needed as they provide crucial forage for numerous predatory species in the region, as well as support major commercial fisheries.

4.2. Acoustic array performance

Our receivers had a detection range comparable with other estuarine studies and were capable of identifying 50% of transmissions at 170 m (Dance et al., 2016), despite natural obstructions such as oyster reefs. Coverage was established at key points along Mesquite Bay's perimeter and provided nearly complete coverage across the width of Cedar Bayou. Most importantly, all the fish detected by our array consistently exhibited high residencies within the Mesquite Bay system, as well as migration-like movements consistent with spawning in Cedar Bayou post-opening, indicating high detection efficiency in the array. These data, along with a related recruitment study (Hall et al., 2016), collectively show that adult Red Drum likely used the reopened inlet for spawning migrations (Hall et al., 2016). While otolith or isotopic chemical tracer studies would be necessary to confirm this, prior work has shown that natal origins of Red Drum can be assigned to adjacent

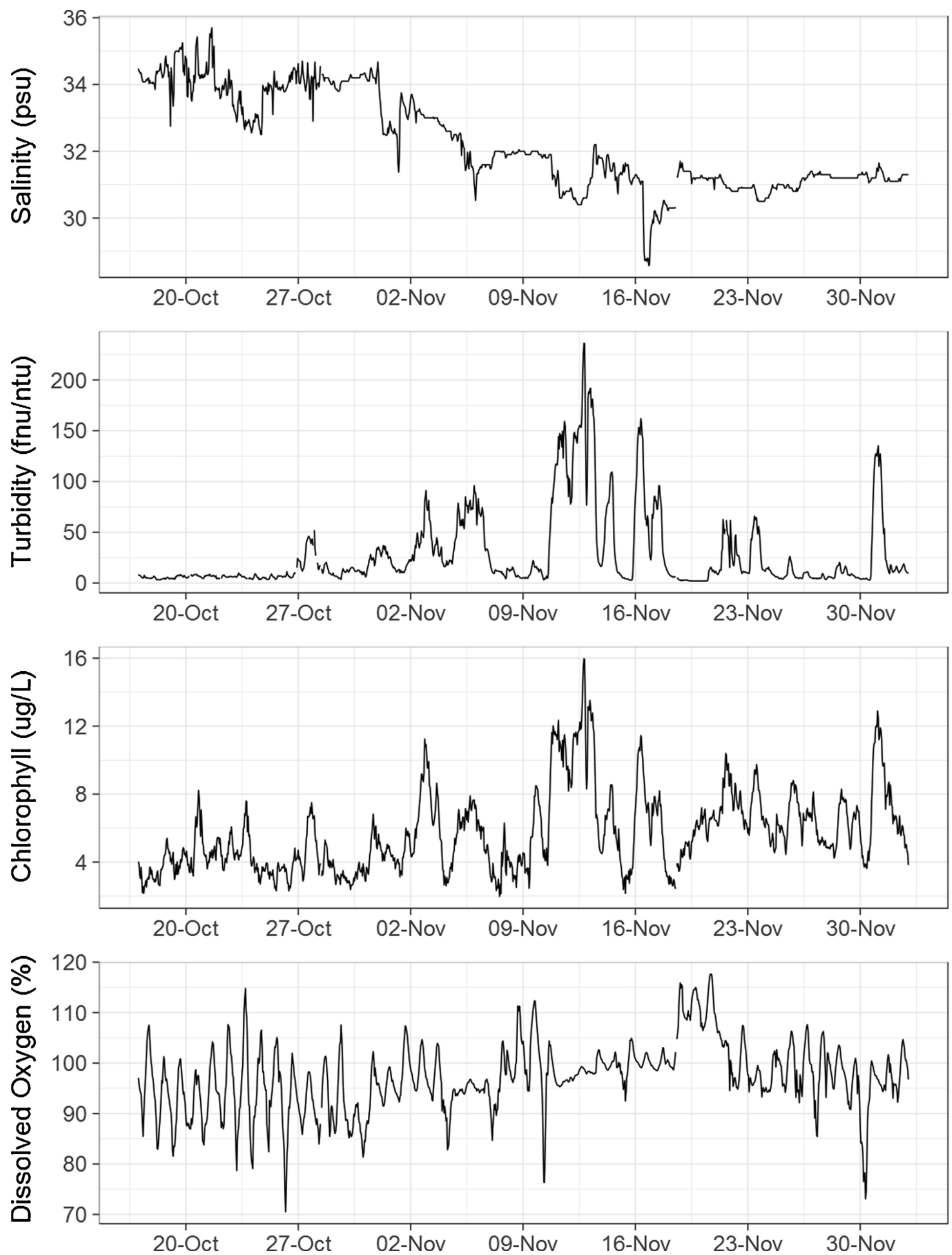

Fig. 5. Environmental variables in Mesquite Bay between October 15, 2014 and December 4, 2014. None of these variables coincided with Red Drum Movement through Cedar Bayou. The change in salinity in November is related to seasonal precipitation.

spawning grounds (Rooker et al., 2010).

There have been numerous attempts to quantify Red Drum movement patterns with varying results (Rooker et al., 2010; Moulton et al., 2016). The results of this study were very similar to those of Reyier et al. (2011) who found that adult Red Drum in Mosquito Lagoon, Florida, remained resident to where they were captured and released during the summer months. In this study, seven of the eleven fish were captured and released nearest to receiver 1. This receiver recorded the most detections and the highest number of individual fish throughout the study period. Two of those seven fish also exhibited a relatively high residency index ($>$ 0.450, Chin et al., 2013). Additionally, given the relatively small detection range of the receivers in Mesquite Bay, these residency index values are likely conservative. These results collectively indicate that adult Red Drum in Mesquite Bay remain relatively stationary over long periods of time, particularly during the summer months.

The experimental design for this project essentially represented a modified BACI design, with before-after-impact components, but lacking a concurrent dedicated control site. Logistical and budgeting constraints prevented us from incorporating a true control site, as this would have required splitting existing resources in half, and given that sample sizes were already somewhat modest, this option was not feasible. Eggenberger et al. (in press) successfully incorporated a BACI design approach using acoustic telemetry for comparing snook movement and trophic effects between areas of differing nutrient enrichment. For future studies in our system, cross-site comparisons utilizing a control site would allow more rigorous hypothesis testing regarding the timing and movement of Red Drum through the newly dredged tidal inlet, in comparison with an existing and established channel to the Gulf of Mexico. It is well known that Red Drum extensively use the Aransas Pass shipping channel located 27 km to the south of Cedar Bayou during their fall migration runs. This *a priori* knowledge of the system could thus be used as a pseudo-control parameter, as we have information on the behavior of Red Drum at this location that would be utilized as a control site (Brown et al., 2004). In a previous study, Hall et al. (2016) effectively used a full BACI design using this exact location as a control site to demonstrate the movement of small nekton through the Cedar Bayou tidal inlet. Similarly, an acoustic telemetry based study using a full BACI design documenting the movement of Red Drum spawning adults would serve as a useful tool in evaluating restoration performance.

4.3. Impact of Cedar Bayou on spawning migration

Understanding how opening Cedar Bayou influenced Red Drum spawning migration patterns in the Mesquite Bay complex is important to ensuring stable recruitment in the region and sustainable populations. Red Drum remained relatively close to the areas they were captured and released during the summer months and were only detected in Cedar Bayou once prior to October 2014. However, detections in Cedar Bayou increased during the well-established spawning months of October and November (Holt, 2002; Patterson et al., 2004; Rooker et al., 2010). These pulses of activity coincide with punctuated decreases in surface water temperature, which are established spawning triggers for this species, as the aquaculture industry has used decreasing ambient light and temperatures to initiate Red Drum spawning in captivity (McEachron et al., 1993). Small changes in other environmental variables did not coincide with Red Drum movement through Cedar Bayou.

Five of the six fish detected in Cedar Bayou during the spawning season were last detected nearest to the Gulf of Mexico (i.e., receiver 4). Generally, Red Drum permanently join the offshore population after their first spawning event (Powers et al., 2012); thus, it is likely these fish remained offshore with the spawning stock, explaining why no detections were made after the spawning season. Moreover, for Red Drum off Florida, a previous study (e.g., Reyier et al., 2011) has shown that the greatest number of detections and movement out of that study area occurred in September and October; this movement out of the study area was attributed in part to Red Drum migrating offshore to spawn. Our results showed a similar temporal trend, suggesting that Red Drum are using Cedar Bayou as an opportunistic migration route to offshore spawning grounds. A future study utilizing larger sample sizes and long-term satellite telemetry would provide a clearer picture of Red Drum spawning migrations and may elucidate other preferred spawning locations that may exist.

4.4. Conclusions

Collectively, this study provides strong evidence suggesting that Cedar Bayou provided an opportunistic spawning migration corridor for adult Red Drum less than a month after it was reopened. The ability of larger fish to easily join the spawning population could potentially increase recruitment as well as the overall population of Red Drum in the Mesquite Bay complex, thereby providing stability to the population throughout the region. It also suggests that Red Drum do not display natal homing in Texas waters, which has broad management implications.

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