Recruitment of estuarine dependent species of commercial and recreational importance through the Aransas Ship Channel

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Several species of shellfish and finfish of commercial or recreational importance in the Nueces and Mission-Aransas Estuaries possess life history patterns that are dependent upon estuaries, whereby juvenile members of these species live and mature in these estuary "nurseries", then migrate to the Gulf of Mexico as reproductive adults, releasing their eggs and planktonic larvae in the open ocean. The larvae feed, grow and develop in the Gulf of Mexico, but must return back to these estuaries to complete their life cycle. These planktonic larvae possess weak swimming skills and are too small to migrate directly back into the estuaries under their own power, so they must depend on hydrodynamic and environmental signals to selectively ride tidal and meteorologically driven currents back into the estuaries and avoid being flushed back out when these currents reverse. Tides are relatively small in the Northwestern Gulf of Mexico, and especially for estuaries in South Texas with little inflow of freshwater, meteorological forcing over times scales of several days play a significant role in estuarine-shelf water exchanges (Smith 1978). The Aransas Pass connecting the Nueces and Mission-Aransas Estuaries to the Gulf of Mexico was originally a shallow inlet between Mustang and San Jose Islands and it has been dredged to allow access for ocean-going vessels to the Port of Corpus Christi. This deeper channel now delivers most of the water exchange between the Nueces/Mission-Aransas Estuaries and the Gulf of Mexico, which has reduced the flow through other shallow historical passes between these estuaries and the Gulf, causing them to fill in with sediments and close unless maintained through dredging (e.g. Fish Pass, Cedar Bayou). As a result of historical passes closing due to the already permitted deepening of the Aransas Pass, this channel is now the main route available for larvae to recruit from the Gulf to local estuaries. It is unclear how additional alterations to the depth of the Aransas Pass and adjacent waters will alter hydrodynamics in this channel, or other remaining channels, and affect the recruitment of estuarine dependent larvae. Below are several examples of important estuarine species that could be impacted.

Shrimp

Brown and white shrimp are both estuarine-dependent species and have similar life history stages (see Figure below). Adult shrimp migrate out to the open Gulf of Mexico through the narrow passes between barrier islands and females spawn their eggs there. Each female will release between 100,000 and one million eggs (a in Figure 1) that typically hatch within one day into larvae called nauplii (b in
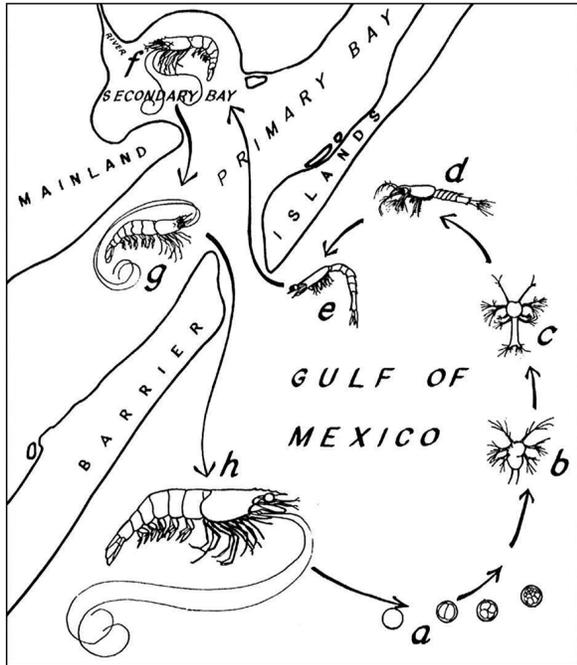
Figure 1. Estuarine dependent life cycle of brown and white shrimp (source: TPWD).

Figure 1). Like all crustaceans, these shrimp possess exoskeletons, and must shed their external shells and molt when they grow. The shrimp larvae molt through several additional developmental stages: protozoea (c), mysis (d) finally becoming postlarvae (e) that are still small (~1/4 inch), transparent, weakly swimming and planktonic, but begin to more closely resemble adult shrimp. Larval shrimp feed on phytoplankton and zooplankton, and are dispersed along the coast by oceanic currents. The postlarvae are carried shoreward by wind-driven currents, and are transported along the shore by longshore currents. When they approach passes between the Gulf and their estuarine nursery grounds they detect the presence of the estuary by sensing the lower salinity waters from the estuary (Matthews et al., 1991). The detection of estuarine water triggers a change in behavior called selective tidal stream transport (Forward et al., 2003), where these small, weakly swimming larvae swim up into the water column on flood tides that carry them into the estuary when they detect increases in salinity. When ebb tides that would carry them back out of the estuary are detected, they swim down towards the bottom where current speeds are slower (Duronslet et al., 1972). When they reach areas of the estuary with seagrasses or other structures that help hide them from predators, they molt into juvenile shrimp (f) and adolescent shrimp (h) before molting to adults that migrate back to the gulf and start the cycles over again (Minello et al., 1989; Rogers et al., 1993).

Blue Crabs

Blue crabs also spawn in the Gulf of Mexico, and possess a complex estuarine dependent life cycle. Spawning females migrate to higher salinities at the mouths of estuaries (Carr et al. 2004, Aguliar et al. 2005) to release multiple clutches of larvae known as zoea, which require full ocean salinity to develop (Darnell et al. 2009). The planktonic zoea live in the ocean for 4-7 weeks before molting into a megalopal stage (Costlow and Bookhout 1959). The megalopae are advected towards estuary mouths by wind driven currents (Epifanio 1995) and move farther up estuary with behavioral adaptations that take advantage of hydrologic movements, such as tides (Forward et al. 2003). These behavioral responses are

triggered by physical factors such as changing salinity and turbulence (Welch and Forward 2001), and possibly by chemical cues associated with estuaries (Forward and Rittschof 1994). The Texas coast has nearly continuous barrier islands separating the Gulf of Mexico from the estuaries, with widely separated narrow passes. These limited passes into the estuaries may make larval recruitment an especially important component of blue crab population dynamics on the South Texas coast.

The behaviors that govern blue crab transport via tides are well understood from studies performed on the US Atlantic coast. Transport is generally limited to the night, as the chemical signature of estuarine waters induces photoinhibition of megalopae activity during daylight, and megalopae only actively swim at night when in the estuarine plume. Welch and Forward (2001) experimentally demonstrated a mechanism for the transport of blue crab megalopae into Atlantic coast estuaries known as selective tidal-stream transport (later reviewed by Forward et al. 2003). Their model proposed that megalopae utilize nocturnal flood tides to move up estuaries, and avoid being transported back out to sea on the ebb tide through a series of responses to changes in salinity and turbulence: (1) Megalopae swim up into the water column in response to increasing salinity and pressure indicating flood tides (2) Megalopae remain swimming in response to high levels of turbulence indicating tidal current (3) Megalopae descend when turbulence declines during slack tide and (4) Megalopae are inhibited from rising again with the ebb tide by decreasing salinity and pressure. While this model is plausible for estuaries on the Atlantic coast that have larger tidal ranges and more consistent freshwater inflows, several issues arise when applying this behavior-response model to transport in systems like the Mission-Aransas Estuary in Texas. In the Gulf of Mexico, tidal ranges are relatively small (Smith 1977). These weaker tides may result in rates of pressure and salinity change too low to stimulate a swimming response (Tankersley et al., 1995), and move smaller volumes of water than more extreme tides observed on the Atlantic. However, recent studies indicate that blue crab megalopae from the Aransas Pass of South Texas have adapted to local conditions and are more sensitive to small changes in salinity than megalopae from the Atlantic Coast (Bittler et al., 2014). Tidal currents alone may not be enough to transport blue crab megalopae into Texas estuaries, and a model of planktonic larval transport for the area has suggested that wind forcing by persistent storm-related or onshore winds is a more important process driving transport of estuarine dependent larvae (Brown et al., 2005).

Fish species of commercial and recreational importance: spawning aggregations

The Aransas Ship Channel is the only connection between local bays and estuaries and the coastal ocean for tens of miles in either direction. As such, it is a critical area for the movement of fishes between these two habitats. The Red Drum (*Scianops ocellatus*), Southern Flounder (*Paralichthys lethostigma*),

Speckled Trout (*Cynoscion nebulosus*), and Sheepshead (*Archosargus probatocephalus*) are some of the best-known fishes that take advantage of this passageway, and all of these important fishery species do so for reasons associated with spawning. While Southern Flounder just pass through, Red Drum, Sheepshead, and Speckled Trout (*Cynoscion nebulosus*) come from miles around to spawn in the channel itself. The Aransas Channel and other ship channels like it have recently been identified as crucial multi-species fish spawning aggregation sites in the Gulf of Mexico (Grüss et al. 2018). Fish spawning aggregation sites are massive gatherings of fish for breeding, a behavior shared by many species across the globe in many different habitats. Fishes select sites such as the Aransas Channel due to their specific physical properties (e.g. geomorphology, currents) (Heyman and Kjerfve 2008), and these areas support the fish populations and fisheries of the wider region (Sadovy de Mitcheson and Erisman 2012). Spawning aggregations occur at all times of year - in the Aransas Channel, Red Drum form large spawning aggregations in mouth of the channel during the fall months (the 'Redfish Run') (Holt 2008), Sheepshead form large spawning aggregations on the rocky jetties that line the channel in the spring (Bolser et al. *in prep*), and Speckled Trout form spawning aggregations in the channel in the summer (Biggs et al. *in prep*). The predictable presence in time and space of these aggregations facilitates the success of Port Aransas' highly productive fishing industry, which is an indispensable part of the region's economy.

The effects of short-term physical disturbances such as dredging and longer-term changes such as significant deepening of the Aransas ship channel on fish spawning aggregations have not been studied in this region. It is likely that the specific geomorphology of the channel has caused fish species to select it as an spawning site, and alterations in depth might cause it to no longer be suitable. In addition, disruption of the current flow regime could affect the transport of eggs and larvae that result from spawning aggregations to the bays and estuaries of the area, which are critical nursery areas for economically-important sport fishes (Rooker et al., 1998). Therefore, it is of critical importance to fully understand the movement, spawning, and larval transport dynamics of fishes in the area before undertaking major alterations to this critical habitat and use the information to eliminate or severely reduce any impacts on these critical natural resources, and monitor these spawning and larval transport activities before and after any significant changes are made.

Fish larval supply and retention in estuaries: role of physical processes

The supply of larval fishes from the Gulf of Mexico to South Texas estuaries may be controlled by circulation through tidal inlets into estuaries (Jenkins et al., 1997). Episodic pulses of high abundances

of fish larvae in tidal passes are commonly observed for estuarine-dependent fish species (Hettler et al., 1997). The spatial and temporal variability of both larval abundance and tidal and meteorological influenced currents (Smith, 1977, 1979) make it challenging to determine the respective roles of larval abundance, hydrodynamics other factors to determine the dominant factors affected recruitment of estuarine dependent larval fishes. Efforts to correlate abundances of larval fish with environmental variables have proved to be especially challenging (Dixon et al., 1999). Combining direct observations with numerical models of site-specific hydrodynamics and simulated larval transport can aid in understanding of the roles of the dominant processes affecting larval recruitment, and can aid in the design of field based studies (Werner et al., 1999).

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