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SHORT PAPERS AND NOTES

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SIZE AND DISTRIBUTION OF BLUE CRABS (*CALLINECTES SAPIDUS*) WITH REGARD TO SALINITY IN THE UPPER NUECES ESTUARY, TEXAS.—Like the blue crab (*Callinectes sapidus*) fisheries on the Atlantic coast, the Texas fishery has been declining over the last two decades and is currently characterized as senescent (Sutton and Wagner, 2007). Independent data from fisheries in Texas indicate coast-wide blue crab population declines for all age classes. The reason for the decline is unclear, but it is likely due to combinations or interactions of ecological, biological, environmental, and/or anthropogenic factors.

The life history traits of blue crabs, such as migration and juvenile habitat use, must be understood if stocks are to be rebuilt and adequately managed (Aguilar et al., 2008). In Atlantic estuaries, the life history of blue crab females is characterized by movements between areas of lower and higher salinities. Typically, adult males and juveniles of both sexes are more abundant in lower salinity and/or shallower areas of the estuaries. Prior to the female's terminal molt, males couple with females and then mate with them while they are soft. Females then move into higher salinity and/or deeper areas, often in two stages (Tankersley et al., 1998), first to the lower estuary prior to brood production, then to the estuary mouth or adjacent coastal waters to release larvae.

Blue crabs in estuaries of the Gulf Coast spawn throughout the year (Perry and McIlwain, 1986), unlike populations along the mid-Atlantic Bight, where peak spawning occurs between July and Aug. (Aguilar et al., 2005). Although fishers are prohibited from taking sponge crabs in Texas, fertilized females may be caught during the first stage of migration, if migration patterns are similar to those in Atlantic estuaries. Lipcius et al. (2001) have proposed protecting migrating females in the Chesapeake Bay as a means of safeguarding and increasing decimated spawning stocks. However, in Texas estuaries it is unclear if blue crab females migrate from lower to higher salinity waters during spawning in the same fashion as do females in Atlantic estuaries. Observations of females completing the spawning cycle within Galveston Bay without moving into the nearshore areas of the Gulf when salinities were >20 psu (More, 1969) indicate

that there may be important differences between female blue crab life histories on the Atlantic and Gulf coasts. A better understanding of the role of salinity in blue crab distribution and potential movements of females is necessary to inform management decisions. The objective of this study was to characterize the adult blue crab distribution, sex ratios, and sizes with regard to season and salinity in the tidal portion of the Nueces River and upper Nueces Bay.

Study area and methods.—The Nueces Estuary, which includes Nueces and Corpus Christi bays (Fig. 1), exhibits a strong salinity gradient from the tidal portion of the Nueces River to where the river enters Nueces Bay. Salinities typically range from near 0 in the upper tidal portion of the river to ≥ 30 psu in the upper portion of the bay. The compression of low-salinity to relatively high-salinity zones in this part of the estuary provided an excellent opportunity to study blue crab distribution with regard to salinity. In addition, only two commercial fishermen work this area, with sparse trap dispersal (M. Schweitzer, pers. obs.), so this portion of the estuary provides an ideal microcosm for studying a population that is relatively unaffected by fishing pressure.

Blue crabs were sampled in the tidal portion of the Nueces River and into Nueces Bay in Nueces County, TX, at 3–6-wk intervals from Nov. 2006 to Nov. 2007 (12 sampling events). Crabs were sampled using standard commercial crab traps that were baited with mixtures of dead fish and left submerged for 24 hr. Crabs collected in traps were sexed and counted, carapace width (in centimeters) was measured, and crabs were then released.

Trapping sites were located along the salinity gradient and within salinity zones that were loosely based on Venice salinity classifications and subclassifications (Anonymous, 1958): <5 psu (oligohaline); 5–10 psu (β -mesohaline); 11–18 psu (α -mesohaline); 19–24 psu (lower interval of polyhaline), and >25 psu (higher interval of polyhaline to euhaline; salinities of >30 psu were not encountered within the study area boundaries). Salinities were measured each trapping day to determine the locations of the zones, but not all zones were present during every trapping event. In particular, after excessive rainfall during July 2007, zones with salinities of greater than 19 psu were not present within the study area for the remainder of the study. Prior to July 2007, three traps

Fig. 1. Map of the upper Nueces Estuary (Nueces Bay and Nueces River) on the central Texas Gulf Coast. The study area extended from the I-37 bridge in the upper left to the high lines near the confluence of Nueces Bay and Corpus Christi Bay.

were deployed at least 30 m apart within each salinity zone. During sampling in July and early Sep. (flood conditions precluded sampling in Aug.), traps were placed 200 m apart in a continuous line across the study area because there was only one salinity zone present. In late Sep. and early Nov. sampling periods (no sampling occurred in Oct.), traps were divided evenly among the zones that were present within the boundaries of the study area. Because there was uneven effort across salinity zones, numbers of crabs were standardized to catch per unit effort (CPUE) based on the total numbers of traps deployed in each zone (crabs/trap/24 hr) in order to eliminate bias in comparing abundances across zones. Abundances by sampling event were also standardized to CPUE (15 traps/sampling event).

Results.—A total of 324 adult crabs and 10 juveniles of indeterminate sex were caught, with an overall CPUE of 1.9. Males predominated (80%), with an overall male to female sex ratio of 4.1:1. No ovigerous females were caught, and only three of the 62 females showed evidence of pubertal molt. One female was captured in a pre-mating embrace with a guarding male. Males dominated all salinity categories except the lower polyhaline category (19–24 psu) (Table 1). The mean sizes of males varied little among salinity zones; females were typically slightly smaller than males, and sizes were somewhat more variable. Males were most abundant in late summer and were anywhere from two to 18 times more abundant than females (Table 2). Juveniles were captured infrequently. Sizes of both males and

females varied over time, and females were frequently smaller than males. The largest males were collected in Nov. 2006, and the sizes of both males and females were greatest in March–May 2007 samples.

Discussion.—In this study, males dominated catches in all salinity zones except the lower polyhaline zone (19–24 psu). Male to female sex ratios in lower salinity zones of Chesapeake Bay ranged from 1:1 to 3:1, depending on seasonal migrations and reproductive activity (Posey et al., 2004). Sex ratios in this study equaled or exceeded, and often greatly exceeded, the most male-dominated ratios from Chesapeake Bay in most salinities and during most sampling events.

Throughout the range of the blue crab, juveniles of both sexes are typically found in the lower salinity areas that are often found in the upper portions of estuaries. Females undergo their pubertal molt, mate, and then migrate into higher salinity waters to spawn, probably because of the larval intolerance of salinities below 32 psu (Costlow and Bookhout, 1959). Thus, it was surprising that there was no time during this study when female blue crabs were abundant within the upper Nueces Estuary, particularly since the vast majority of females that were caught were large enough for their pubertal molt (~8.5 cm; Jivoff, 1997). This raises the question of whether female blue crabs in this estuary enter the lower salinity waters of the upper estuary as juveniles and then migrate into the lower estuary after they mate. In lower Galveston Bay, many females completed the spawning cycle within the estuary when salinities

TABLE 1. Summary of crab abundance and size (S.E.) in the tidal portion of the Nueces River and upper Nueces Bay, TX, by salinity category. CPUE indicates catch per unit effort.

Salinity	Effort	CPUE				Carapace width (cm)			Sex ratio
		♂	♀	Juvenile	Total	♂	♀	Juvenile	
<5	53	1.4	0.3	0.2	1.8	14.1 (0.2)	12.3 (0.5)	3.7 (0.7)	4.7:1
5–10	44	2.7	0.4		3.1	14.5 (0.2)	13.4 (0.4)		5.8:1
11–18	35	1.3	0.2	0.03	1.5	14.5 (0.3)	12.4 (1.1)	3.0 (0.0)	6.4:1
19–24	21	0.5	0.7		1.2	14.5 (0.4)	14.5 (0.6)		0.7:1
>25	27	0.4	0.2		0.6	14.3 (0.9)	11.9 (0.5)		2.4:1

were greater than 20 psu, whereas when salinities were <10 psu during spring and summer, most moved to the Gulf before the egg mass developed (More, 1969).

The Rhode River subestuary of the Chesapeake Bay is very similar to the portion of the Nueces Estuary that we studied. In the Rhode River, blue crabs partitioned habitat by size, sex, and molt stage, with most juvenile premolt crabs moving upstream (toward less saline waters) and most larger, postmolt individuals moving downstream (Hines et al., 1987). Females rarely went into the creek (lowest salinities) to molt, and the authors noted that it was likely that prepubertal females molted in the open-water basin (higher salinity, but still low), where mature intermolt males were abundant. This pattern of habitat partitioning may partially explain the low numbers of females encountered in the upper Nueces Estuary during this study. Females may not enter the river or upper bay as juveniles but may instead remain in the lower portions of the bay to both molt and mate.

Ultimately, however, the lack of females in the portion of the upper Nueces Estuary that we sampled may be a result of a lack of preferred juvenile habitat and/or attenuation of larval

transport mechanisms. Like juvenile blue crabs in Atlantic estuaries, those in Texas show a preference for seagrass habitat (Thomas et al., 1990). However, unlike their Atlantic counterparts, in the northwestern Gulf of Mexico juvenile blue crabs also use salt marsh surfaces as a nursery. Nueces Bay is primarily characterized by relict oyster reefs and unvegetated bottom, with limited areas of fringing salt marsh and some sparse seagrass, mostly along the northwestern edge.

While there is significant cover of salt marsh in some portions of the Nueces River Delta, numbers of juvenile blue crabs there are very low. Monthly juvenile blue crab abundance data (1998–2008; Erin Hill, Center for Coastal Studies, Texas A&M University–Corpus Christi, unpubl. data) from six stations in the upper Nueces Estuary averaged from 0 to 13 CPUE. The highest mean abundance for the 10-yr period (4.4 CPUE) was measured at a station in the delta characterized by fringing salt marsh. These juvenile blue crab abundances correspond to densities of less than 1 m^{-2} and are much lower than the $1.3\text{--}22.1 \text{ m}^{-2}$ juvenile blue crab densities reported for salt marsh habitat in the lower portions of the Galveston Bay system

TABLE 2. Summary of crab abundance and size (S.E.) in the tidal portion of the Nueces River and upper Nueces Bay, TX, by sampling event. CPUE indicates catch per unit effort, Juv, juveniles.

Event	CPUE				Carapace width (cm)			Sex ratio
	♂	♀	Juv	Total	♂	♀	Juv	
25 Nov. 2006	0.4	0.1	0	0.5	16.7 (1.4)	13.4 (0.4)		3:1
14 Dec. 2006	0.6	0.2	0.07	0.9	12.8 (0.7)	11.7 (1.1)	3.0 (0.0)	3:1
13 Jan. 2007	1.5	0.1	0	1.6	14.2 (0.4)	11.5 (1.0)		11:1
10 Feb. 2007	0.7	0.4	0	1.1	13.1 (0.3)	13.2 (0.9)		1.8:1
24 March 2007	1.3	0.7		2.0	15.1 (0.5)	13.3 (0.5)		1.8:1
22 April 2007	1.3	0.6		1.9	14.8 (0.4)	14.9 (0.9)		2.2:1
18 May 2007	2.1	0.7	0	2.8	15.1 (0.5)	14.2 (0.7)		2.8:1
22 June 2007	0.8	0.2	0	1.0	12.9 (0.7)	12.8 (1.3)		4:1
27 July 2007	0.9	0.3	0.3	1.5	13.5 (0.8)	12.5 (1.2)	5.0 (1.2)	2.8:1
8 Sep. 2007	4.1	0.3	0.07	2.9	14.1 (0.3)	12.1 (0.2)	2.5 (0.0)	12.2:1
29 Sep. 2007	2.5	0.3	0.3	3.1	14.7 (0.3)	11.4 (1.2)	2.6 (0.2)	7.4:1
11 Nov. 2007	1.2	0.1	0	1.3	14.7 (0.3)	10.0 (0.0)		18:1

(Thomas et al., 1990). Cover of both salt marsh and seagrass are greater in the lower portion of the Nueces Estuary (Corpus Christi Bay) and adjacent Redfish Bay, areas that would be encountered first, regardless of whether larvae were spawned in the nearshore area or within the more saline portions of the bay.

Blue crab postlarvae on the Atlantic Coast use selective tidal stream transport to move up-estuary to nursery areas (Forward et al., 2003). However, in Corpus Christi and Redfish bays tidal movements played a relatively small role in particle transport, and accumulation of particles is primarily a result of nontidal processes (i.e., wind forcing and seasonal variations in coastal water levels; Brown et al., 2005). Simulation models of particle transport showed that particle concentration and input were relatively low in the mouth of Nueces Bay and absent in the area that more or less corresponds to our study area.

Clearly, this study raises more questions than it answers. It underscores the need for a greater understanding of the life history of blue crabs in Texas bays, in particular the factors governing distribution of females. There appear to be substantial differences between blue crab life histories in Texas and on the Atlantic coast. Thus, relying on generalizations about blue crab life history that are based on data from Atlantic coast populations is unlikely to prove satisfactory when trying to manage the species and its fishery in Texas.

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