Relationship of Blue Crab Abundance to River Discharge and Salinity

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Abstract: The relationships between 2 environmental factors (river discharge, salinity) and blue crab *(Callinectes sapidus)* abundance, as measured by juvenile recruitment and commercial landings, were evaluated. Correlation coefficients were calculated between a blue crab recruitment index (Jan–Feb catch-per-unit effort of individuals <40 mm carapace width) or commercial harvest and lagged or concurrent salinity and river discharge. The recruitment index was correlated with monthly means of lagged late summer/early fall Mississippi River discharge (positively) and salinity (negatively) whereas commercial harvest were significantly correlated with unlagged Mississippi River discharge (positively) and salinity (negatively). The effects of Mississippi River discharge and salinity on blue crab recruitment and abundance were probably manifested indirectly through biotic mechanisms such as predation.

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The blue crab (*Callinectes sapidus* Rathbun) is an abundant macroinvertebrate that supports valuable recreational and commercial fisheries in Louisiana. Approximately two-thirds of Gulf of Mexico blue crab landings are from Louisiana (Guillory and Perret 1998). The life history of the blue crab involves a complex cycle of planktonic, nektonic, and benthic stages which occur throughout the estuarine-nearshore marine environment (Perry et al. 1984). Spawning peaks in mid summer in the lower estuary and adjacent marine waters. Zoea are transported offshore where they transform into megalopae. The megalopae later reenter the estuary, settle to the bottom, and transform into the first crab stage. Juvenile blue crabs become widely distributed throughout the estuary. Harvestable size, or 127 mm carapace width (CW), is reached within 10–12 months.

Wetland loss in coastal Louisiana is approximately 65 km^2 per year. Controlled Mississippi River freshwater diversions may be a viable coastal restoration tool to combat coastal land loss in Louisiana. The diversions would allow freshwater to be introduced into the recipient estuary to mitigate the adverse effects of saltwater intrusion on marsh vegetation. One such project has been completed (Caernarvon), one is under construction (Davis Pond) and several more have been proposed.

The spatial distribution and abundance of juvenile and adult blue crabs and subsequent commercial harvest may be influenced by altered salinity regimes associated with freshwater diversions. Proponents of freshwater diversion postulate that the preservation of coastal marshes and reduction in salinities will benefit some estuarine-dependent species such as blue crab. However, the effects of river discharge or salinity on blue crab recruitment or abundance has not been adequately quantified in Louisiana. In contrast to other major commercial invertebrate species in Louisiana such as brown shrimp *(Penaeus actecus)* and white shrimp *(P. setiferus)* (Gunter and Edwards 1969, Barrett and Gillespie 1973) and American oyster *(Crassostrea virginica)* (Owen 1953, Van Sickle et al. 1976, Chatry et al. 1983), the effects of river discharge or salinity on interannual variability in blue crab recruitment or abundance has not been adequately verified.

This study investigates the potential effects of river discharge and salinity on blue crab abundance. The objectives are to examine the relationships between annual blue crab recruitment and commercial landings and river discharge and salinity.

Methods

Long-term juvenile blue crab recruitment, commercial harvest, and environmental data were obtained from several sources. Juvenile recruitment data were obtained from the Louisiana Department of Wildlife and Fisheries (LDWF) 1967–1998 assessment and monitoring program from the south-central Louisiana coast between the Mississippi and Atchafalya rivers. There are 3 coastal study areas (CSAs) in the study area (Barataria Bay, Timbalier/Terrebonne Bay and Caillou Lake/Lake Mechant), each with 3 to 4 inshore trawl stations. Ten-minute 4.9-m trawl samples were taken weekly from March–October and biweekly from November–February. Blue crabs were counted, sexed, and CW of up to 50 individuals measured in 5-mm intervals. The total number of scheduled samples generally ranged from 550 to 600 per year. This is the most extensive estuarine trawl data base in the Gulf of Mexico and south Atlantic.

Commercial blue crab harvest data were obtained from the National Marine Fisheries Service (NMFS) prior to 1989 and from the LDWF from 1989 to 1998. Numbers of commercial blue crab fisherman were obtained from the NMFS estimates from 1970 to 1977 and from LDWF commercial trap license records from 1978 to 1998. Data were not available specific to the study region over the entire study period, so statewide figures were used. Statewide data were considered acceptable because it has been estimated that approximately two-thirds of the Louisiana harvest comes from within the study area (Guillory et al. 1996).

Monthly means of Mississippi River discharge (MRDISC) in cubic feet/second (cfs) were obtained from Tarbert's Landing, and lower bay (LBSAL) and upper bay (UBSAL) salinity in parts per thousand (ppt) were obtained from constant recorders at Grand Terre, Barataria Bay and St. Mary's Point, Barateria Bay, respectively.

Pearson correlation coefficients and probabilities were calculated between either a blue crab recruitment index or commercial harvest and monthly means of each environmental factor. The time frame of the included environmental factors was based upon known blue crab life history parameters. Spawning peaks in mid- to late-summer (Perry 1975), with a subsequent late summer – early fall megalopal settlement peak (Perry et al. 1995, Rabalais et al. 1995). Monthly growth has been estimated at 24–25 mm CW in Mississippi (Perry 1975) and 14 mm CW in Louisiana (Adkins 1972) for small juveniles and 15–20 mm CW for larger juveniles >85 mm CW in Louisiana (Adkins 1972). Harvestable size is reached by 12 months.

Results

Determination of the blue crab recruitment index involved several steps. First, 1967–1998 CW frequency data were used to characterize relative abundance of blue crabs by 10 mm CW size groups (Fig. 1). Few (0.3%) blue crabs <10 mm CW were collected. The modal peak included the 20–29 and 30–39 mm CW size groups; each size group contributed more than 17% of the total. Numbers of blue crabs sharply declined from 40–79 mm CW while blue crabs >80 mm CW declined more gradually. Blue crabs <40 mm CW comprised 41.5% of the total and were classified as recruits. Second, monthly recruit catch-per-unit-effort (CPUE) was used to select the appropriate time period for inclusion in the recruitment index (Fig. 2). The highest CPUEs were in January and February. The recruitment index was subsequently defined as January–February. CPUE of blue crabs <40 mm CW. The inclusive sizes and time period of the index corresponds to early blue crab life history patterns and known growth rates in the northern Gulf of Mexico.

The recruitment index fluctuated from year to year, ranging from 1.3 in 1977 to 14.4 in 1980 (Fig. 3). Correlation coefficients were calculated between the recruitment

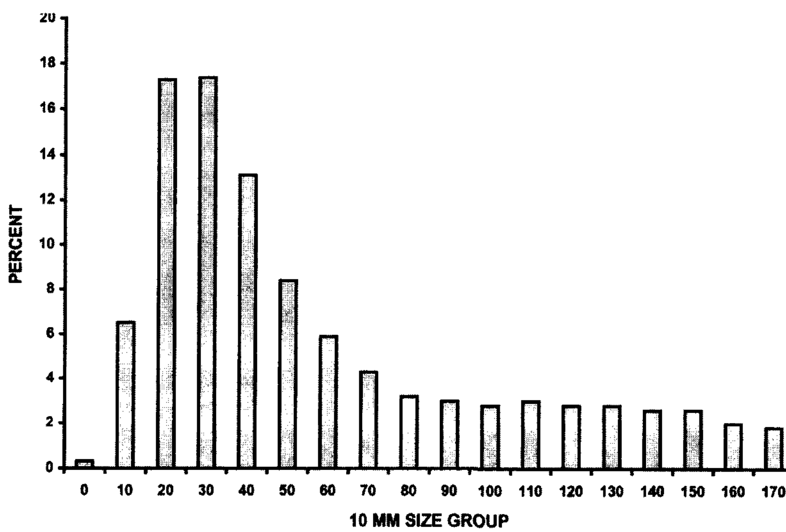

Figure 1. Overall carapace width frequency distribution of blue crabs by 10 mm CW size group collected in 4.9-m trawl samples, 1967–1998.

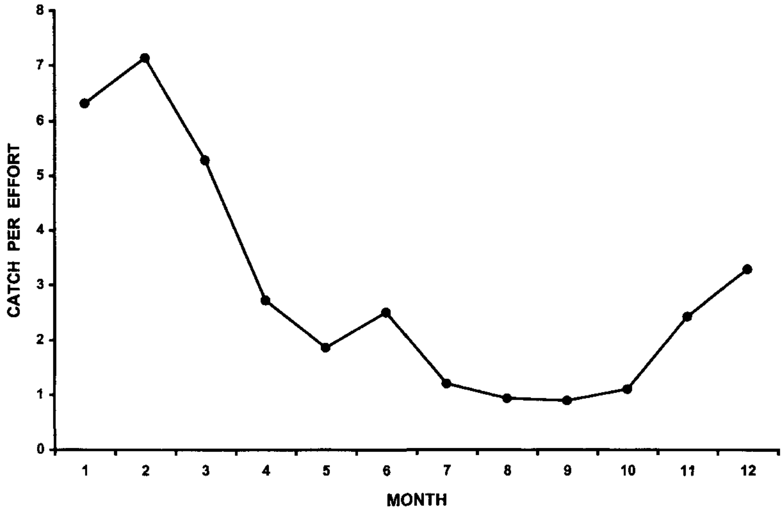

Figure 2. Monthly catch per effort (CPUE) of blue crabs <40 mm CW, 1967–1998.

index and lagged July–December and unlagged January–February monthly MRDISC, LBSAL, UBSAL; these months ranged from peak megalopal settlement in the estuary through the defined recruitment index. Significant correlations included July LBSAL ($r=-0.43$, $P=0.017$), August MRDISC ($r=-0.49$, $P=0.006$), September MRDISC ($r=-0.58$, $P=0.0008$), and September LBSAL ($r=-0.43$, $P=0.021$).

Both blue crab commercial harvest ($r=-0.87$, $P=0.0001$) and number of commercial fisherman ($r=-0.83$, $P=0.0001$) from the 1960 to 1997 period significantly

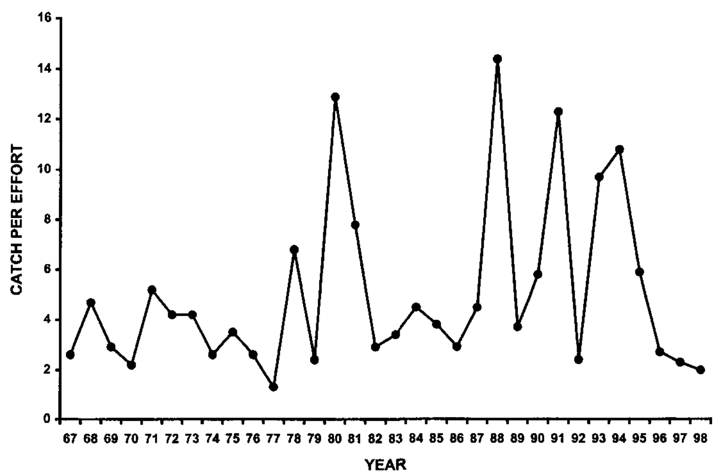

Figure 3. Annual January–February catch per effort (CPUE) of blue crabs <40 mm CW, 1967–1998.

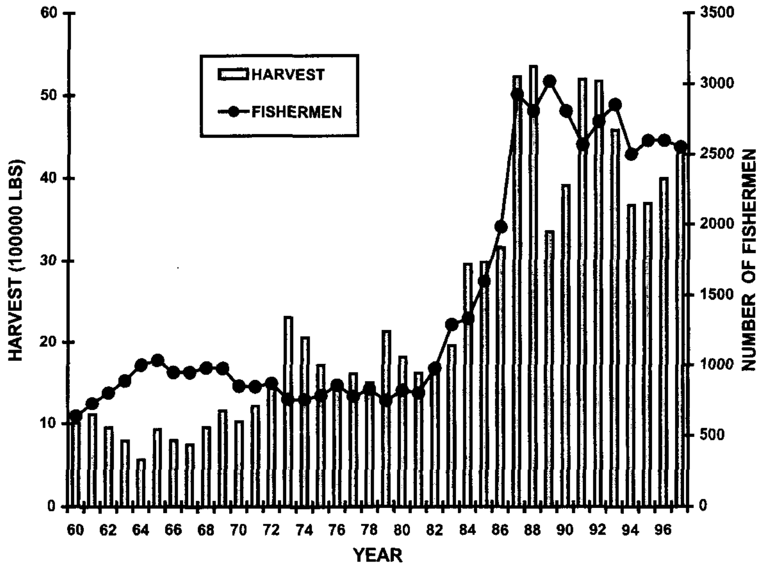

Figure 4. Annual Louisiana blue crab commercial harvest and numbers of commercial fishermen, 1960–1997.

increased over time (Fig. 4). There was a significant correlation between harvest and fishing effort (r=−0.91, P=0.0001). Consequently, catch per commercial fisherman (CPF) was used in the correlation analyses. Correlation coefficients were calculated between CPF and lagged July–December and unlagged January–June monthly MRDISC, LBSAL, and UBSAL. Significant correlations with CPF included

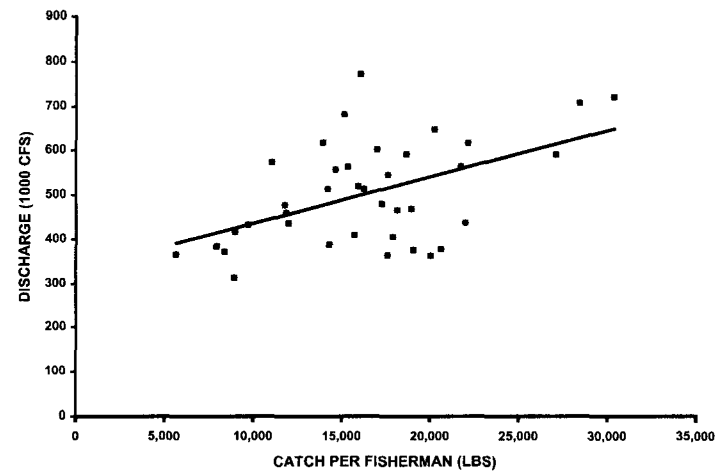

Figure 5. Scatter plot and trend line between annual catch per commercial fisherman (CPF) and unlagged Mississippi River discharge, 1960–1997.

November (r=−0.36, P=0.0267), December (r=−0.40, P=0.004), January (r=−0.44, P=0.0066), and April (r=−0.38, P=0.0252) LBSAL; and April (r=−0.34, P=0.0430), May (r=−0.40, P=0.0182), and June (r=−0.37, P=0.0225) UBSAL. Correlation coefficients were then calculated between CPF and lagged mean July–December, unlagged January–March, and unlagged January–December MRDISC, LBSAL, and UBSAL. Lagged July–December (r=−0.42, P=0.009), unlagged January–March (r=−0.39, P=0.0152), and unlagged January–December (r=−0.48, P=0.0026) LBSAL were significantly correlated CPF.

To further illustrate the relationship between CPF and MRDISC, years from 1960 to 1997 were characterized as having high (>600,000 cfs), average (400,000–599,000 cfs), and low (<400,000 cfs) annual river discharge. In high-flow years, CPF increased from the previous year in 6 of 8 instances. In low-flow years, CPF declined from the previous year in 6 of 9 instances. Additionally, annual MRDISC is plotted against CPF in Fig. 5.

Discussion

High Mississippi River discharge and low salinity were associated with increased blue crab recruitment or commercial harvest. Discharge from the Mississippi River and Atchafalaya River (a major distributary) represents over 90% of the total river discharge in Louisiana (Perrett et al. 1971) and, at high discharge rates, dilute salinities along two-thirds of the Louisiana Coast (Barrett and Gillespie 1973). Recruit CPUE was related to late summer–early fall (July–September MRDISC (positively) and LBSAL (negatively). This period corresponds to peak megalopal settlement (Perry et al. 1995, Rabalais et al. 1995) and early juvenile crab development in the northern Gulf of Mexico. Other literature also supports my observation that high Mississippi River discharge and low salinities may be beneficial to blue crabs. The association of juvenile blue crabs and low salinity habitats in Louisiana was documented by Perret et al. (1971); highest catches were found at salinities below 5 ppt. Significant correlations were found between CPF and unlagged and lagged MRDISC and LBSAL. A positive association between river discharge commercial blue crab landings was also noted in Texas (More 1969) and Apalachicola Bay, Florida (Wilber 1994).

The reported correlations between blue crab recruitment or harvest and river discharge or salinity do not necessarily imply causality. Potential effects of environmental factors on blue crab population size may be synergistic, intrinsic (i.e., physiological), and/or extrinsic (i. e., affecting composition of the surrounding biotic environment) (Perry et al. 1984). Wilber (1994) concluded that the positive effects of high Apalachicola River discharge on blue crabs were attributed to several possible mechanisms: increased estuarine input of detritus and nutrients; increased area of suitable habitat for juveniles; and, reduced predation because of lower salinities. For several reasons, river discharge and salinity probably has an indirect effect on blue crabs in Louisiana through biotic mechanisms such as predation. First, juvenile blue crabs can tolerate a wide range of salinities (Tagatz 1969, Holland et al. 1971, Copeland and

Bechtel 1974). Second, recent literature has emphasized the influence of biotic mechanisms, including predation, on blue crab distribution and abundance (Laughlin 1979, Orth and Von Montfrans 1990). Orth and Von Montfrans (1990) partially attributed regional differences in juvenile blue crab abundance to latitudinal differences in diversity and abundance of predators. Predation of recent megalopal settlers quickly damped differences in juvenile abundance among sites in Mobile Bay, Alabama regardless of initial settlement densities (Heck et al., unpubl. data, cited in Morgan et al 1996). Morgan et al. (1996) concluded that early post-settlement predation may limit population size of blue crabs in the northern Gulf of Mexico. Guillory (unpubl. data) found significant relationships between red drum *(Sciaenops ocellatus)* CPUE in assessment and monitoring trammel net samples and blue crab commercial catch per fisherman (negative correlation) and instantaneous mortality rates of individuals >35 mm CW (positive correlation); red drum are a major fish predator of juvenile blue crabs (Guillory and Elliot 2001). The net result of high river discharge and low salinities may be to displace some marine fish predators and subsequently reduce the predation component of natural mortality.

The positive link between blue crab recruitment or commercial harvest and river discharge identified in this study and in Texas and Florida (More 1969, Wilber 1994) and the high abundance of juvenile blue crabs in low salinity habitats in Louisiana (Perret et al. 1971) suggest that freshwater diversions and associated lower salinities could be beneficial to the blue crab resource.

Literature Cited

Adkins, G. B. 1972. Study of the blue crab fishery in Louisiana. La. Wildl. Fish. Comm., Tech., Bull. No. 2. 57pp.

Barrett, B. B. and M. C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. La. Wildl. Fish. Comm., Tech. Bull. No. 21. 28pp.

Chatry, M., R. J. Dugas, and K. A. Easley. 1983. Optimum salinity regime for oyster production on Louisiana's state seed grounds. Contrib. Mar. Sci. 26:81–94.

Copeland, B. J. and T. J. Bechtel. 1974. Some environmental limits of six gulf coast estuarine organisms. Contrib. Mar. Sci. 18:169–204.

Guillory, V. and M. Elliot. 2001. A review of blue crab predators. Pages 69–83 *in* V. Guillory, H. M. Perry, and S. Vanderkooy, eds. Proc. Blue Crab Mortality Symp. Gulf States Mar. Fish. Comm., Publ. No.—.

——— and W. E. Perret. 1998. Management, history, and status and trends in the Louisiana blue crab fishery. J. Shellfish Res. 17(2):413–424.

———, P. Prejean, M. Bourgeois, J. Burdon, and J. Merrell. 1996. A biological and fisheries profile of the blue crab, *Callinectes sapidus*. La. Dep. Wildl. and Fish., Fish. Manage. Plan Ser. No. 8, Part 1. 210pp.

Gunter, G. and J. C. Edwards. 1969. The relation of rainfall and fresh water drainage to the production of penaeid shrimp (*Penaeus fluviatilis* Say and *Penaeus aztecus* Ives) in Texas and Louisiana waters. FAO Fish. Rep. 57:875–892.

Holland, J. S., D. V. Aldrich, and K. Strawn, 1971. Effects of temperature and salinity on growth, food conversion, survival and temperature resistance of juvenile blue crab, *Callinectes sapidus* Rathbun. Texas A&M Univ., Sea Grant Publ. TAMU-SG-71–222. 166pp.

Laughlin, R. A. 1979. Trophic ecology and population distribution of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola estuary (North Florida). PhD. Diss., Fla. State Univ., Tallahassee. 143pp.

More, W. R. 1969. A contribution to the biology of the blue crab (*Callinectes sapidus* Rathbun) in Texas, with a description of the fishery. Texas Parks and Wildl. Dep., Tech. Ser. 1. 31pp.

Morgan, S. G., R. K. Zimmer-Faust, K. L. Heck, Jr., and L. D. Coen. 1996. Population regulation of the blue crabs, *Callinectes sapidus,* in the northern Gulf of Mexico: postlarval supply. Mar. Ecol. Prog. Ser. 133:73–88.

Orth, R. J. and J. Von Montfrans. 1990. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus:* a latitudinal perspective. Bull. Mar. Sci. 46(1):126–144.

Owen, H. M. 1953. The relationship of huigh temperatures and low rainfall to oyster production in Louisiana. Bull. Mar. Sci. Gulf Caribb. 3(1):34–43.

Perret, W. S., W. R. Latapie, J. F. Pollard, W. R. Mock, G. B. Adkins, W. J. Gaidry, and J. C. White. 1971. Fishes and invertebrates collected in trawl and seine samples in Louisiana estuaries. Section 1. Pages 39–105 *in* Cooperative Gulf of Mexico estuarine inventory and study. Phase IV. Biology. La. Wildl. and Fish. Comm.

Perry, H. M. 1975. The blue crab fishery in Mississippi. Gulf Res. Rep. 5(1):39–57.

———, G. Adkins, R. Condrey, P. C. Hammerschmidt, S. Heath, J. R. Herring, C. Moss, G. Perkins, and P. Steele. 1984. A profile of the blue crab fishery of the Gulf of Mexico. Gulf States Mar. Fish. Comm., Publ. No. 9. 80pp.

———, C. K. Eleuterius, C. B. Trigg, and J. R. Warren. 1995. Settlement patterns of *Callinectes sapidus* megalopae in Mississippi Sound: 1991, 1992. Bull. Mar. Sci. 57(3):821–833.

Rabalais, N. N., F. R. Burditt, L. D. Coen, B. J. Cole, C. Eleuterius, K. L. Heck, Jr., T. A. McTigue, S. G. Morgan, H. M. Perry, F. M. Treusdale, R. K. Zimmer-Fause, and R. J. Zimmerman. 1995. Settlement of *Callinectes sapidus* megalopae on artificial collectors in four Gulf of Mexico estuaries. Bull. Mar. Sci. 57(3):855–876.

Tagatz, M. E. 1969. Some relations of temperature acclimation and salinity to thermal tolerance of the blue crab, *Callinectes sapidus.* Trans. Am. Fish. Soc. 98(4):713–716.

Van Sickle, V. R., B. B. Barrett, T. B. Ford, and L. J. Gulick. 1976. Barataria basin: salinity changes and oyster distribution. La. Wildl. and Fish. Comm., Tech. Bull. No. 20. 22pp.

Wilber, D. H. 1994. The influence of Apalachicola River flow on blue crab, *Callinectes sapidus,* in north Florida. Fish. Bull. 92:180–188.