The Relationship Between Flows, Salinity, and Blue Crabs

By

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Conclusion

Blue crab are an economically and ecologically important species. Historically, San Antonio Bay appears to have had a near optimum salinity for blue crab. Declines in blue crab would likely occur with increasing salinity in San Antonio Bay.

Introduction

Crabs are one of the most numerous and diverse group of organisms that use all Texas estuarine habitats. Formally, crabs are crustaceans in the Subphylum Crustacea, and Class Decapoda. An analysis of the Texas Parks and Wildlife (TPWD), Coastal Fisheries data base shows that 66 species of crabs have been found in Texas bays. Of the 66 species found, three species belong to the genus *Callinectes*, which are commonly called "Blue Crabs." The blue crab that is most often of interest of the three is *Callinectes sapidus*. *Callinectes sapidus* is the largest in size of the three species, the most commonly distributed, and supports an important commercial and recreational fishery. Additionally, blue crabs in the San Antonio Bay system are a very important item in the diet of the endangered Whooping Cranes (Slack et al. 2009).

Blue Crab Biology

The biology and life history of blue crabs is well known because it is an important fisheries species. The following discussion is based on several sources (The Blue Crab Archives, Steele 1991, Steele and Bert 1994, and Steele and Perry 1990).

Blue crabs have an estuarine dependent life cycle in which the organism depends on the structure and function of estuaries in order to complete its life cycle. Adult crabs are also benthic, meaning bottom-dwelling, organisms. In contrast, juvenile crabs are pelagic, meaning they swim in the water column. This combination of an alternating life cycle (where juveniles are pelagic and adults are benthic) and estuarine dependency is the most common life cycle for estuarine organisms. This is because the juvenile stages take advantage of the salinity gradient, and the concomitant productivity gradient, in the water column to obtain nutrition and act as a cue to finding nursery habitats. As mentioned earlier, it is common for the upper parts of estuaries, near the river mouths, to be lined with marshes. Marshes are important as nursery habitats because the structure of the marsh provides a refuge from predation by larger organisms, increasing the probability that the juveniles will survive to adulthood. Marshes are also rich in productivity so the nursery habitats contain a large amount of food that is required for growth.

Adult crabs spawn offshore or in the inlets where the ocean water mixes with bay water. The eggs float in the water and hatch. Hatching occurs at night during a high slack tide to promote seaward movement of larvae. The hatched larva is named a zoea. The zoea are planktonic,floating in the offshore water. The zoea metamorphose into a lobster-like stage name the megalops. The megalops also live offshore, invade estuaries on rising tides, and settle on bottom of the primary bays at slack tide (Tankersly et al 2004).

The first crab stage disperses to lower salinity areas by following the cue of changing salinity. There can be 18-20 juvenile instar molts and much of this growth occurs in the secondary bays. Eventually the crabs molt into adult stages. For the females the adult molt is a terminal molt, but males can molt more as they age.

Mating takes place within a 3-5 day window after female terminal molt. Females are catadromus, meaning they mate only once in their lifetime. In contrast, males have multiple mates. The males live in estuary all of their post-larval life, and to prevent mortality molt en masse at freshwater streams.

Spawning occurs in spring, summer and fall. Sperm can remain viable within female for a year or more and can be used for repeat spawning. Females migrate offshore to hatch eggs.

Role of Salinity

Salinity plays an important role in the blue crab life cycle. Hatching requires salinity >20 ppt, and there no hatching at 15 ppt or below. This is because females normally release eggs offshore. The optimal range of salinity for hatching is between 23 - 28 ppt. Development of the megalopae can proceed over a large range of salinity, but it proceeds most rapidly in the range of 15-35 ppt (Tankersley and Forward 2007). Older juvenile molt stages and adults can range throughout an estuary and are very tolerant of a wide range of salinity. However, growth rates and size at maturity occurs are higher at lower salinities (Fisher 1999). Temperature also affects growth and size, and bigger crabs are found in cooler waters (Darnell et al. 2009). Blue crabs partition habitat by salinity. For example in central Chesapeake Bay, most crabs move upstream to lower salinity areas to molt, and then start to move downstream (Hines et al. 1987).

One of the most important roles of salinity is that disease and parasites have much higher occurrences at high salinities than at low salinities. One disease is the fungus *Lagenidium callinectes*, which attacks egg masses, but the fungus does not grow normally in fresh water (Rogers-Talbert 1948). The Nemertean worm, *Carcinonemertes carcinophila*, is an egg predator, which is restricted to high salinity (Shields 1994). The gooseneck barnacle *Octolasmis muelleri* is a gill parasite, which is restricted to high salinities greater than 15 ppt (Walker 1974).

Another crustacean parasite that is found in the Gulf of Mexico is the rhizocephalan barnacle *Loxothylacus texanas*, which infects the gonads of blue crabs. The *Loxothylacus* larvae survive best in salinities between 20 to 35 ppt, and not at all below 20 ppt (Tindle et al. 2004). There are also dinoflagellate parasites, such as *Hematodinium perezi*, which invades the blood and kills blue crabs. *Hematodinium* is most prevalent in crabs collected from salinities of 26 to 30‰ with no infected crabs found in salinities below 11‰ (Messick and Shields 2000).

Methods for New Analyses

This study was conducted in San Antonio bay, TX using a data set that extends from 1977 - 2010. Nekton catch data were obtained from the Texas Parks and Wildlife Department coast-wide fisheries bag seine monitoring program that was established in all Texas bay systems in 1977 and continued through 2010. Data were collected using a randomized, stratified sampling design along the shoreline of each bay with 18.3 x 1.8-m bag seines. Bag seines used in this study were designed to sample juvenile, estuarine fish populations (Martinez-Andrade et al., 2009; Froeschke and Froeschke, 2011). Bag seines were deployed each month and sample locations were selected independently and without replacement for each month (Martinez-Andrade et al., 2009). For this study, data from San Antonio Bay (n = 3,434) were used to identify blue crab-habitat relationships and develop distribution maps.

Six variables (month, year, dissolved oxygen (DO, temperature, salinity, and depth) relevant to blue crab were examined. Salinity, temperature, turbidity, and DO were collected in surface waters (0-15 cm) during each sampling event. Turbidity readings were processed in the laboratory within 24 h of sampling using a calibrated turbidimeter. Maximum depth was recorded for each sampling event. All variables were measured during each sampling event.

Boosted regression trees (BRTs) were used to examine relationships between blue crab distribution and environmental variables and to predict probability of capture across a range of environmental conditions. Analyses were carried out using R (version 2.10.0, R Development Core Team, 2009) and the "gbm" library supplemented with functions from Elith et al. (2008). The model was fit to allow interactions using a tree complexity of 5 and a learning rate of 0.001. Optimum model complexity and learning rate were determined iteratively using exploratory analyses across a range of plausible settings. Ten-fold, cross-validation of training data was used to determine the optimal number of trees necessary to minimize deviance and maximize predictive performance.

To develop maps of predicted blue crab distribution based on environmental conditions, suites of environmental conditions were developed in San Antonio Bay based on the environmental sampling data measured during nekton sampling. The fitted BRT model was then used to predict the probability of capture to the mapped grids of environmental conditions in the entire study area in average and varying salinity conditions.

Results

Salinity influences blue crab abundance in San Antonio Bay (Figure 1 and Figure 2). The variables that influence blue crab abundance the most are temperature, year, dissolved oxygen, and salinity.

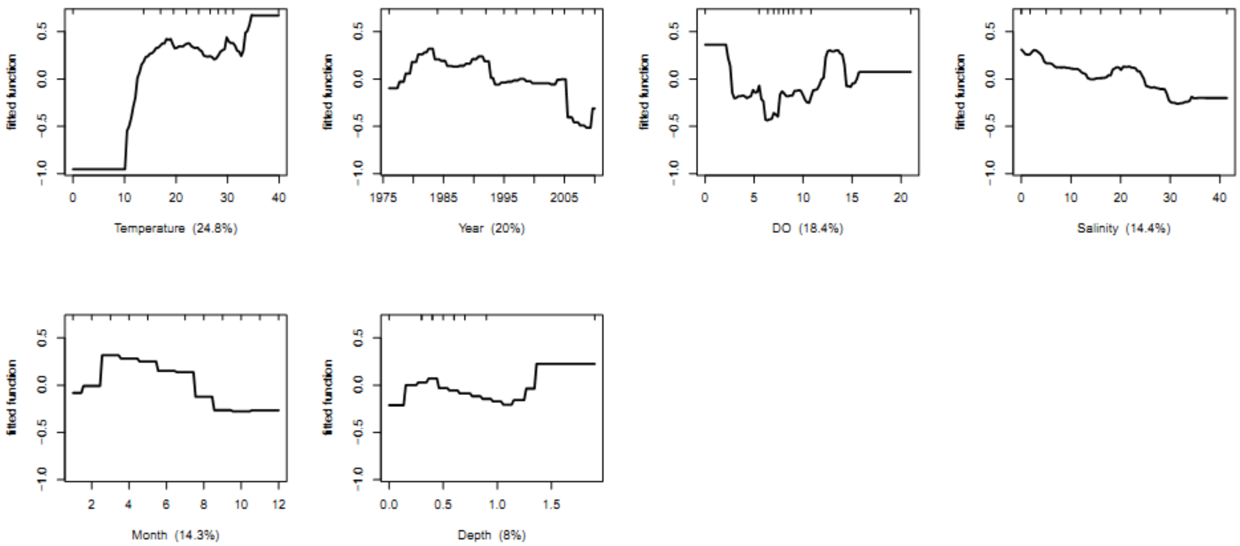

Figure 1. Functions fitted to the predictor variables by a boosted regression tree (BRT) model relating the probability of occurrence of blue crab to the environment. Y-axes are on the logit scale with mean zero. X-axes parameters: temperature (°C), salinity (psu), dissolved oxygen (DO) (mg O_2 l^{-1}), year, and month. Percentages indicate proportion of explained deviance attributed to each predictor variable.

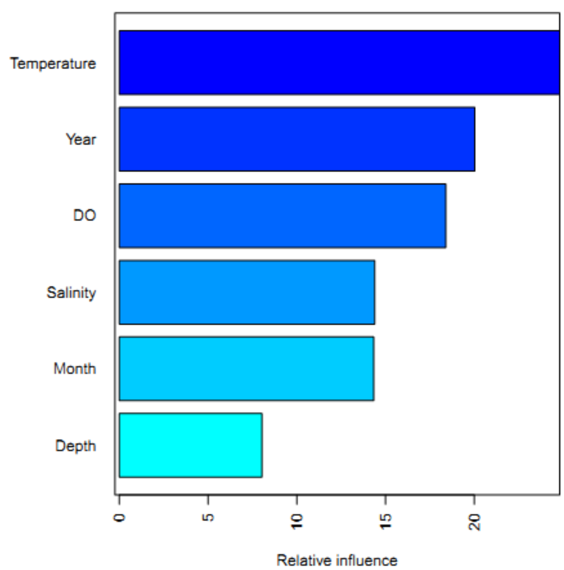

Figure 2. Average contributions (%) of environmental variables predicting presence or absence of blue crabs. DO = dissolved oxygen.

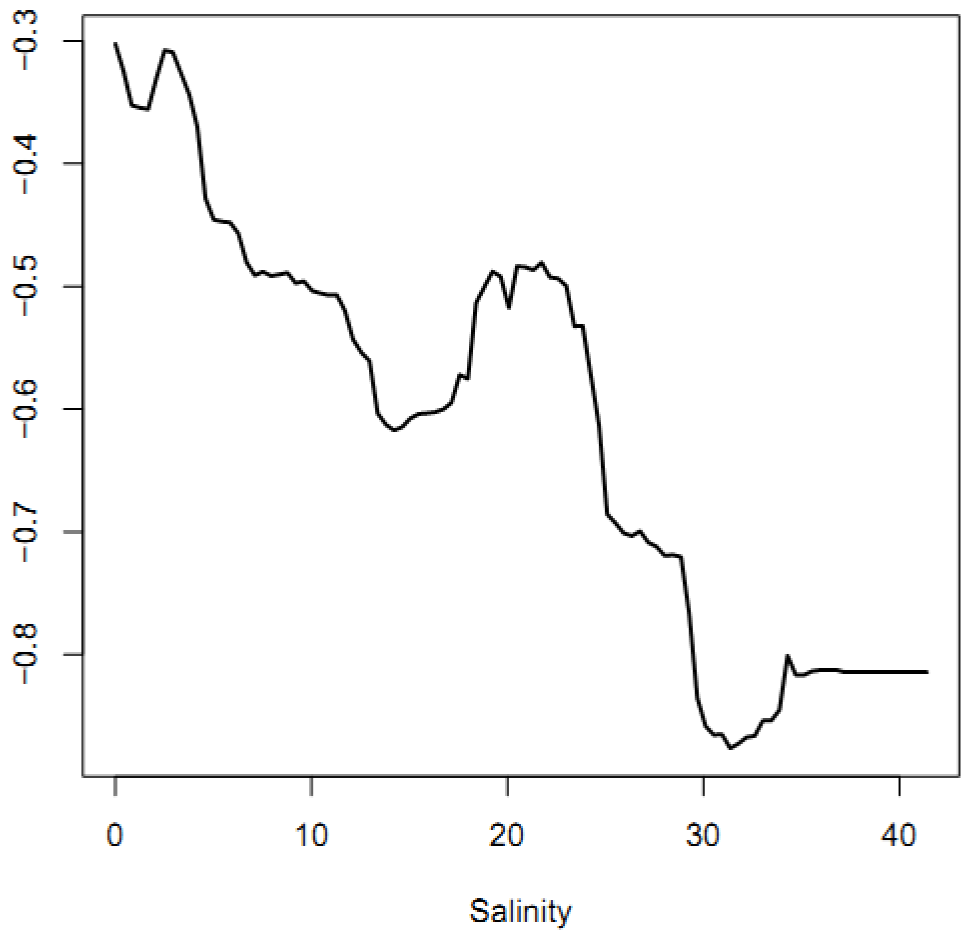

Figure 3. Functions fitted to salinity by a boosted regression tree (BRT) model relating the probability of occurrence of blue crab to salinity. Y-axis is on the logit scale.

The preferred salinity range for blue crab is approximately 10 - 25 psu (Figure 3). Blue crab abundance in San Antonio Bay dramatically decreases above and below this salinity range.

Maps of blue crab probability of occurrence (proxy for abundance) under varying salinity regimes were produced to visually show their distinct freshwater inflow response. Predictions were restricted to the shoreline areas of the bay where samples were collected. Under average salinity conditions at each sampling location, blue crabs are most abundant in the northern and western areas of the bay (Figure 4).

By reducing salinity (increasing freshwater inflow) 5 psu (Figure 5A) and 10 psu (Figure 5B) from the average there is a higher probability of capture of blue crabs throughout the bay. When salinity is decreased 10 psu from the mean, the abundance of blue crabs will increase up to 10% throughout the bay (Figure 5A). In contrast, when the salinity is increased 10 psu from the mean blue crab abundance will decrease up to 5%. Increasing salinity (decreasing freshwater inflow) by 5 psu (Figure 5C) and 10 psu (Figure 5D) from the average greatly reduces the likelihood of blue crab capture along the bay margins.

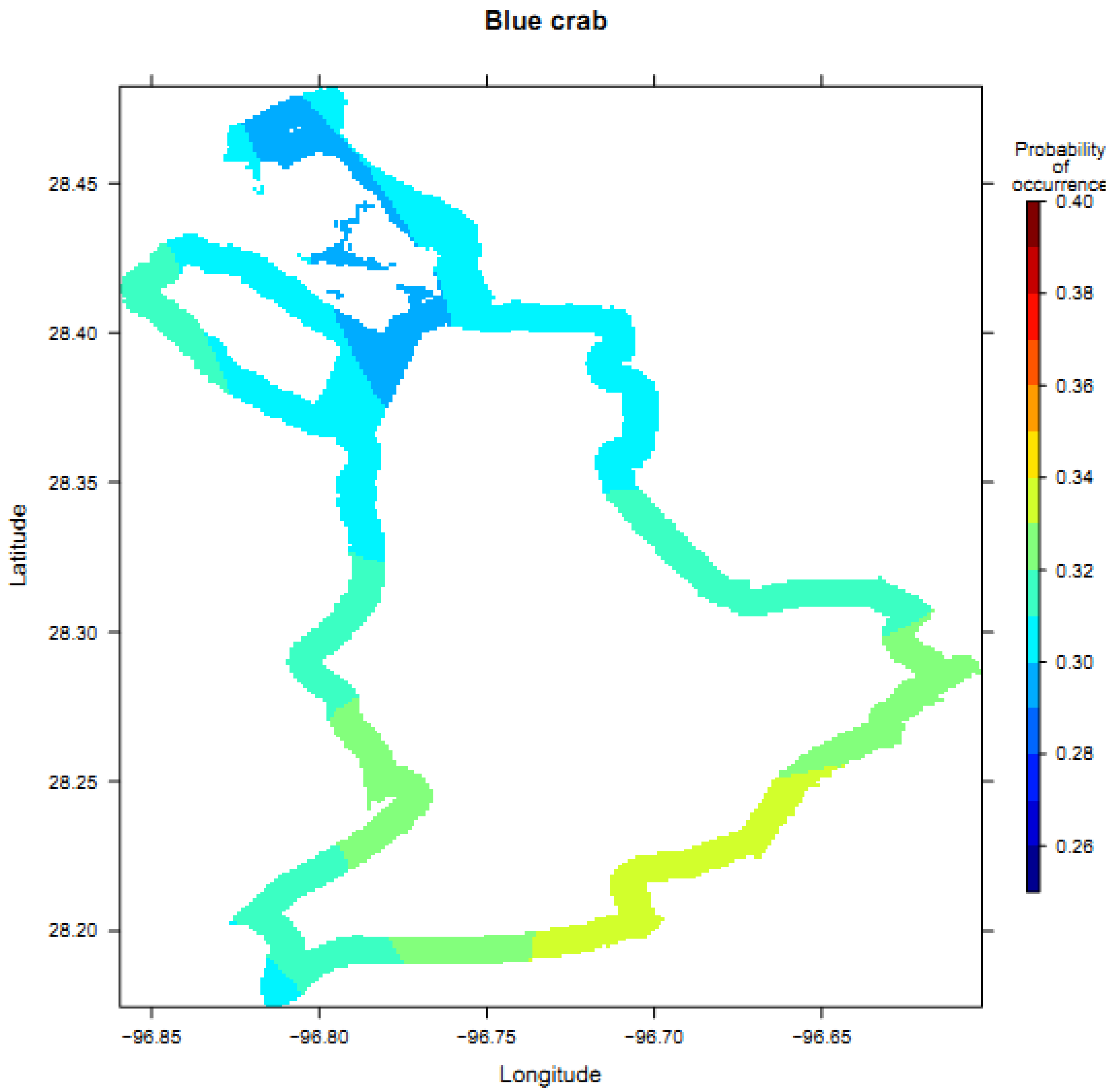

Figure 4. Probability of occurrence map of blue crab as predicted by a boosted regression tree (BRT) model under average salinity conditions.

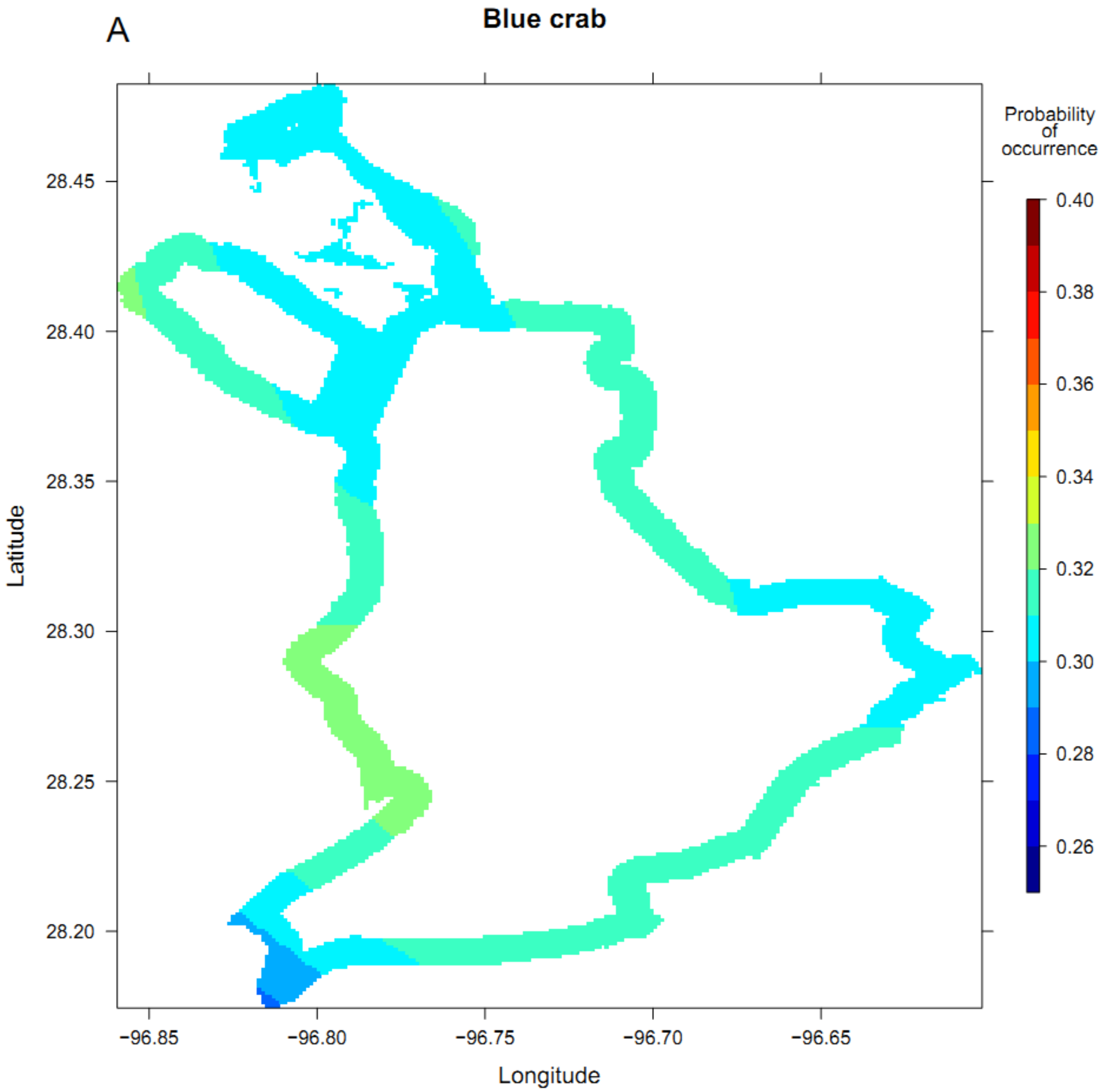

Figure 5A. Blue crab predicted probability of occurrence as predicted by a boosted regression tree (BRT) model when mean salinity is reduced 5 psu (A).

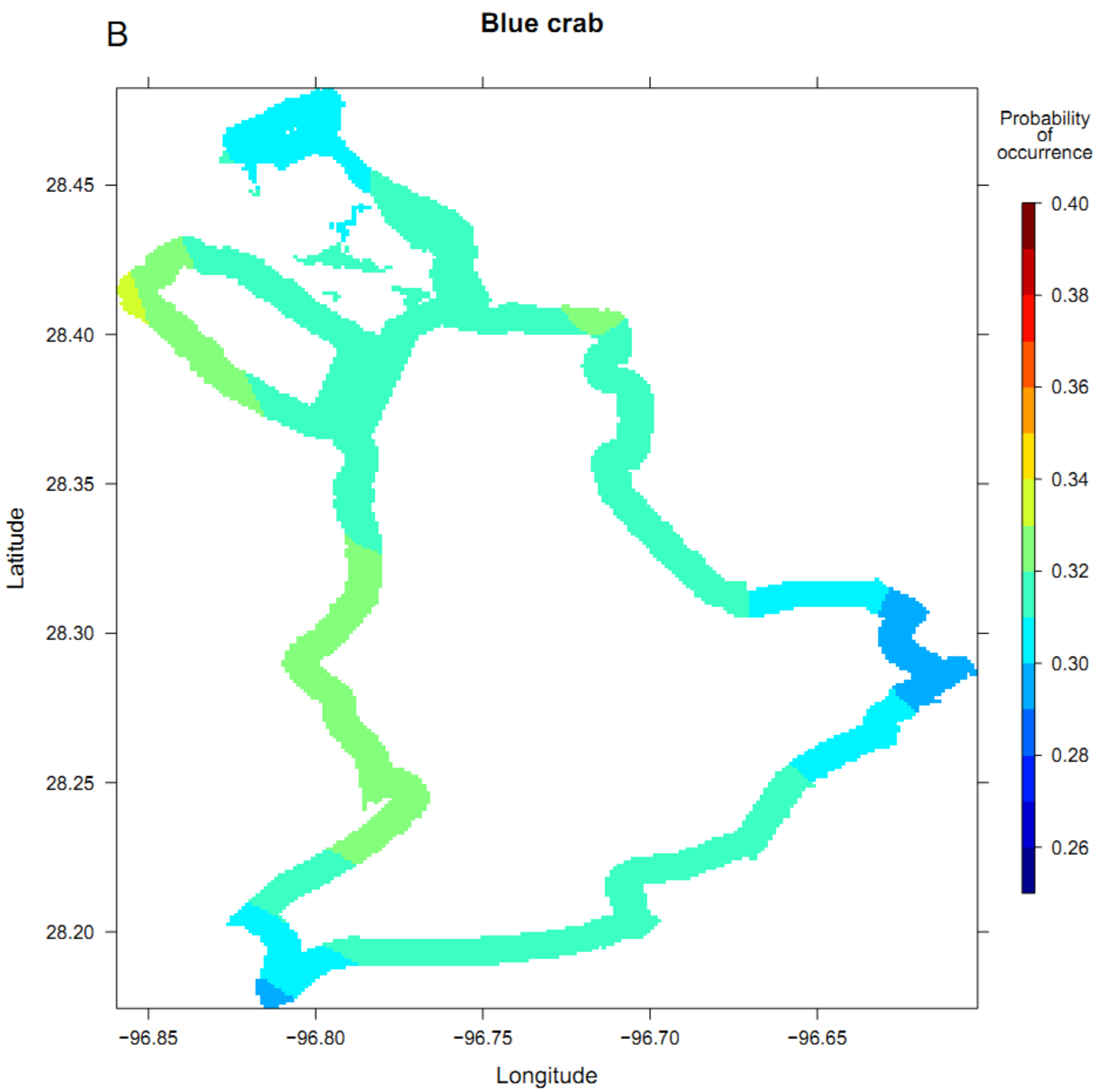

Figure 5B. Blue crab predicted probability of occurrence as predicted by a boosted regression tree (BRT) model when mean salinity is reduced 10 psu (B).

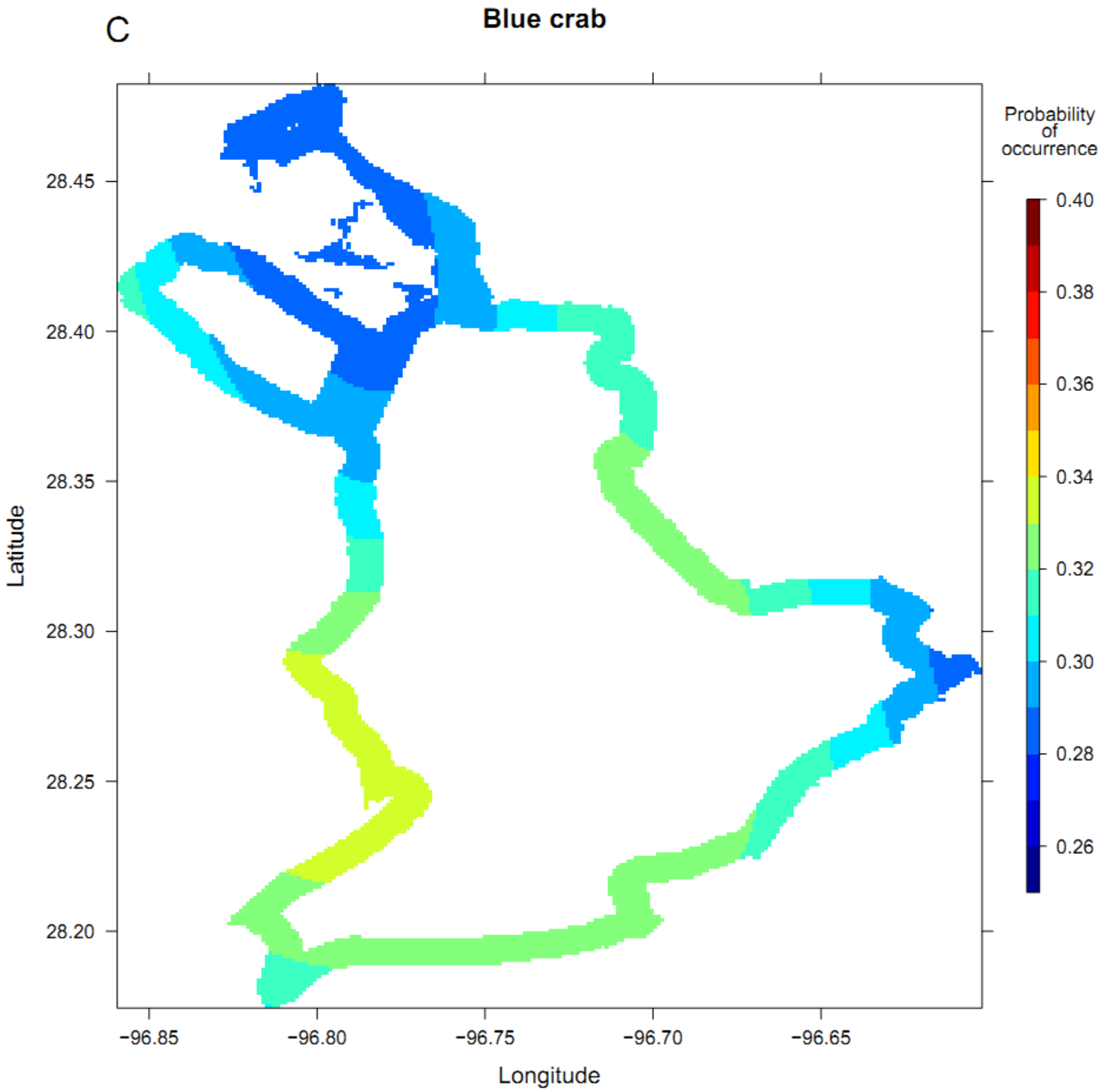

Figure 5C. Blue crab predicted probability of occurrence as predicted by a boosted regression tree (BRT) model when mean salinity is increased 5 psu (C).

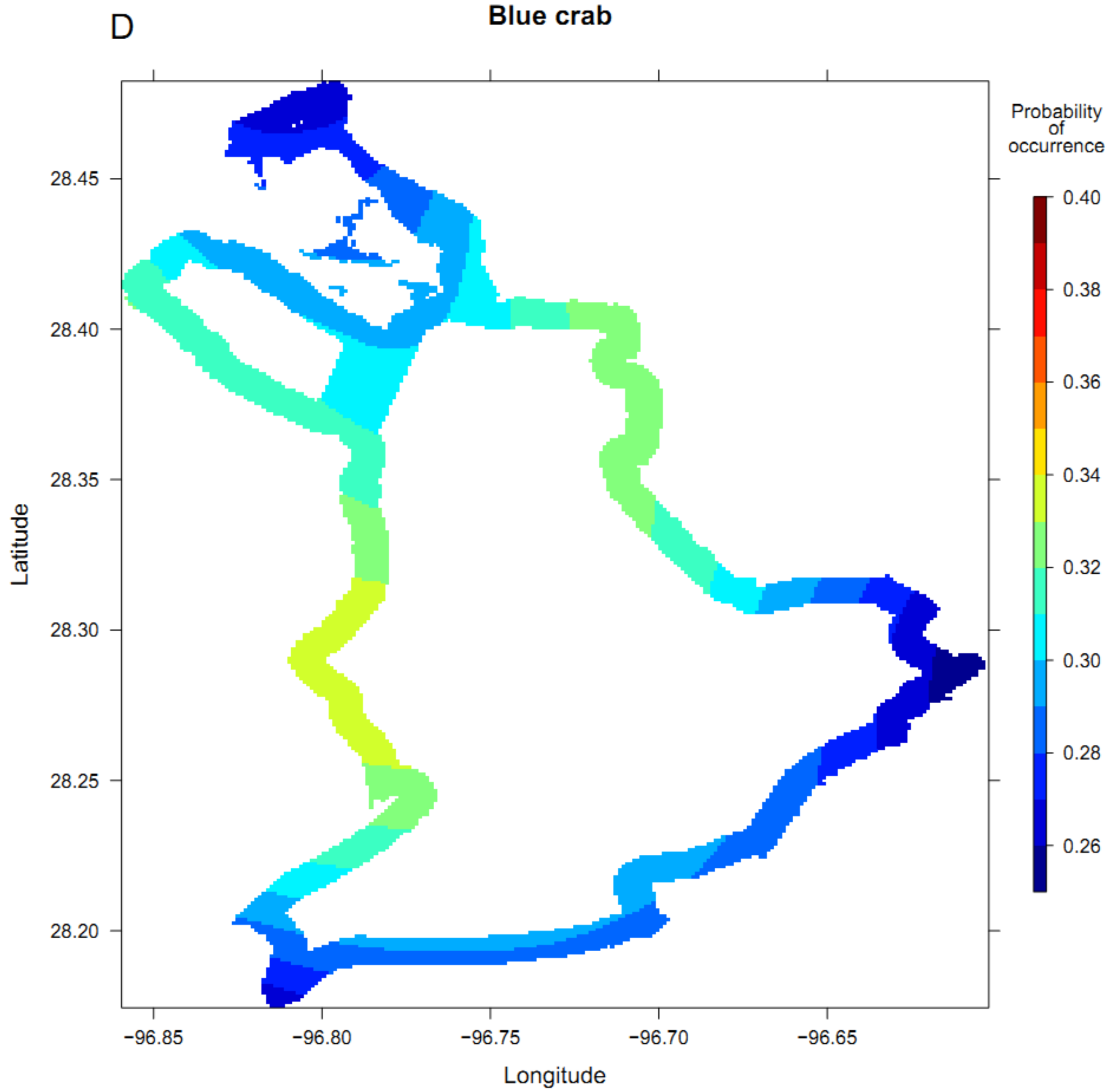

Figure 5D. Blue crab predicted probability of occurrence as predicted by a boosted regression tree (BRT) model when mean salinity is increased 10 psu (D).

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