# Predicting fish populations in the Mission-Aransas National Estuary Research Reserve based on water quality.

Leighann Martin
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The University of Texas at Austin

# I. Introduction

An estuary is the intersection where rivers and the sea meet. This results in many different geomorphological or biological characteristics, but all are booming and diverse ecosystems. Classical estuaries are characterized as having a well-mixed salinity gradient from the freshwater riverine inputs to the open ocean; this is most famously seen in the Chesapeake Bay in Maryland and Virginia. Water quality is a major determinant for what species can survive and live in a certain area, and since estuaries are relatively shallow and small environments many parameters change due to changes in the ambient environment. Major factors like dissolved oxygen, temperature and salinity can limit which species can inhabit an estuary (Baptista et al 2010). Birds, fish, invertebrates, seagrasses, algae, and microbes all interact with each other in these ecosystems and therefore each link in the food web is important to conserve and monitor.

Along the South coast of Texas there are many lagoons and estuaries, one of which is the Mission-Aransas National Estuary Research Reserve (MANERR). It is home to many important seagrasses, invertebrates, birds and fish species that support the Texas economy through fisheries and eco-tourism, making this diverse ecosystem such an interesting place for research. The MANERR is a program managed by the University of Texas Marine Science Institute (UTMSI) in Port Aransas, TX and shares data based on water quality, biomass indicators, habitat and watershed mapping in an open source data form since 2006. This is the 3rd largest NERR and the only one in the state of Texas, making it a valuable and ideal source of data.

A popular sport fish in the Gulf is the red drum (*Sciaenops ocellatus*), and its physiology and habitat preferences have been extensively studied by researchers at UTMSI. Most fish have a specific range of salinity, temperature and dissolved oxygen (DO) that they can survive in and a smaller range that causes them the least amount of stress, which is known as their optimal zones and is usually in their habitat preferences. Salinity is a huge osmoregulatory stress for fish as they have to constantly deal with loosing water to the environment in marine environments, and in freshwater environments have to worry about conserving ions. Thus, there is usually a range that fish can comfortably live in. Marine and freshwater fish typically have a small range of salinities that they can live in but estuarine fish, like red drum, can live in a much larger range. Red drum can survive in almost any salinity from freshwater to hypersaline, but moving between environments can cause a large osmoregulatory stress for up to a week (Watson, Nordi & Esbaugh, 2014). Anectdoteally, from fisherman it is known that they're salinity preferences are around 13 to 46. As ecotherms, fish need to live in a temperature that allows for their enzymatic processes to occur in a timely manner but also that they do not denautre in too hot water. Red drum's thermal tolerance preferences vary on body size, but on average live between 12 to 30 degrees Celsius (Pan, Ern, Morrison, Brauner & Esbaugh, 2017). Lastly, DO is critical for the life of fish because under a certain level of oxygen, usually 20% saturation, fish cannot survive long periods of hypoxia (Pan, Ern & Esbaugh, 2016). For this study the preferences for red drum were anything above 6.0 mg/L, which is usually around 70% saturation in the summer months.

This study aims to determine the most likely spots within the Mission-Aransas estuary of where red drum will be at any time of the year, by using the water quality data from the MANERR for salinity, temperature, and DO and combining that with the preferences for red drum. This would make it possible for anyone to limit their search for red drum within the estuary and especially make it easier for scientists using wild-caught red drum for studies.

## II. Methods

### Data Collection

Data was collected from multiple public resources. The subwatersheds, catchments, and streams were downloaded from the National Hydrography Dataset (NHD) using HUC8 12100407, 12100406, and 12100405. Digital elevation models were downloaded from USGS. MANERR has 5 systems wide monitoring program (SWMP) sites, which have constantly been measuring water quality parameters, like salinity, temperature, and dissolved oxygen, since 2006. This data from the past 10 years was accessed, along with the SWMP locations and MANERR boundaries. Texas Water Development Board (TWDB) has an open source database, containing the same water quality parameters along with their dates and locations throughout the Texas coast and rivers in the state. Salinity, temperature, and dissolved oxygen points were accessed within the MANERR boundaries for the year 2011, due to it being the most complete dataset.

### Mapping

Mapping was done in ArcGIS Pro. The NHDPLus data for HUC8 12100407, 12100406, and 12100405, USGS DEM, and MANERR boundaries were downloaded and projected. The streams and rivers were restricted to this basin and graduated based on the mean annual flow of the stream to show importance of each stream to the estuary. This was the base map, as shown in Figure 1.

The SWMP water quality data was separated by seasons (winter, spring, summer and fall) for the 10 years collected and averaged over the 10 years at each SWMP location. The data was uploaded as graduated points to the MANERR, interpolated using the spline tool across the estuary, and finally restricted to the estuary boundaries using extract by mask. This was done for each water parameter at each season. Each raster was then classified, with the reclassify tool, to be a 1 for red drum preferences and a 0 for anything outside those preferences; classifications used are in Table 1. Then using a raster calculator, the reclassified rasters for each parameter in one season were added together to create that season's raster. For example, the reclassified winter salinity, temperature, and DO rasters were added together to create the winter raster. These seasonal rasters are the predictions of where red drum would prefer to be at any given season.

Since water quality parameters were interpolated from only 5 sample sites, there was not enough field data to see finer scale differences across the estuary. Additional salinity, temperature, and DO data were downloaded from TWDB. Only data from 2011, which had the most robust data set, was used to control for interannual variability in water quality parameters. Using spline interpolation to estimate water quality parameters across the watershed, predictions could be done on a much finer scale.

## III. Results

The first prediction maps made with only the SWMP data could not finely distinguish between most areas in the estuary, except for where freshwater was entering the estuary in the summer and spring. This was the only area deemed not preferable to red drum, and therefore finer scaled maps were made using the TPWB data.

DO was measured in mg/L, rather than percent saturation, to get a constant measurement of DO throughout the year. Figure 2 shows the estuary's DO concentration in each season in 2011. Notably, the winter season (a) has the highest concentration and the summer season (c) has the lowest.

Temperature was measured in degrees Celsius. Figure 3 depicts the estuary's temperature throughout 2011. Again, winter (a) the lowest temperature and summer (c) had the highest. Fall (d) had the most variable temperature zones within the estuary.

Salinity is a unit-less measure depicted throughout 2011 in figure 4. Winter (a) once again had the lowest salinity, but the highest salinity observed was in the fall (d). Summer (c) saw the most variability within the estuary; there is a moderately defined salinity gradient here from fresher water near the riverine inputs and higher salinities near the open ocean.

The final prediction maps in figure 5 are the combinations of the classified raster of each parameter within a season. Spring (b) had the most area of where red drum prefers to be. While, the other seasons had similar sized areas of where red drum prefer to be. However, there are large variations of where the non-preferred areas are within the seasons.

## IV. Discussion

This study aimed to find the areas of where red drum will most likely be located at any time of the year by using their DO, temperature, and salinity preferences. From the data collected in the year 2011, these probable areas were found.

DO is an important determining factor for all fish; without oxygen fish cannot breathe and therefore cannot perform necessary functions. Hypoxia is defined as oxygen levels below 20% saturation and anoxia is less than 2%. Low oxygen levels have been shown to cause neural changes in fish, where they may be bolder and therefore be more susceptible to predation (Domenici, Allan, McCormick & Munday, 2011). This is an important problem, especially on the Texas coast where dead zones are becoming increasingly larger each year. With growing dead zones, there are increased rates of behavioral changes in fish that can lead to ecological changes where certain fish species are out competed. In the DO maps below (fig. 2) you can see that winter, spring, and fall are within the normal range of a fish's DO tolerance. This makes sense since oxygen concentration is increased with decreasing temperature in water. The summer months show multiple times where the DO is around 1 to 2 mg/L, which is considered hypoxic and a major stress for red drum.

Along with DO, temperature can affect a fish's ecological performance. Temperature is directly linked to a fish's aerobic scope, which determines their swim performance; this is a measure of their ability to swim away from predators or to attack prey (Fulton, Johansen & Steffensen, 2013). As temperatures across the globe and regionally in Texas are increasing the aerobic scope of red drum are diminished and therefore are not performing as well. Loss of ecological performance results in less prey found and predators more easily find them. In the temperature maps (fig. 3) the summer months are right at the thermal limit of red drum around 30 degrees Celsius. This is fine for now but this map was made with data from 2011 and average temperatures could have increased since then.

Lastly, salinity determines zonation patterns for all aquatic animals, as it is one of the largest osmoregulatory stressors. Red drum have the ability to move between large range of salinities and will acclimate to these different salinities after a period of stress. However, it does take time to acclimate to a largely different salinity than the one they are acclimated to (Watson, Nordi & Esbaugh, 2014). In the salinity maps (fig. 4) there is a wide range of salinities throughout the year, from freshwater to salinities in the mid 40s. These maps follow the predicted salinity patterns in a year. The winter and spring months are fresher due to less evaporation and more rain bringing in freshwater. Summer and fall months show a higher salinity due to increased evaporation rates, which correspond to the temperature maps shown in fig. 3.

Combining these maps resulted in where red drum would most likely have been during a season in the year 2011. The black shows where they would most likely not be due the three parameters combined. In the winter, the blacked out area appears to be due the freezing water. While the summer blacked out area appears to be due to the low DO concentrations. Finally, the fall blacked out areas appear to be due to the high variability of the temperatures with extreme highs and lows. These areas could be increasing as the global temperature is increasing each year.

There were some limitations to this project. The MANERR website was useful for collecting data but there were months of data missing in certain years and 3 of 5 SWMP sites have been shut off since Hurricane Harvey. It would also be nice to have more SWMP sites to have a finer look at what is happening in the middle of the estuaries and not just along the boundaries. TWDB is a useful source of crowd-sourced data, but there is no easy way to obtain data together, each day of data collection had to be downloaded separately. It is not easily assessable to find how the data was collected or what for, so there can be some uncertainty in the validity of the data there as well.

## V. References

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Watson, C., Nordi, W., & Esbaugh, A. (2014). Osmoregulation and branchial plasticity after acute freshwater transfer in red drum, Sciaenops ocellatus. *Comparative Biochemistry And Physiology Part A: Molecular & Integrative Physiology*, *178*, 82-89. doi: 10.1016/j.cbpa.2014.08.008

## VI. Tables and Figures

Table 1:

| **GIS Class** | **Dissolved Oxygen (mg/L)** | **Temperature-C** | **Salinity** |
|---|---|---|---|
| 0 | 0.0-5.9 | 0.0-11.9 | 0.0-12.9 |
| 1 | 6.0 + | 12.0-29.9 | 13.0-45.9 |
| 0 | | 30.0 + | 46.0 + |

Table shows red drum preferences that were used for classifying water parameter rasters in ArcGIS Pro.

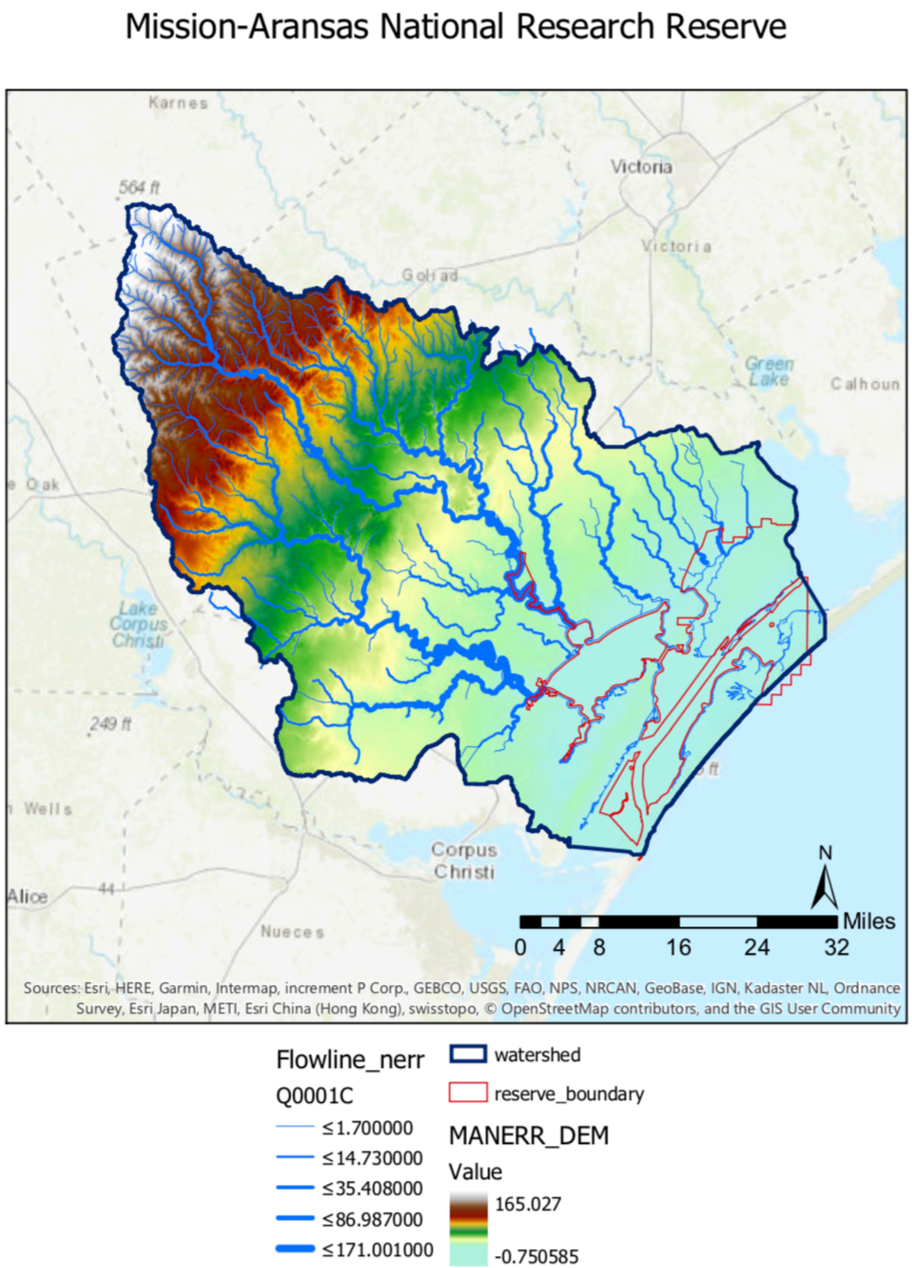


Figure 1: Basemap of the Mission-Aransas National Estuarine Research Reserve boundaries and combined HUC8 12100407, 12100406, and 12100405 streams and USGS DEM data.

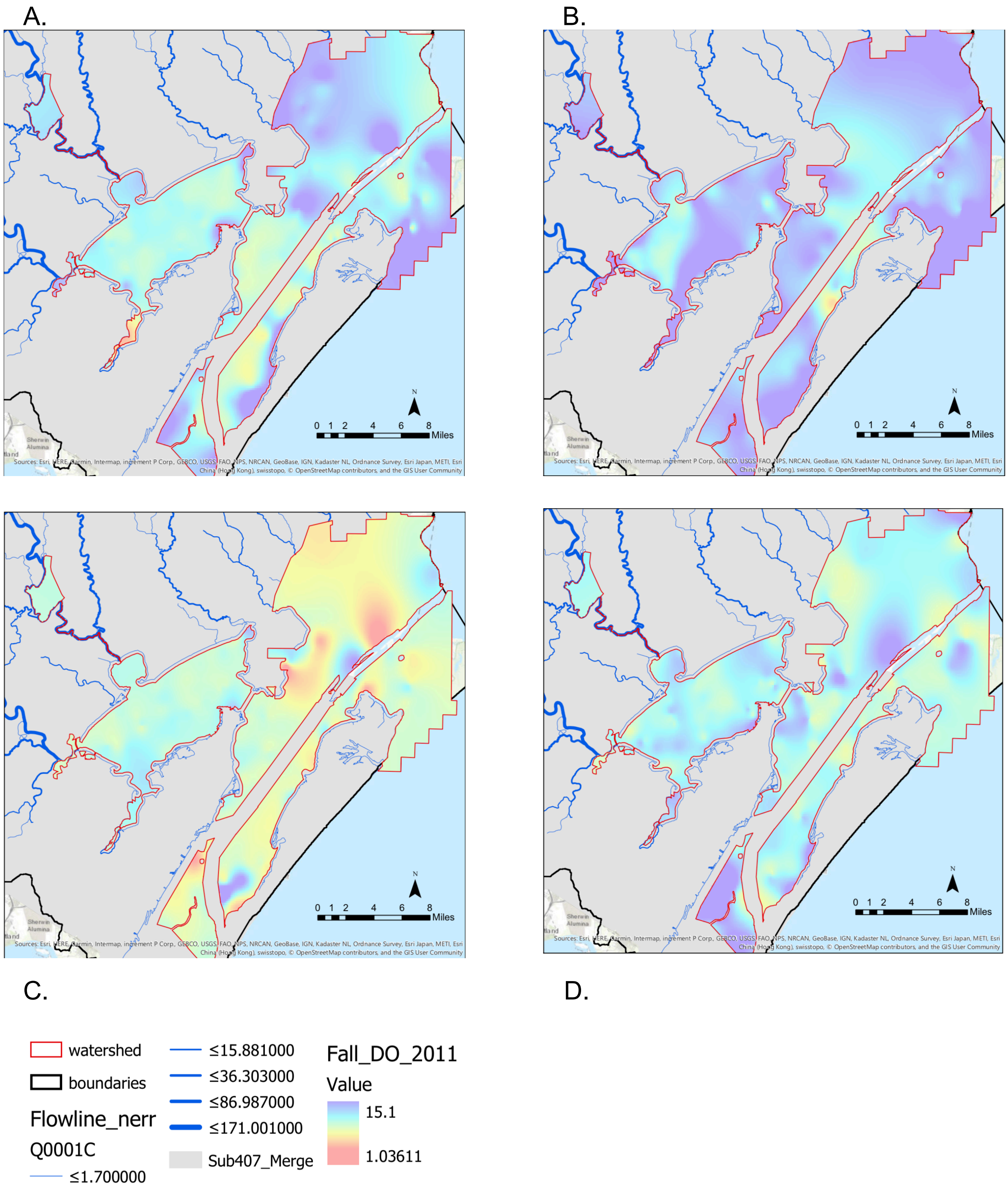


Figure 2: The dissolved oxygen (mg/L) within the MANERR in 2011 at (a) Winter, (b) spring, (c) summer, and (d) fall. Key is along bottom.

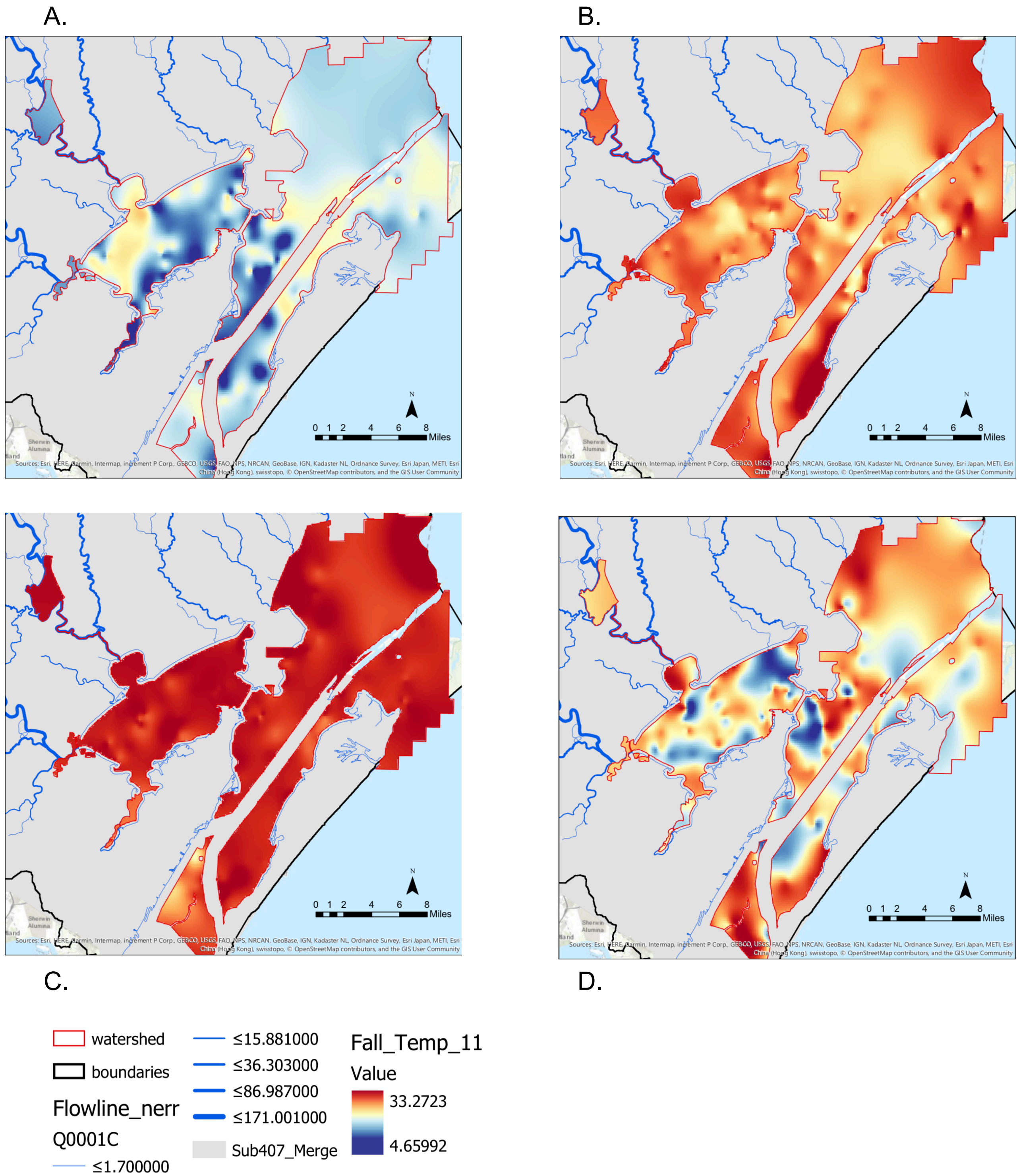


Figure 3: The temperature (degrees C) within the MANERR in 2011 at (a) Winter, (b) spring, (c) summer, and (d) fall. Key is along bottom.

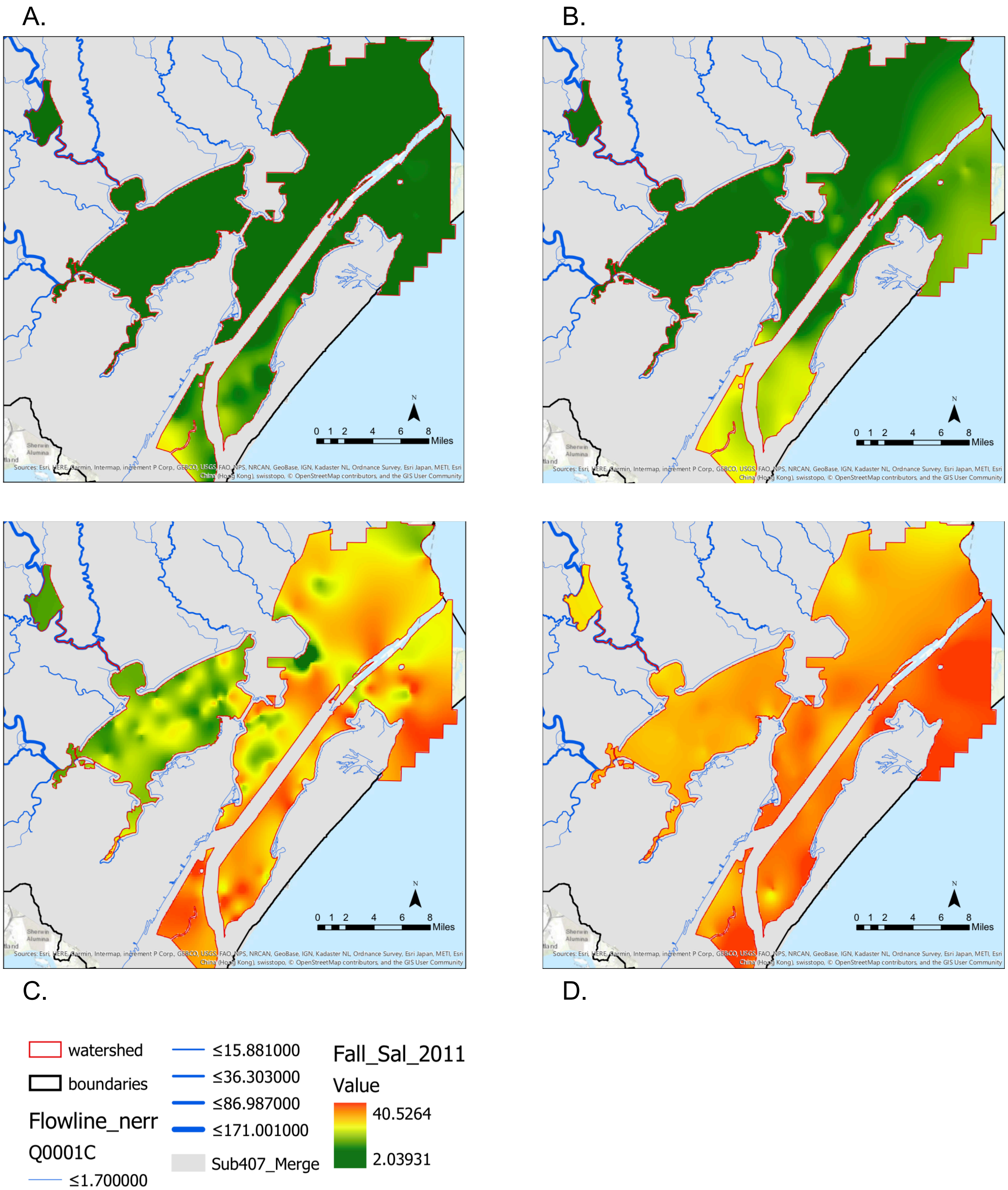


Figure 4: The salinity within the MANERR in 2011 at (a) Winter, (b) spring, (c) summer, and (d) fall. Key is along bottom.

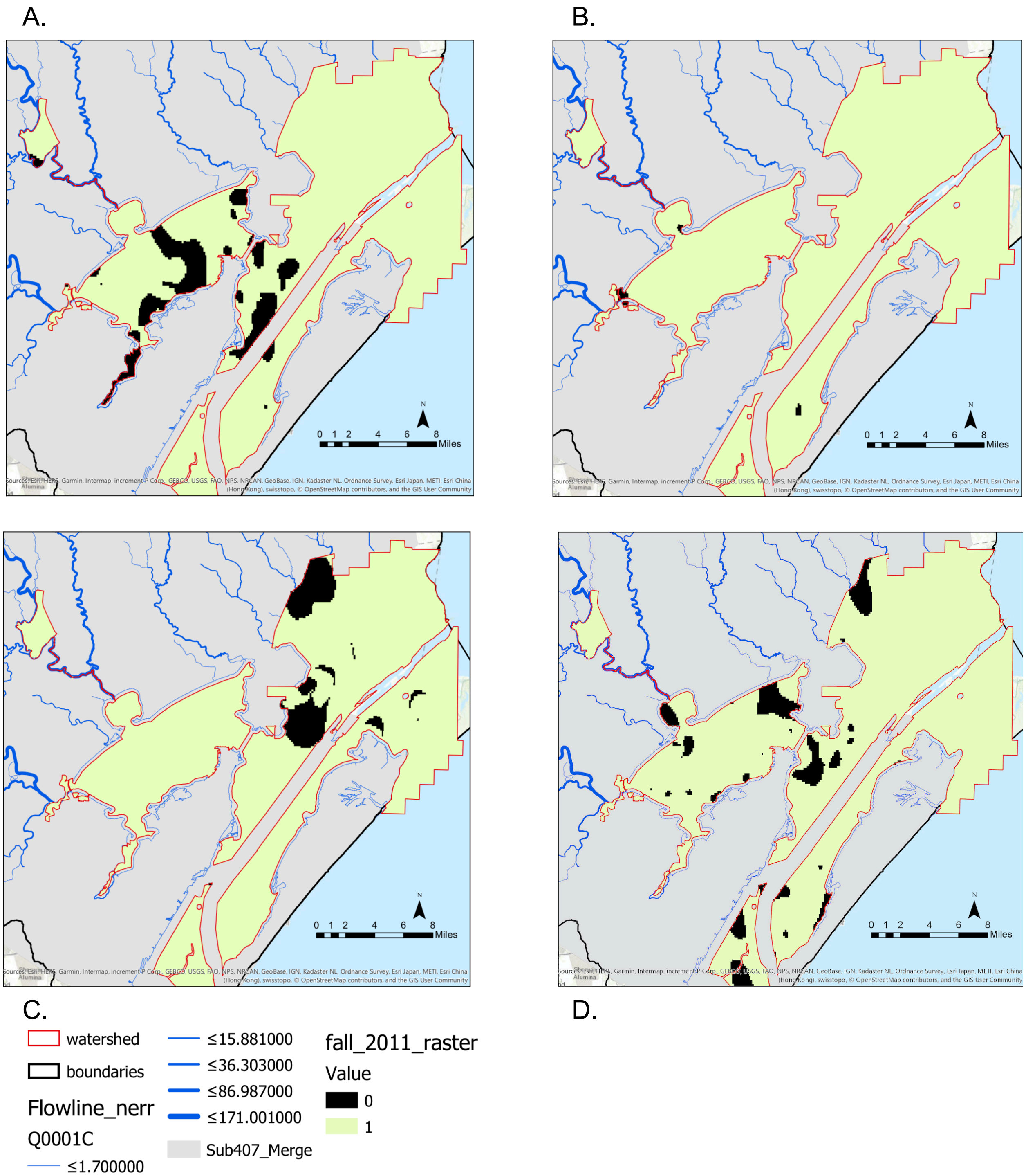


Figure 5: The red drum predictions within the MANERR in 2011 at (a) Winter, (b) spring, (c) summer, and (d) fall. Key is along bottom.