

Watershed and Flow Impacts on the Mission- Aransas Estuary

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Introduction

Background

Estuaries are vibrant and dynamic habitats occurring within the mixing zone of fresh and salt water. They are home to species often capable of surviving in a variety of salinities and other environmental stressors, and are often highly productive due to the high amount of nutrient input from both terrestrial and marine sources.

As droughts become more common in certain areas due to climate change, understanding how species adapt, expand, or die is crucial for management strategies (Baptista et al 2010). Salinity can fluctuate wildly in back bays with limited rates of tidal exchange with the ocean and low river input, leading to changes in ecosystem structure and function (Yando et al 2016). The recent drought in Texas from 2010 to 2015 provides a chance to study the impacts of drought and river input on an estuarine system.

While some studies have shown that climate changes are more impactful on Texas estuaries than changes in watershed land use (Castillo et al 2013), characterization of landcover in the watersheds leading to estuaries are important for a variety of reasons. Dissolved organic carbon and particulate organic matter influx is an important driver of microbial growth in estuaries (Miller and Shank 2012), and while DOC and POM can be generated in marine systems, terrestrial sources are also significant.

Study Site

The site chosen for this project is the Mission-Aransas estuary, located within the Mission-Aransas National Estuarine Research Reserve (NERR). In addition to being an ideal model of a Gulf Coast barrier island estuary, the Mission-Aransas NERR continuously monitors water parameters, weather, and nutrient data at a series of stations located within the back bays and ship channel. This program, called the System Wide Monitoring Program (SWMP), has provided high resolution data available to the public from 2006 to the present, making the Mission-Aransas estuary an ideal location to study long term impacts of drought and freshwater inflow fluctuations.

The National Estuarine Research Reserve system spans 28 sites across the contiguous United States and Alaska, and protects a variety of estuarine systems. The range of distance from river mouth to ocean inlet in The Gulf of Mexico is 15-30 miles, which makes the Mission-Aransas NERR the third largest in the system, covering 185,708 acres (missionaransas.org 2016). The Mission and Aransas rivers are undammed and the two main contributors of freshwater to the estuary, which has one primary inlet near the town of Port Aransas. While the ship channel has been stabilized with jetties and is regularly dredged to allow passage of freighters to the nearby Corpus Christi Harbor, the estuary is largely free of significant anthropogenic influences. This makes it an ideal study site to model the flow of carbon and nutrients from the rivers to the Gulf of Mexico, as well as determine the ecosystem impacts of drought and non-drought periods.

Objectives

There are three main objectives to this project. The first is to explore the relationship between river discharge and nutrient input to the Mission-Aransas estuarine system by comparing the rivers' flow data from 2010 to 2016 to the presence of certain nutrients at the SWMP stations in Copano and Aransas Bay. The second objective is to compare salinity and nutrient parameters in the Mission-Aransas Estuary over periods of drought to periods of drought recovery to determine the influence of the Mission and Aransas rivers. The final objective is to then determine the nature of the land cover in the watersheds draining to the estuary and their potential impact on ecosystem processes.

Methods

Data Sources

All data used for this project is publicly available from either USGS or NOAA's National Estuarine Research Reserves.

- The watersheds used for this project were HUC8 12100407, 12100406, and 12100405 downloaded from the National Hydrography Dataset. Corresponding subwatersheds, digital elevation models, and streams were also downloaded from the same resource.
- Nutrient and salinity data, as well as geographic coordinates of the SWMP stations in the Mission-Aransas NERR was downloaded from the NERR Centralized Data Management Office.
- The Mission River and Aransas River stream gage data was compiled by the USGS National Water Information System.
- Landcover data was from the 2011 National Land Cover Dataset compiled by the USGS, accessed via the ArcGIS Landscape Server.

Mapping

All mapping was done using ArcGIS Pro and the above datasets. The first step of the project was to isolate the Mission River, Aransas River, and Aransas Bay watersheds, corresponding to HUC8 12100407, 12100406, and 12100405 respectively. The specific HUC8 numbers were identified before downloading from the NHD site, so only those watersheds were added to the map. The HUC10 subwatersheds corresponding to each HUC8 watershed were also added to the map. In order to make the map simpler, another feature class was created by using the Union tool to join the three watersheds into a single feature called "watersheds".

The digital elevation model downloaded from the NHD site was added to the map and the Extract by Mask tool used the union of the watersheds to create an elevation raster covering all three watershed areas.

NHDFlowlines were added and the Clip tool was used to separate them into their corresponding watersheds. Then, Select by Attribute was used to select stream

segments with the ID of either Mission River or Aransas River to create separate features of just those rivers.

The ArcGIS landscape server was accessed via a connection to the url <http://landscape2.arcgis.com/arcgis/>, and the 2011 National Land Cover Dataset was loaded to the map. The Extract by Mask tool was also used with the watersheds union to create a landcover raster spanning the three watershed areas.

Finally, the outline of the Mission-Aransas National Estuarine Research Reserve was downloaded from the CDMO site and added as a feature class to the map.

Graphing

Nutrient data, salinity data, and percent landcover were best displayed graphically rather than with maps. Nutrient datasets including orthophosphate concentrations, ammonium concentrations, and chlorophyll a concentrations for the SWMP stations in Copano Bay (east and west) and Aransas Bay from January 2010 to December 2015 were downloaded from the CDMO site as excel files. Data at these stations was taken twice a month and analyzed using four trials. This data was synthesized by taking the average of the four analytical trials for each sampling date, and then graphed as scatter plots.

Salinity data was downloaded from the CDMO site only at the Copano East station. This station is centrally located in the estuary and is representative of the general salinity of the entire estuary. Salinity at this station is monitored every 15 minutes 24 hours a day, which gave upwards of 200,000 data points for the plot of estuary salinity over the past 6 years.

Percent landcover was determined by opening the attribute table of the extracted landcover raster on ArcGIS Pro. Rasters corresponding to open water were omitted from this calculation, as only terrestrial landcover was of use to the analysis. Rasters measured 30 meters by 30 meters, and the total number of dry land rasters was computed to be 9,388,762, corresponding to 8,450 square kilometers. Percentages of this total made up by the various types of landcover were also calculated and compiled into a pie chart for simple visualization.

Results

The elevation of the combined watersheds (figure 1), was mapped in centimeters due to the extremely small elevation changes throughout the watersheds. The result is a very high-resolution map showing just how flat the Gulf Coast of Texas really is. The highest point in the watershed is a mere 165 meters above sea level, with most of the land in the watershed at around 50 to 0 meters above sea level.

Salinity data from the Copano East station (figure 5), shows an impressive correlation between the lack of freshwater inflow from the Mission and Aransas rivers (figures 3 and 4) and high salinity values. Some seasonal variability can also be seen with higher salinity values generally occurring during the summer months where there is more evaporation taking place. The difference between a seasonal shift is around 10 psu, whereas the largest shifts from late 2010 to 2011 and from 2014 to

May of 2015 are 30 psu. The flow rates from the stream gages show a related pattern: there are frequent flood events in early 2010, followed by minimal flow until May 2015.

The national landcover dataset (NLCD) from 2011 was mapped over the combined watersheds in figure 6. Visually, the map is dominated by the brown color representing agriculture, and red development rasters are few and far between. The total dry land area covered by the watersheds was calculated to be 8,450 square kilometers with open water omitted, and the relative percentages of different land use types are graphed in figure 7. Agriculture does indeed take up the highest percentage of land usage at 45.3%, while development is relatively low at 5.2%. The remaining 49.5% is undeveloped, relatively natural space.

Nutrient data from three of the NERR's SWMP stations, Copano West, Copano East, and Aransas Bay (shown in detail in figure 2) was graphed to show changes in orthophosphate (figure 8), ammonium (figure 9), and chlorophyll a (figure 10). Orthophosphate showed the most striking correlation with increased flow into the estuary, and the graph demonstrates pronounced peaks in early 2010 and late 2015. Also interesting to note is that levels of orthophosphate are highest nearest to the mouth of the Aransas River at the Copano West station, and drop with distance. This could imply that the main contributor of orthophosphate to the estuary is located in the Aransas River watershed. Ammonium showed a similar correlation with river input, though the variability visibly increased in the later years from 2014 to late 2015. Chlorophyll a concentration, which measures the abundance of phytoplankton and general primary productivity in the area, showed no obvious correlation with river input, though seasonal variability was seen from summers to winters.

Discussion

The Mission and Aransas rivers are relatively unique on the Texas Gulf Coast in that they remain undammed and free flowing. That being said, they are not particularly swift rivers, nor do they produce a significant amount of average flow into the estuary. Stream gages on the Mission River at Refugio, TX (figure 3) and on the Aransas River at Skidmore, TX (figure 4), reveal that the average daily input to the estuary is anywhere from 10 to 1 cubic foot per second per river. Additionally, the elevation map (figure 1), shows that there is not a lot of elevation change throughout the watershed, so it follows that the rivers would have a very low rate of flow into the estuary under normal circumstances. The small elevation change also implies that there would be a relatively slow rate of runoff by precipitation into the river. It is possible that runoff has more time to leach organic carbon or other nutrients from the soil as it makes its way to the rivers, allowing for a higher nutrient inflow to the estuary.

In spite of their typical low flow, the Mission and Aransas rivers are capable of producing high-flow flood events with enough precipitation. These events can be seen in the stream gages (figures 3 and 4) as sharp spikes. Most noticeably, May of 2015 is a common point of change in both the stream gages and the salinity of the estuary. A series of high flow events from the rivers took the salinity in Copano Bay from a salinity of 30, which is typical of open ocean seawater, down to 3, which is

nearly fresh (figure 5). While the estuary did not remain at that low salinity for very long, the average value over the next few months was significantly lower than the previous 5 years.

Although variable, inflow to the estuaries brings important nutrients. The Mission-Aransas estuary is shallow and wide, and does not have regularly predictable tides. On windy days, water can be pushed to one side of the bays regardless of tidal shifts, which means that exchange with the open Gulf is irregular. The most influential inputs to the estuarine system, therefore, are the rivers and runoff. This makes the estuary especially vulnerable to changes in land usage in its watershed, and while it is positive to note that nearly half of the watershed remains totally undeveloped (figure 6), 45.3% of the remaining half is dedicated to agriculture.

The nutrients this project chose to focus on were orthophosphate and ammonium, both of which are indicators of anthropogenic influence. As seen in figures 8 and 9, the drop in flood events on the Mission and Aransas rivers also corresponded to a drop in orthophosphate and ammonium found in the estuary. The fact that orthophosphate appears to be higher closer to the mouth of the Aransas River can be explained by the proximity of development along its upper reaches. The Mission River watershed has much less development. Chlorophyll a (figure 10) is a measure of the number of phytoplankton present in the estuary. While too many phytoplankton can lead to eutrophication, too few can cause a breakdown in the trophic structure of the estuarine system. Phytoplankton blooms can be caused by excess fertilizer runoff, which is a concern in this system with the high percentage of agriculture. The phytoplankton biomass of this estuary seems to be relatively constant however, with natural fluctuations occurring with seasonal change. It is likely that the community structure of the plankton present changes drastically with nutrient and salinity flux, but this cannot be determined by measuring chlorophyll a alone.

Conclusions

It is clear that the drought Texas experienced from 2011 to 2015 had a drastic impact on the Mission-Aransas Estuary. Salinity increased dramatically as flood events diminished in frequency, while orthophosphate and ammonium concentrations decreased. In May of 2015, huge amounts of precipitation prompted several large river discharges into Copano Bay, which had a quick effect on the salinity and nutrient concentrations. The minimal elevation change in the watersheds coupled with a dominant percentage of agricultural or natural landcover means that there is ample time and opportunity for organic materials to be leached, dissolved, or washed into the estuary. While this makes for a productive system, it is important to realize the potential impact development or fertilizers can have on the system.

The Mission-Aransas estuary is a vibrant and dynamic ecosystem. Changes in salinity and nutrient availability can have dramatic effects on the diversity of species living in the estuary. As an example, black mangroves (*Avicennia germinans*) have been expanding their range northward. Mangroves do not require freshwater input to survive, and can therefore outcompete native salt marshes in coastal wetlands.

Prolonged periods of drought highlight this delicate balance and the importance of river input to this estuarine system.

References

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- Yando, Erik S., Michael J. Osland, Jonathan M. Willis, Richard H. Day, Ken W. Krauss, and Mark W. Hester. "Salt Marsh-Mangrove Ecotones: Using Structural Gradients to Investigate the Effects of Woody Plant Encroachment on Plant–soil Interactions and Ecosystem Carbon Pools." *Journal of Ecology* 104, no. 4 (July 1, 2016): 1020–31. doi:10.1111/1365-2745.12571.

Resources

- National Hydrography Dataset: <<http://nhd.usgs.gov/>>
National Water Information System: <<http://waterdata.usgs.gov/nwis>>
NERR Central Data Management Office: <<http://cdmo.baruch.sc.edu/>>
ArcGIS Landscape Database: <<http://landscape2.arcgis.com/arcgis/>>

Figures

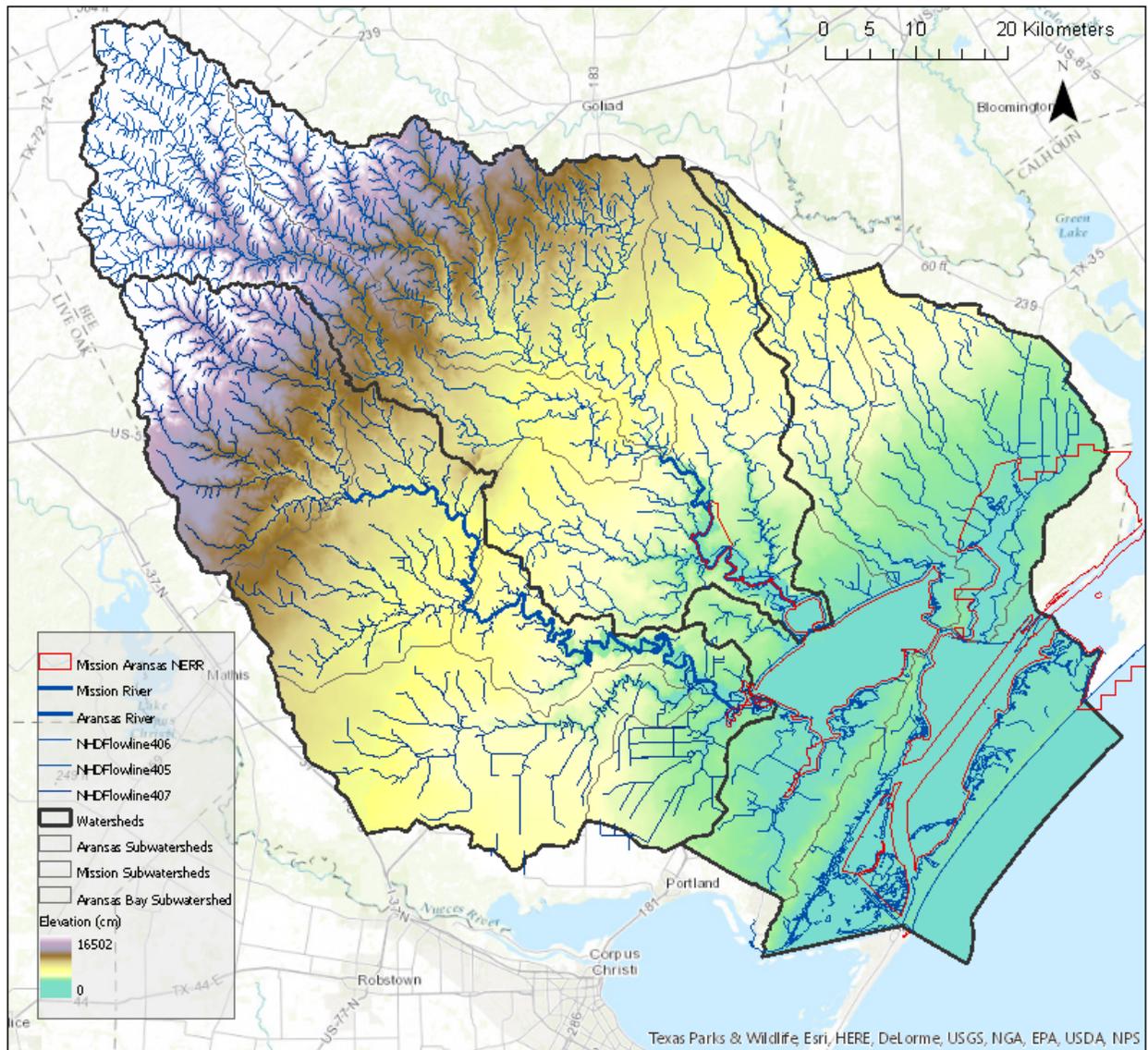


Figure 1: Elevation raster in centimeters of the entire estuary watershed extent. The Mission (center watershed) and Aransas (lower left) rivers are highlighted with a larger blue line, while the contributing streams are also present. The NERR boundaries are in red, and extend beyond the watersheds used in this project. Shipping lanes are also excluded from the reserve, which explains the breaks seen in the boundaries within the watersheds of interest. Elevation, stream lines, and watershed data is from the National Hydrography Dataset while the NERR boundaries are from the NERR CDMO. The projection used is the NAD 1983 Albers.

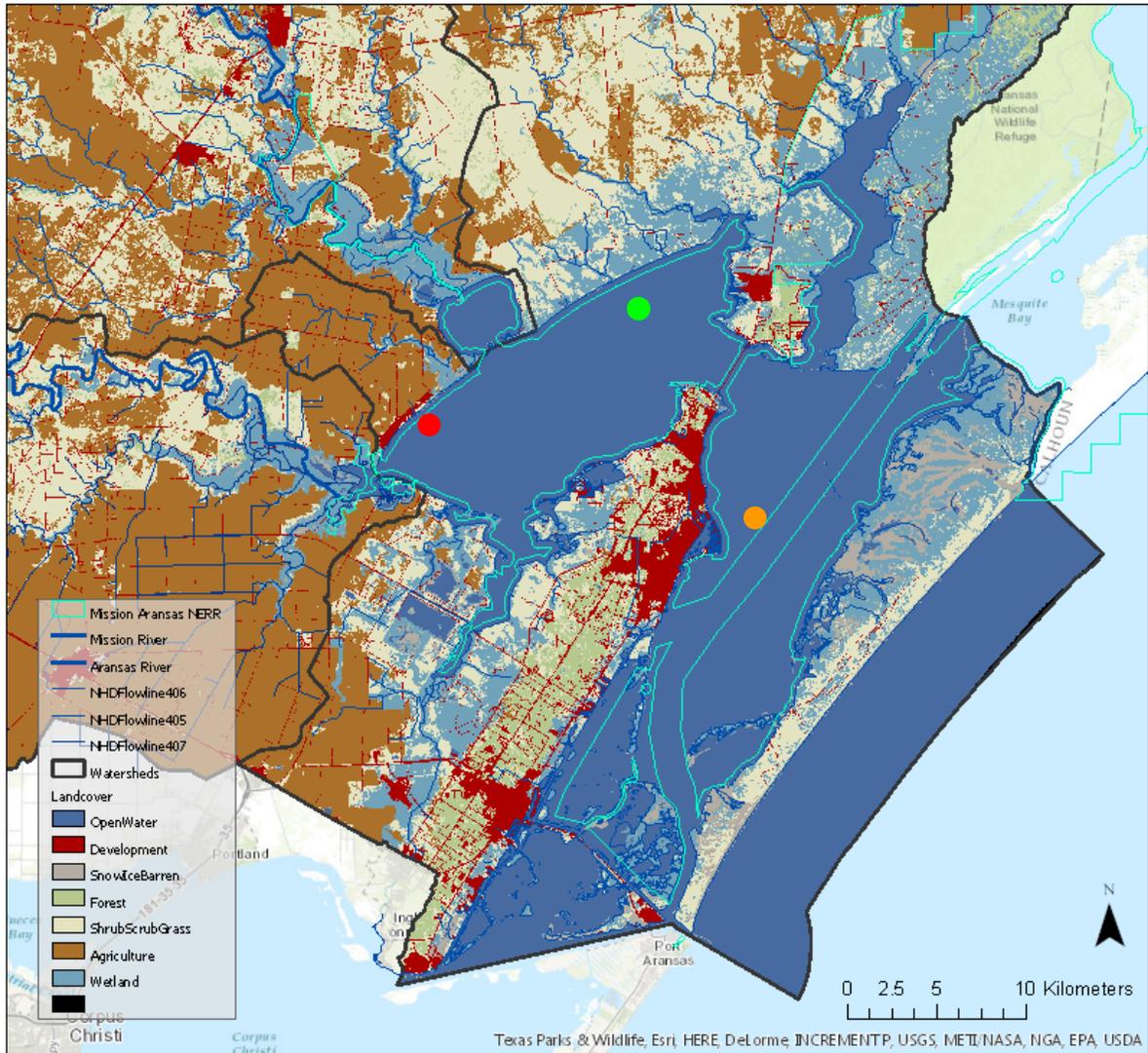


Figure 2: Detail map of the Mission-Aransas estuary within the watershed boundaries used for this project. SWMP stations are highlighted on this map: the red dot indicates the location of the Copano West (CW) station, the green indicates Copano East (CE), and the orange indicates Aransas Bay (AB). The 2011 NLCD is also mapped here, as well as the NHD streams. The projection used is the NAD 1983 Albers.

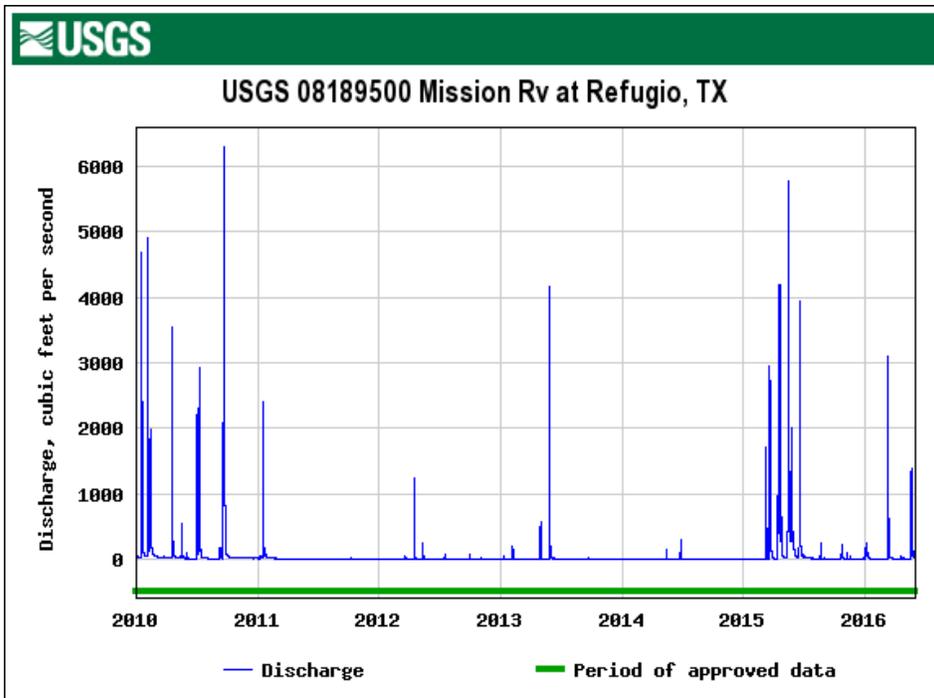


Figure 3: Mission River flow from the stream gage at Refugio, TX from 2010 to 2016. The five year drought from 2011 to 2015 is readily apparent in the center of the chart, and the precipitation that finally lifted Texas from drought in May of 2015 can be seen as a closely spaced series of high flows with a maximum of around 6,000 cubic feet per second.

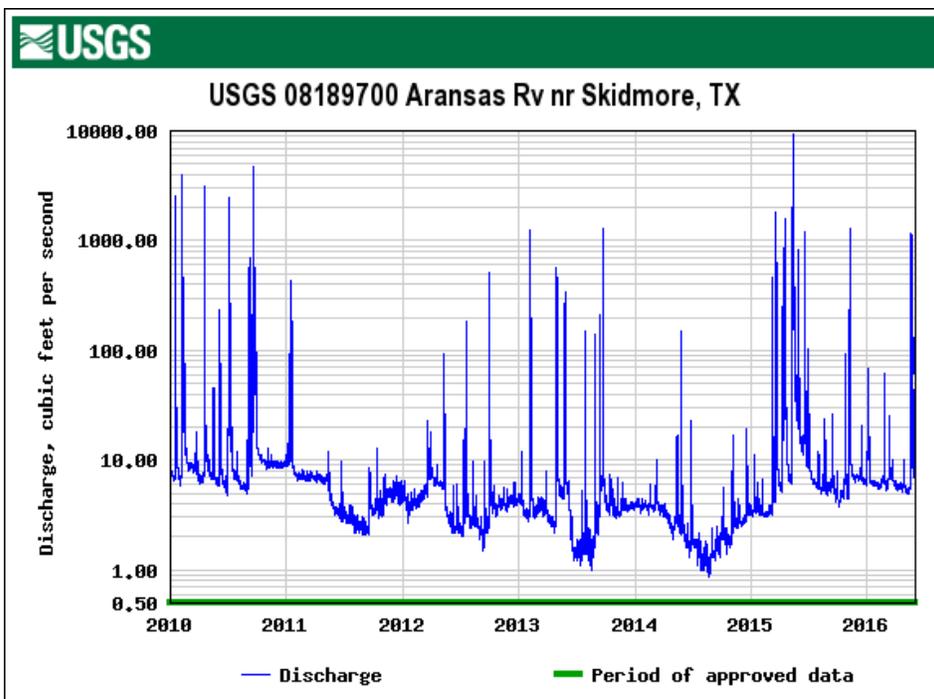


Figure 4: Aransas River flow from the stream gage near Skidmore, TX from 2010 to 2016. The Aransas River has a more constant flow than the Mission River, but the five year drought from 2011 to 2015 can be seen as a period of reduced flow in the center of the chart. The high precipitation in May of 2015 can be seen as a closely spaced series of high flows with a maximum of 10,000 cubic feet per second.

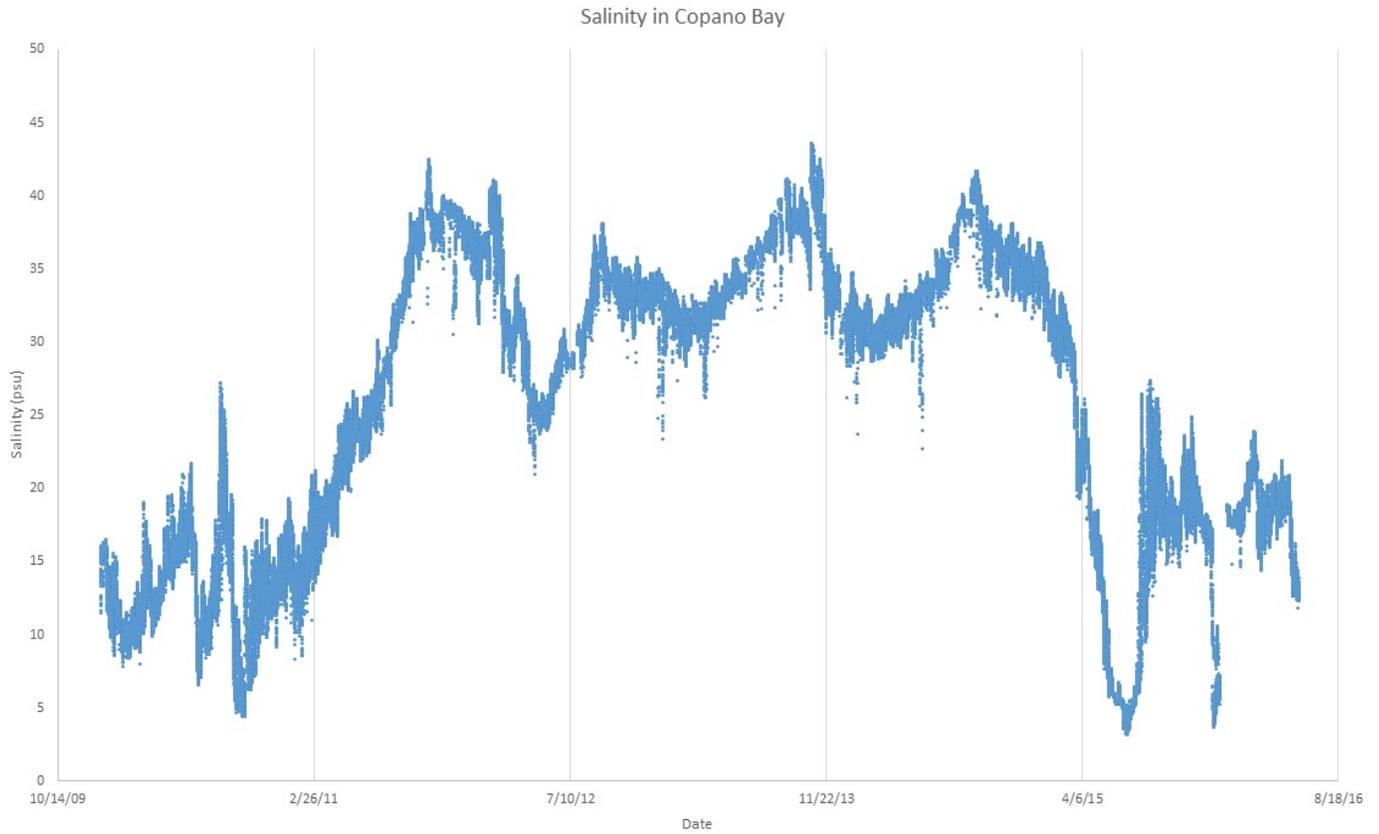


Figure 5: Salinity data from the Copano East station in Copano Bay from January 2010 to June 2016. The years of drought correspond to high salinity from 2011 to mid 2015, where the salinity suddenly drops with the high influx of freshwater.

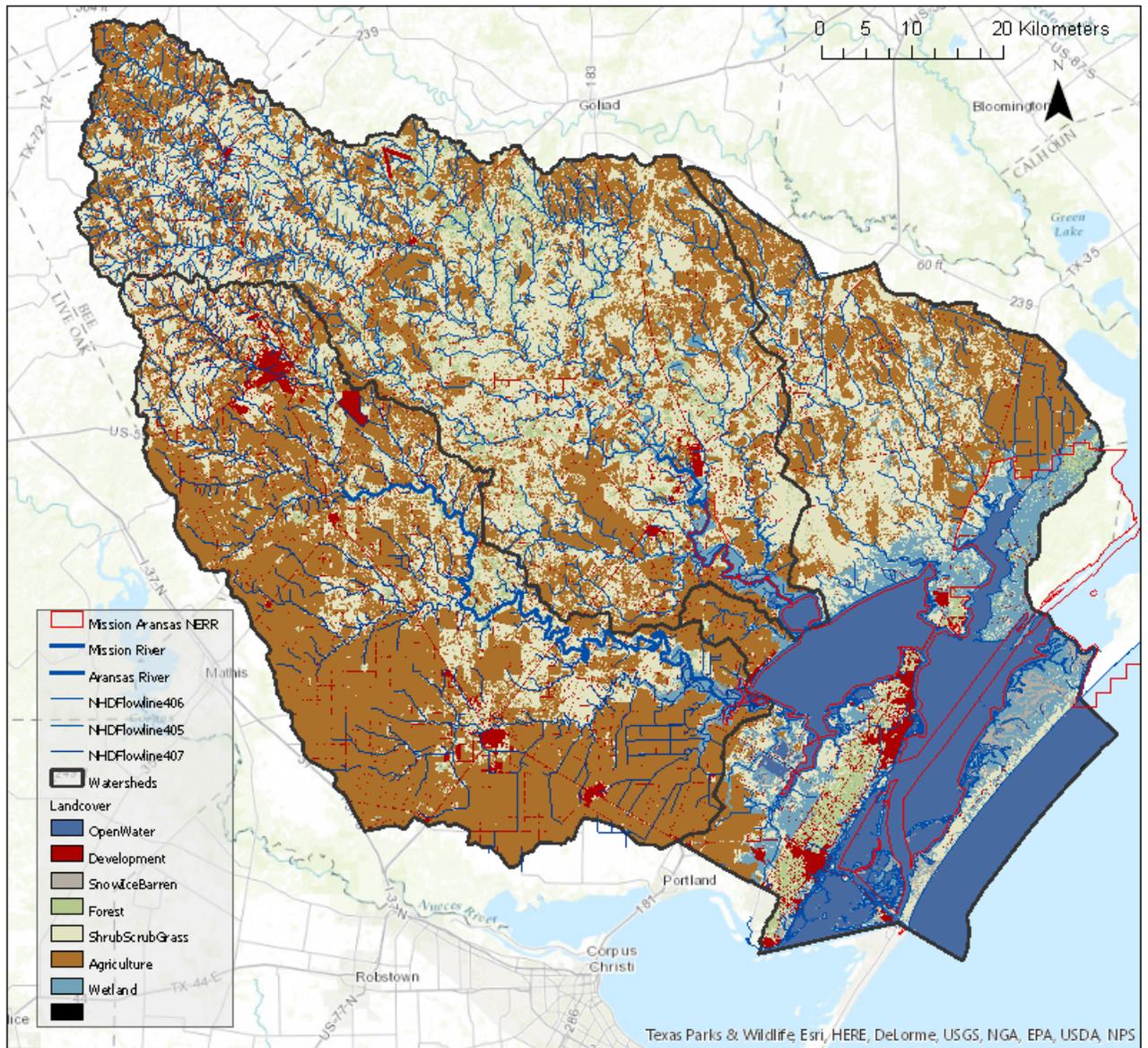


Figure 6: Landcover from the 2011 NLCD across the entire estuary watershed. Areas of open water, development, barren land, forest, grassland, agriculture, and wetland are differentiated. The Mission (center watershed) and Aransas (lower left) rivers are highlighted with a larger blue line, while the contributing streams are also present. The NERR boundaries are in red, and extend beyond the watersheds used in this project. The projection used is the NAD 1983 Albers.

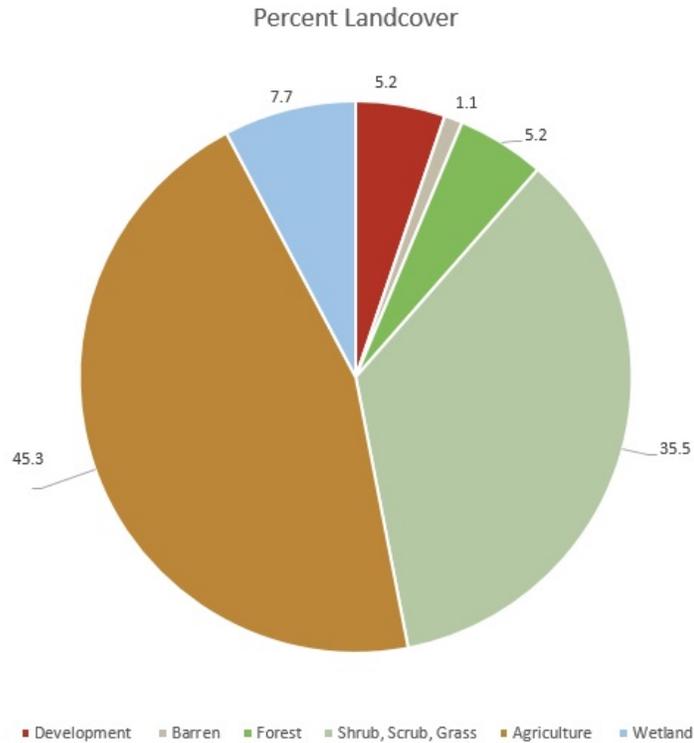


Figure 7: Percent landcover calculated from the 2011 NLCD raster within the estuary watershed. Open water was removed from the total, so these areas are for a total of 8,450 square kilometers of terrestrial landcover. The dominant usage of land is for agriculture, followed by open grasslands. Only 5.2% is developed, making the estuary watershed strikingly rural.

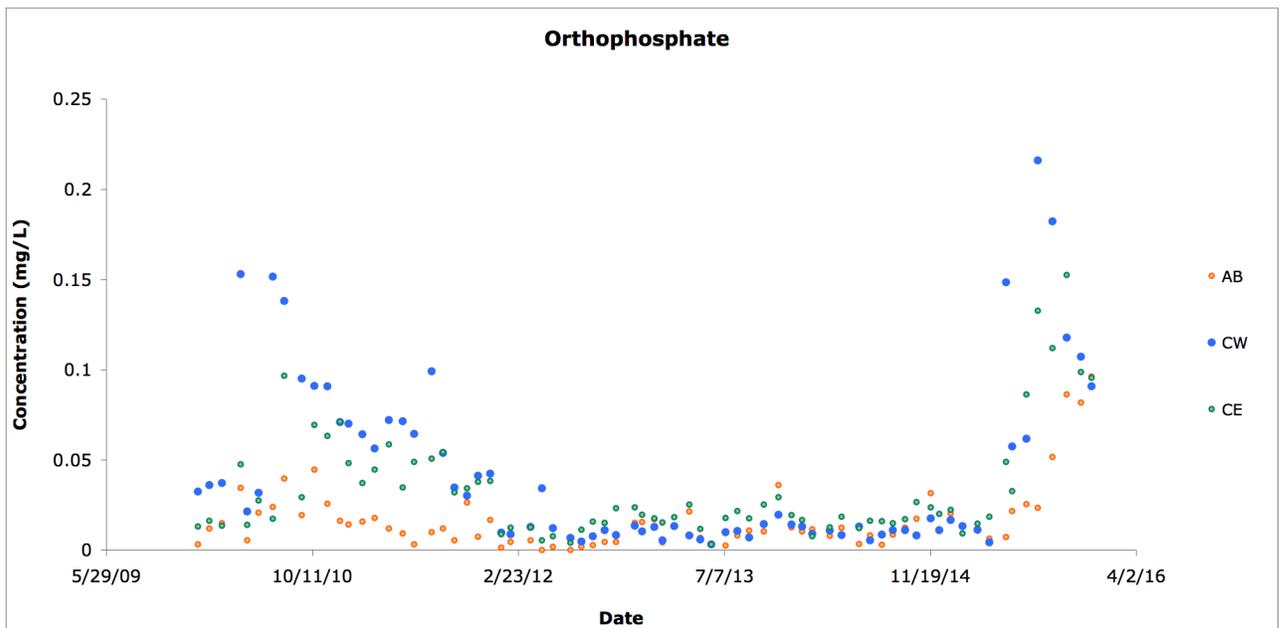


Figure 8: Orthophosphate concentrations measured at the Copano West (CW), Copano East (CE), and Aransas Bay (AB) stations from January 2010 to December 2015. Concentrations were noticeably low during the drought from 2011 to 2015.

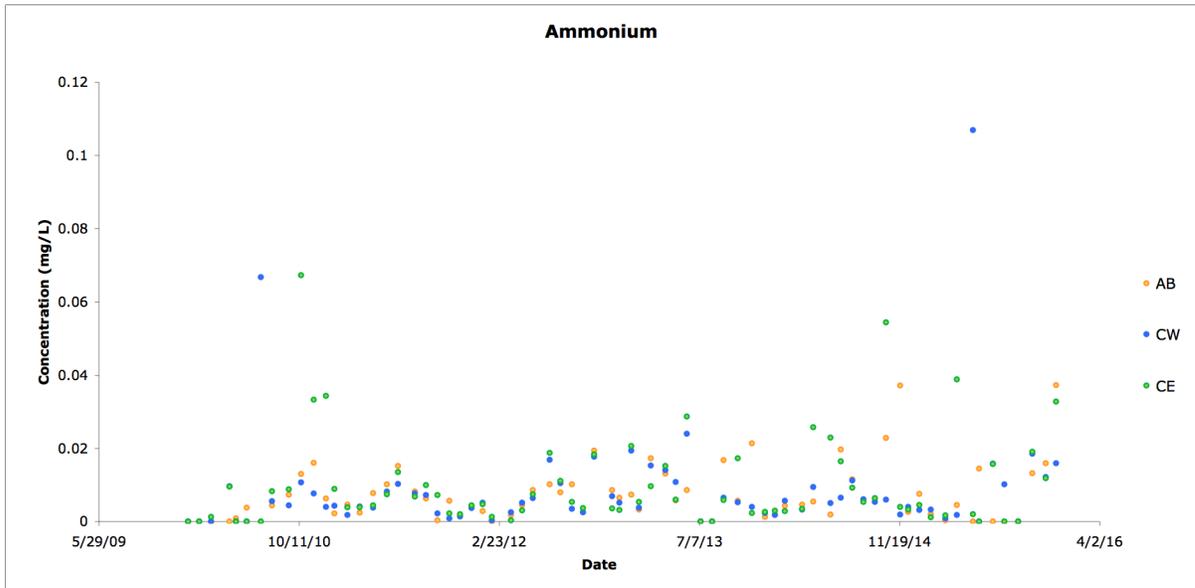


Figure 9: Ammonium concentrations measured at the Copano West (CW), Copano East (CE), and Aransas Bay (AB) stations from January 2010 to December 2015. Concentrations were noticeably low early during the drought in 2011, and grow more variable as the drought intensity decreased toward 2015.

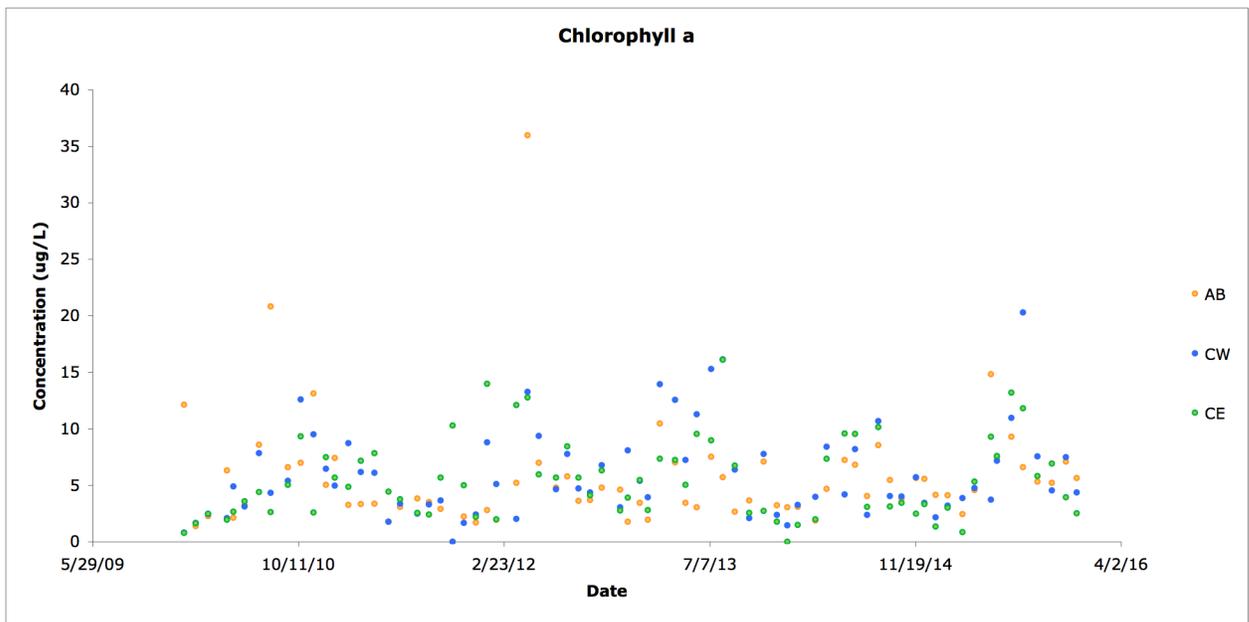


Figure 10: Chlorophyll a concentrations measured at the Copano West (CW), Copano East (CE), and Aransas Bay (AB) stations from January 2010 to December 2015. Seasonal variability can be seen with higher productivity in the spring and summer, but there is no clear correlation with the drought.