National Estuarine Research Reserve System Science Collaborative

Freshwater Inflows: Determining Flow Regimes in the Face of Land Use Change, Climate Change, and Other Unknowns

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Project Coordinator: Mr. Jace Tunnell
Applied Science Lead: Dr. Edward J. Buskey
Collaboration Lead: Dr. Tarla Peterson

Submitted by:

Name: Jace Tunnell
NERR: Mission-Aransas
Email: jace.tunnell@austin.utexas.edu
Phone: 361-749-3046

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Freshwater Inflows: Determining Flow Regimes in the Face of Land Use Change, Climate Change, and Other Unknowns

Abstract

A team led by the Mission Aransas National Estuarine Research Reserve (NERR) received a grant to conduct research that will inform freshwater inflow recommendations for the Guadalupe-San Antonio and Mission-Aransas Estuaries and address the needs of estuaries and the growing communities that depend on them. The team used collaborative methods to bring stakeholders together to identify and fill gaps in knowledge related to freshwater inflows. Specifically, the project addressed the effects of land use and climate change on freshwater inflows, the circulation of freshwater within and between estuaries, and the effects of freshwater inflow and salinity on commercially and biologically important estuarine dependent organisms. The overall goal of this project was to improve the quality of environmental flow recommendations for the Guadalupe-San Antonio and Mission-Aransas Estuaries by collaborating with local stakeholders and scientists to prioritize research needs in the BBASC adaptive management plan and address research questions to provide additional information and data for the Senate Bill 3 adaptive management process. The collaborative process identified four objectives, the results of which are summarized in this report.

Management Problem and Context

Freshwater quality and quantity are the biggest management concerns that Texas resource managers face today, and climate change is expected to significantly magnify these existing challenges. Freshwater is a critical component of Texas estuaries. The mixing of fresh and salt water creates a gradient of salinity that is vital to the survival of estuary-dependent species such as fish, shrimp, oysters, and crabs. Freshwater also supplies necessary nutrients and sediments to estuaries. However, more and more water is being drawn from rivers and streams to meet the growing needs of industry, agriculture, and municipalities. The population of Texas is expected to more than double between the years 2000 and 2060, growing from approximately 21 to 46 million. This growth is expected to increase the state's water demand from almost 17 million acre-feet (maf) to 21.6 maf during that same time frame (TWDB, 2007). As water demand increases throughout the state, the amount of freshwater that reaches the coast is projected to decrease. Water budgets for the year 2050 show a 5% decrease in downstream flows to the Texas coast when compared to 2000 values (Ward, 2011).

When examining future freshwater inflows to Texas estuaries, it is especially important to consider the potential impacts of climate change. Texas is projected to have an average 2° C increase in temperature and a 5% decrease in precipitation over the next 100 years (IPCC, 2007). If this climate scenario is considered in conjunction with population growth, the Texas coast is expected to see a decrease in downstream flows of 30% over the next 50 years (Ward, 2011). This is a much larger impact compared to the predicted 5% decrease based on population growth alone. Some areas of the coast are expected to see more severe changes. For example, the central Texas coast is projected to experience a 36% decrease during the same time frame (only 6% without climate change). These projections become even more severe when drought is added to the population growth and climate change scenario. In this instance, freshwater inflow to the central Texas coast will decrease by 74% compared to normal conditions. Droughts are historically common in Texas and the severity of these events is expected to increase as a result of climate change (Ward, 2011).

Land cover changes that result from increasing population growth and development can also impact water supplies through changes in runoff and infiltration. In Texas, runoff is produced during and immediately following infrequent but intense thunderstorm events. Numerous dams have been constructed throughout the state to establish reservoirs and capture runoff in order to meet water needs. However, these reservoirs only capture a small portion of the higher river flows and the remaining water flows through the dams (Ward, 2011). Land cover changes that result in increased runoff are likely to have an impact on the ability of current reservoirs to hold runoff, which will ultimately affect downstream flows to the coast. The extent of impervious surfaces could also decrease aquifer recharge by lowering infiltration capacity. In a state that depends heavily on both surface water and groundwater, this could be very important for both future water needs and freshwater inflows to the coast.

Texas estuaries are vital to the state's economy and support multibillion dollar recreational and commercial fisheries, as well as a growing tourism industry. Historically, little thought has been given to the freshwater needs of estuaries and the species that depend on them for shelter and food. This changed, however, when the Texas Legislature recognized the need to establish environmental flow standards and enacted Senate Bill 3 in 2007. The law created a public process by which state authorities would solicit input from scientists and stakeholders before establishing legal environmental flow standards for Texas estuaries and rivers (Figure 1). The legislation called for the creation of Basin and Bay Area Stakeholder Committees (BBASC) and Basin and Bay Expert Science Teams (BBEST) in each of the seven major bay/basin systems in Texas. The BBEST and BBASC are ideal user groups to engage in a science collaborative project. Participants of these groups were selected to create a diverse and experienced working body. In addition, Reserve staff and partners are members of these groups, which provided a unique opportunity to create a successful collaboration.

The BBEST is made up of scientists and technical experts with knowledge of region-specific issues and/or experience in developing flow recommendations. They develop flow regime recommendations based on best-available-science and provide their findings to the BBASC. The BBASC is composed of 17 members, reflecting various stakeholder groups (e.g., agriculture, recreational water use, municipalities, commercial fishing, regional water planning, etc.). The stakeholders are tasked with considering the BBEST recommendations in conjunction with water policy information and making a separate recommendation to the Texas Commission on Environmental Quality (TCEQ). TCEQ considers recommendations from both groups before establishing the legal minimum flow standards (Figure 1).

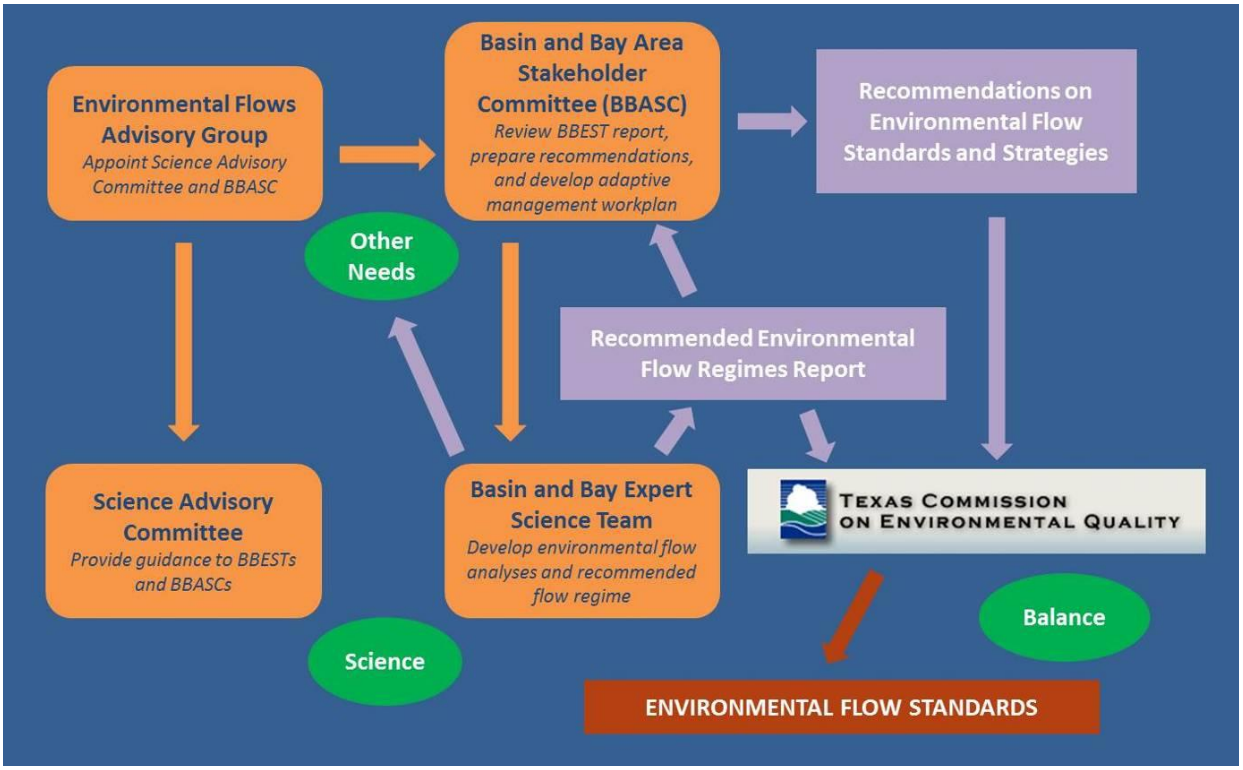


Figure 1. Summary of the Senate Bill 3 environmental flow process (Figure adapted from GSA BBEST, 2011).

The Guadalupe-San Antonio (GSA) bay/basin is located on the central Texas coast and includes the Guadalupe and Mission-Aransas estuaries and their watersheds. The Senate Bill 3 process is based on an adaptive management approach that will require experts and stakeholders to further review the initial flow recommendations which were submitted in the fall of 2011. Even after the initial recommendations were submitted to TCEQ, these groups have continued to meet to provide guidance on freshwater inflow needs and related research needs within the watershed. The BBASC are "*charged to develop a work plan that addresses periodic review of environmental flow standards, prescribes necessary monitoring and studies, and establishes a schedule for continuing validation or refinement of environmental flow regime recommendations*" (GSA BBEST, 2011). The primary goal of this project was to work with the BBASC and BBSET groups to provide better scientific information for adaptive management by tapping into the existing energy and efforts already completed by the BBEST and BBASC. This project also addressed the research gaps identified in the GSA BBEST report by working with the BBASC, BBEST, and other user groups to refine the goals and objectives of the applied science research. Members from the BBEST and BBASC were the primary intended users of the project and participated in the collaborative process, which included workshops, interviews, and mediated modeling. This helped ensure that research gaps were filled and scientific results benefit the future adaptive management approach for defining environmental flows for the GSA bay/basin.

The GSA BBEST report identified a need for more information on circulation patterns of the estuaries. Accurate salinity models are crucial since the BBEST uses a salinity zone approach to determine flow regime recommendations. Salinity modeling was based primarily on the TxBLEND hydrodynamic and salinity transport model that conducts simulations of circulation and salinity patterns within the estuary based on various freshwater inflow scenarios. Data on the exchange of water between adjacent bay systems was collected under this project to improve predictions of salinity changes that are the result of different amounts of freshwater inflow into adjoining bay systems behind the barrier island. To help address these needs, the team gathered circulation data to improve the TxBLEND model by characterizing exchange rates between the Mission-Aransas Estuary and adjacent bays.

In addition to the research barrier mentioned above, the BBEST report also indicated that biological information was needed to identify specific areas within the estuary where focal species are found in high abundance and/or in the best physical condition. Additional research on habitat condition verses salinity requirements was also addressed in the report. Sessile eastern oysters and *Rangia* clams were chosen as the primary focal species, but there was also a strong interest in the motile white shrimp and blue crabs. To help address this lack of information, the team collaborated with the BBASC (and other stakeholder groups) to conduct a research project that was identified by the BBEST that best met their highest priority needs and that could be completed with the expertise of the project team.

Future changes in water demand and availability are also imperative to consider during the adaptive management process and the revision of environmental flow recommendations. Future urban development within the watershed of the Guadalupe Estuary is especially concerning since it contains the growing San Antonio metropolitan area, as well as several smaller, but growing, communities. Although the majority of the Mission-Aransas Estuary watershed is currently rural, several cities in this region are also expected to see significant population increases over the next 50 years, which will place an increased demand on freshwater resources in this region. In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the effects of land use and climate change on water usage and runoff would greatly enhance environmental flow recommendations. To help address these barriers, the project team used decision support tools to examine the impact of land use and climate change on freshwater inflow volume. The user groups were highly involved in providing guidance and input to this effort.

The freshwater inflow research is a priority for the State of Texas, as evidenced by the passage of Senate Bill 3, but it is also a priority of the Mission-Aransas National Estuarine Research Reserve (NERR). Research on freshwater inflows is identified in *The Mission-Aransas NERR Management Plan* (US Department of Commerce, 2006) as a major goal of the NERR Research and Monitoring Program. The collaboration and applied science techniques developed from this project will greatly benefit the natural resources of Texas estuaries by improving the management of freshwater inflows.

Outcomes, Methods, and Data

Through this project, several outcomes were developed that included social, climatic, physical, and biological areas of research for improving freshwater inflow recommendations, including: (1) better understanding of the impacts of land use and climate change on water usage and runoff, (2) more information about specific areas within the estuary where focal species are found in high abundance and/or in the best physical condition, (3) additional data on circulation within and between estuaries to improve predictions of salinity distribution, and (4) a model of shared systems of learning for stakeholder groups. These outcomes were developed through a process of setting objectives, which are listed below:

- Examine the effects of land use and climate change on the amount of freshwater inflow to the Guadalupe-San Antonio and Mission-Aransas estuaries.
- Work collaboratively to design and carry out a research project related to one of the priority species identified during the Senate Bill 3 process, such as white shrimp, blue crab, *Rangia* clams, or oysters.
- Improve understanding of how water moves within and between the Mission-Aransas Estuary and adjacent bay systems.
- Improve access to freshwater management information, including products generated by this project, by developing shared systems of learning among the local stakeholders and scientists, and integrating that learning to construct a system dynamics model of the Guadalupe-San Antonio and Mission-Aransas estuaries.

Each of these objectives and their outcomes are described in the following pages.

1. Land Use and Climate Change Impacts in the Mission-Aransas and Guadalupe-San Antonio Estuaries

In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the combined effects of land use and climate change on water usage and runoff could enhance environmental flow recommendations. For this project, mapping tools were used to examine various scenarios of future land use and precipitation in order to explore potential changes to water use and runoff within the Mission-Aransas and San Antonio-Guadalupe estuary watersheds.

Scenario planning offers a framework for developing more resilient policies and decisions when faced with uncertainties, and therefore, was used for this portion of the project. A scenario in this context refers to a plausible future. In scenario planning, several of these plausible futures are compared in order to explore the uncertainty surrounding future consequences. Stakeholders were polled during the January 17, 2013 workshop to determine what combination of variables they would like to see included in the scenarios. Stakeholders were surveyed twice during the presentation using keypad polling software. The first survey occurred after reviewing the objectives for this portion of the project, and the second survey occurred after the stakeholders were presented projections for future land use and precipitation within the watershed. The goal of the surveys was to gather input from the stakeholders on the types of scenarios that they would like to see included in the modeling. This will help ensure that stakeholders benefit from the scenario planning results and can use the information in future decisions.

Stakeholders were asked their preference related to the following scenario variables: (1) time horizon (2020, 2040, 2060, 2080, 2100), (2) approaches (monthly, seasonal, annual, or combination), and (3) greenhouse gas emissions scenarios (A2, A1B, B1, or combination). Based on the answers provided, twenty scenarios were developed using a combination of the highest priority variables. Two mapping tools, CommunityViz and OpenNSPECT, were then used to examine the chosen scenarios of future land use and climate in order to understand potential changes to future water usage and runoff.

CommunityViz planning software is an extension for ArcGIS that is used by planners, resource managers, and local and regional governments to model the implications of different plans and choices. It supports scenario planning, suitability analysis, growth modeling, and impact assessment (Figure 2). For the purposes of this project, CommunityViz was used to assess the impact of future housing density scenarios on residential and agricultural water use within the Mission-Aransas and Guadalupe-San Antonio estuary watersheds.

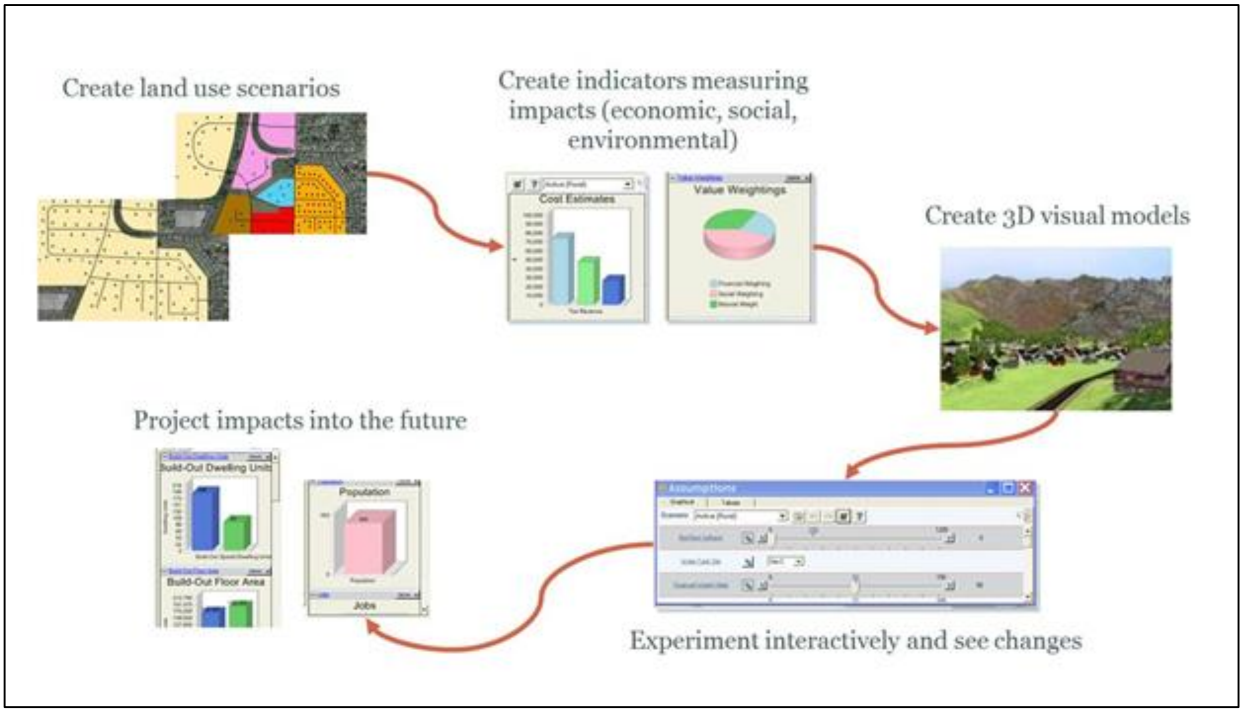
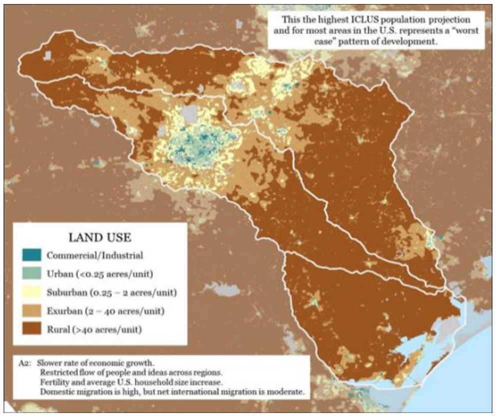


Figure 2. CommunityViz tools allow you to envision alternatives and understand their potential impacts.

The Integrated Climate and Land-Use Scenarios (ICLUS) developed by the Environmental Protection Agency's Global Change Research Program were used to construct future housing density projections that were based on the social, economic, and demographic storylines of the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) (Figures 3). ICLUS outputs were derived from a demographic model that generates population estimates and a spatial allocation model that distributes housing density across the landscape. In order to generate maps that could be included in CommunityViz and used to estimate population and future water usage, the ICLUS data was combined with the 2006 data from the U.S. Geological Survey National Land Cover Dataset (NLCD) to generate maps of future land use/land cover for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries.

Information about parcel size (derived from future land use/land cover maps), assumptions about the size of dwelling units (i.e., rural = 500 acres/unit, exurban = 25 acres/unit, suburban = 0.5 acre/unit, urban = 0.2 acre/unit), and information about average household size were then used to estimate future population within the watershed for six scenarios (i.e., 2010 A2, 2020 A2, 2060 A2, 2010 B1, 2020 B1, 2060 B1). Next, assumptions about the amount of water used per person

County	Average Household Size
Kerr	2.35
Gillespie	2.38
Bandera	2.49
Kendall	2.70
Blanco	2.50
Bexar	2.78
Medina	2.91
Atascosa	2.99
Comal	2.64
Hays	2.69
Caldwell	2.82
Guadalupe	2.83
Wilson	2.89
Gonzales	2.69
Karnes	2.66
DeWitt	2.53
Victoria	2.75
Goliad	2.57
Bee	2.74
Calhoun	2.75
Refugio	2.59
Aransas	2.43
San Patricio	2.97



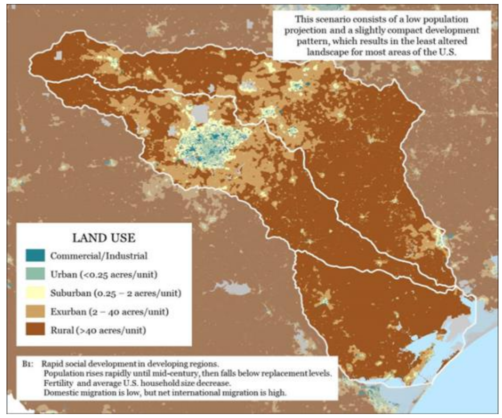


Figure 3. The images above show the ICLUS projected housing density in 2060 for the Guadalupe-San Antonio and Mission-Aransas estuary watersheds based on the A2 (middle) and B1 (right) SRES storyline. The image on the left shows the average household size per county used to model future population in the watershed.

per day were applied to calculate residential water use. By changing the assumption about the amount of water used per person, it was also possible to see how future water conservation efforts could affect residential water use. Future land use/land cover scenarios were also used to estimate how the amount of cultivated cropland would change over time and how this would affect the amount of water used for irrigation. By changing the assumption about how much water is used to irrigate an acre of cropland, it was possible to see how improvements in irrigation efficiency could affect future irrigation water use. Similarly, by changing assumptions about the amount of cropland being irrigated, it was possible to see how changes in the number of irrigated acres (due to drought, changes in crop type, etc.) could affect future irrigation water use.

OpenNSPECT is the open-source version of the Nonpoint Source Pollution and Erosion Comparison Tool developed by the NOAA Coastal Services Center. The tool is designed to help planners and managers understand potential water quality impacts from development and climate change. It uses spatial elevation data to calculate flow direction and flow accumulation throughout a watershed. Land cover, soils, and precipitation data sets are then processed to estimate runoff volume. Coefficients representing the contribution of each land use/land cover class to the expected pollutant load can also be applied to land use/land cover data sets to approximate total pollutant loads. The tool's output layers display estimations of runoff, pollutant loads, pollutant concentration, and total sediment loads. These layers can help resource managers make informed decisions about water quality and determine what areas to target for improvement, as well as predict the impacts of management decisions on water quality. OpenNSPECT also provides functionality to compare current land use/land cover conditions to proposed changes in both land use and land cover (NOAA, 2014).

For the purpose of this project, digital elevation maps, soils data, precipitation data (Figure 4), land use maps (examples provided in Figure 3; additional maps in Appendix) were used in OpenNSPECT to estimate runoff volumes for all twenty scenarios. Due to processing limitations of the tool, however, analyses could not be performed at the scale of the entire watershed. As a

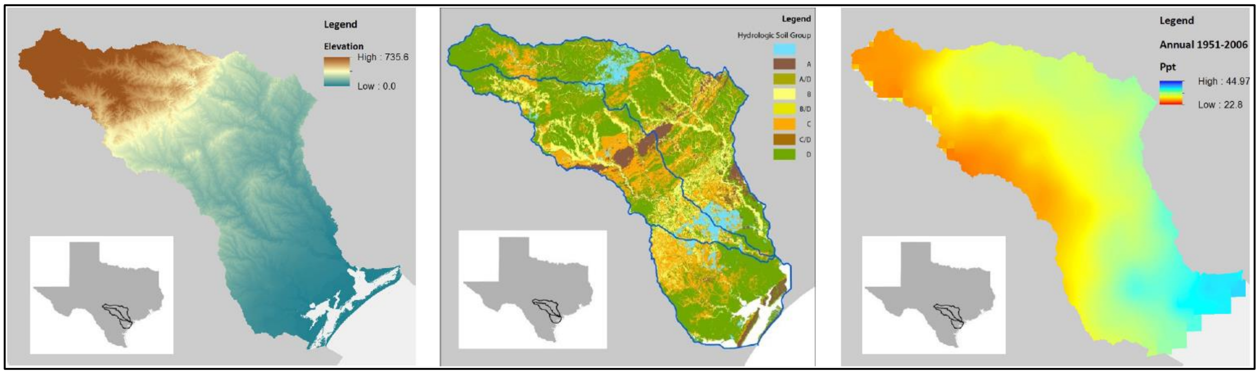


Figure 4. The images above show elevation (left), hydrological soil groups from NRCS Soil Survey Geographic Database (center), and average annual precipitation from 1951-2006 (right) in the Guadalupe-San Antonio and Mission-Aransas estuary watersheds.

result, analyses were restricted to two sub-basins, one which represented a rural portion of the watershed (Mission Sub-Basin) and one which represented an urbanized area (Upper San Antonio Sub-Basin). The tool was only used to examine runoff volumes - pollutant loads were not examined as part of this project. However, since the tool does provide the opportunity to examine how land use and climate change could affect future pollutant loads to the estuary, this represents an area of future potential research.

In conclusion, CommunityViz software was used to examine changes in population, residential water use, acres of cropland, and water use for irrigation. Results showed a major increase in watershed population and residential water use over time, but the level of this increase was not the same for the A2 and B1 emissions scenarios. The A2 scenario showed more significant increases compared to the B1 scenario when looking at a longer time period. The acres of cultivated cropland and the amount of water used for irrigation both decreased over time. Similar differences between the A2 and B1 emissions scenarios were observed for these variables, with the A2 scenario showing greater changes in cropland and irrigation water use over the longer time scales when compared to the B1 scenario. This provides some evidence that when climate change is considered in freshwater inflow planning, it is important to carefully consider which emissions scenarios (i.e., A2 or B1) are examined, particularly when looking at longer time frames. If uncertainties exist about which emissions scenario represents the most plausible future, it is probably best to examine multiple scenarios. By changing several of the assumptions within the CommunityViz model, we were also able to quickly and easily see how changes in the amount of water used by individuals, the amount of water used for irrigation, and the number of acres irrigated could impact the amount of water used within the watershed. Although these assumptions were hypothetical, they do provide some indication about the level of water conservation and improvements in irrigation efficiency that may be required to offset the demands of increasing populations and an increased demand for more irrigated cropland.

OpenNSPECT was used to estimate runoff volumes for all twenty scenarios, but due to processing limitations, analyses were restricted to two sub-basins, one which represented a rural portion of the watershed and one which represented an urbanized area. Results showed that when precipitation varies significantly with season, it is important to look at seasonal differences in runoff, rather than annual averages. Results also showed that differences in land use and precipitation at the scale of the sub-basin can have an effect on future runoff patterns, although changes in precipitation appear to be the major driving factor in future runoff volume. Finally, results indicate that runoff volumes could be impacted by the way in which precipitation is delivered in the future. If the future climate in this region is characterized by less frequent intense rainfall events separated by longer, dry periods, runoff may increase over time. However, if the future climate is characterized by more frequent, less intense rainfall events, runoff is more likely to decrease over time.

The mapping tools used for this portion of the project were chosen based on the project teams' previous experience with watershed mapping and modeling. Although they are relatively simple tools and rely on a number of assumptions, CommunityViz and OpenNSPECT are designed to allow the user to quickly assess and compare a large number of potential scenarios. While more sophisticated hydrologic and land use planning models are available, the purpose of this portion of the project was to encourage stakeholders to think about how land use and climate change may influence future freshwater inflows to the coast by comparing a variety of different scenarios. Therefore, the tools that were chosen were deemed appropriate. However, it is important that the caveats described throughout this report are considered when examining the results.

2. Focal Species

Although there is often anecdotal evidence that some estuarine species are more abundant or productive in years with more freshwater inflow, good long term data sets are rarely available that allow these relationship to be statistically verified, if they do exist. In addition, many data sets do not include all the critical life history stages. Motile species also pose additional challenges since they may be selecting for other habitat characteristics such as food, habitat structure, etc., and not choosing their location based on salinity preferences alone.

The main focal species studied in this project is the blue crab, which is both economically and ecologically important within the reserve, and also highly motile. Stakeholders selected blue crabs as a priority species for research during a workshop that was held at the beginning of the project. Blue crabs have a complex life history with adults spawning in the Gulf of Mexico and crab larvae recruiting back to the estuary (Figure 5). Juvenile blue crabs prefer the lower salinities of estuaries, where they also experience more food and lower rates of parasitism and predation. Adult female blue crabs seek higher salinities (offshore water) to release their planktonic larvae. The larvae use salinity signals to recognize the passes into estuaries and tidal currents to transport them back into the estuary. The only long term data sets for the Mission-Aransas estuary are those of the Texas Parks and Wildlife Department, and their trawl data only measures the abundance of larger juvenile and adult crabs. Long term data are not available for larval or early juvenile blue crabs.

As part of the Mission-Aransas NERR's "Blue Crab Megalopae Citizen Science Program," we continued our larval blue crab sampling program at the entrance to the Mission-Aransas Estuary. Volunteers collect daily samples of blue crab larvae that are ready to settle and become juvenile blue crabs using "hogs hair collectors" deployed for 24 hours (Figure 6). The volunteers then rinse the larvae off the collectors and preserve them for counting under a microscope.

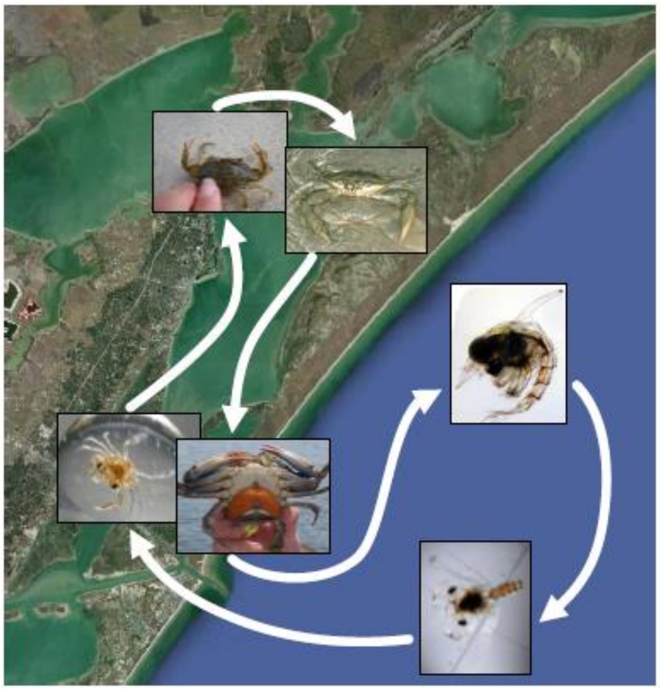


Figure 5. Blue crab life cycle and migration between the estuary and the Gulf of Mexico. Figure courtesy of Zack Darnell.

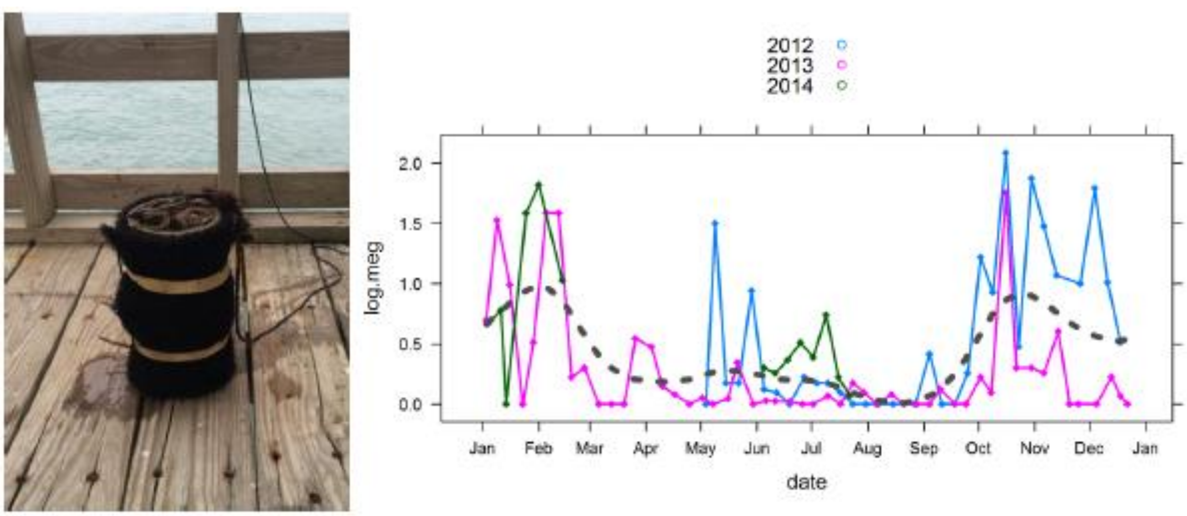


Figure 6. A hog's hair collector ready for deployment at the MSI pier and a plot of the numbers of blue crab larvae sampled at the MSI pier during the three years the Citizen Science Project has been running (average trend shown as gray dotted line). Photo courtesy of Claire Weirich.

Kimberly Bittler, as master's student in the laboratory of lead scientist Dr. Edward Buskey was supported by this project and carried out her thesis research on the ecology of blue crab larvae, entitled "The ecology of Blue Crab (Callinectes sapidus) megalopae in the Mission-Aransas Estuary, Texas: Salinity, settlement and transport".

Blue crabs are a widely distributed estuarine species with broad economic and ecological importance. Several studies have linked blue crabs to freshwater inflows, but the precise nature of this link is still uncertain, as blue crabs have a complex life cycle that utilizes both marine and estuarine environments. One potential link between blue crabs and freshwater inflows is during recruitment, when megalopae developing offshore return to estuaries before molting into juvenile crabs. Megalopae swim during the flood tide to ensure delivery into and farther up estuaries. The behaviors regulating selective tidal stream transport (STST) on the flood tide were originally studied in North Carolina in an estuary with regular freshwater inflows and a strong salinity gradient. The model of STST was re-examined in the Mission-Aransas, an estuary with episodic freshwater inflows and salinity gradients ranging from normal estuarine conditions to hypersaline during droughts. The behavioral responses of megalopae to a range of rates of salinity increase were tested, and then modeled onto rates of salinity change observed in the field to determine the theoretical ecological consequences of STST for blue crab populations in the Mission-Aransas Estuary.

To validate the ecological trends predicted by the behavioral model of STST, a simple, long-term data set reflecting changes in megalopae abundance is needed. Hog's hair collectors are a simple and widely used method of quantifying abundance of brachyuran megalopae, including blue crabs. However, the efficiency of hog's hair collectors in sampling for megalopae is unknown. Several studies have reported poor correlations between settlement on hog's hair collectors, transport, and abundance of megalopae in the plankton due to disparate temporal scales and potentially turbulence-driven decoupling. Each of these issues were addressed in field and flume experiments, which were used to develop a model for interpreting settlement on hog's hair collectors in terms of transport and planktonic abundance.

In addition, the project team performed a meta-analysis of existing blue crab abundance data sets for trawl samples that included salinity and habitat information from throughout its range on the east and Gulf coasts of North America. The analysis included 30 estuaries from New Jersey to Texas, and time series data sets covering from 5 to 36 years. Statistical analysis of these data revealed a subtle but significant relationship between salinity and crab abundance with maximum abundance predicted for salinities of 9-10 PSU, although salinity explained only about 6% of the variance in blue crab abundance.

3. Water Circulation and Current Monitoring

The environmental flow recommendations made by the GSA BBEST were based primarily on salinity values predicted by the Texas Water Development Board TxBLEND hydrodynamic and salinity transport model. Model inputs include bay bathymetry, tides, rainfall, evaporation, wind, freshwater inflow from rivers, and exchange with adjacent bay systems. The GSA BBEST noted that refinements to the model would improve the quality of flow recommendations. In particular, higher quality data on the magnitude and direction of water exchange between the Mission-Aransas Estuary and adjacent bay systems are needed because a considerable amount of water from the San Antonio/Guadalupe Rivers enters into the Mission-Aransas Estuary from San Antonio Bay. The volume of water carried by the Guadalupe and San Antonio rivers into San Antonio Bay is typically about an order of magnitude greater than the amount of freshwater carried by the Mission and Aransas rivers into Copano Bay.

The TxBLEND model predicts salinity patterns, but it does not identify the sources of freshwater that affect salinity at a given location. In order to understand how freshwater inflows of individual rivers affect the ecology of estuaries on the Texas coast it is critical to understand water circulation patterns within and between adjacent bays. However, up until now, no detailed measurements of currents throughout the Mission-Aransas Estuary had been made. One of the four main objectives of this project was to deploy "tilt" current meters at strategic locations throughout the bays to gather circulation data that could be used to improve inputs to the TxBLEND model.

A set of 18 tilt current meters was originally acquired for the project, but an additional 9 meters were ordered to replace instruments that were lost and to test an updated version of the meters. Each tilt meter looks like a two foot pipe with a tether on one end and a cap on the other. The tether attaches the meter to a stake anchored in the sediment, allowing the meter to float freely in the water above. A data logger under the cap records how far and in what direction the meter leans in a current. The angle and direction of the tilt can then be converted to current speed and direction.

Test deployments of the current meters were done at four of the Mission-Aransas NERR System Wide Monitoring Program (SWMP) stations to become more familiar with the type of data that the loggers record and to experiment with different deployment methods. It was verified that the meters provide data that, when smoothed over time, represent realistic current directions and velocities and correspond well to tidal predictions and wind data for the area (Figure 7). A deployment method using a pole deployer and a hook retriever was developed and successfully implemented. A PVC pole was customized to fit over the top of a meter stake such that pressure could be put on the top of the stake, but the attached meter could float freely within the pole. This design allowed the pole to be lifted away from the meter after the stake was driven into the sediment. To minimize losses due to boaters and vandalism, surface markers were not directly attached to the meters. Meters were either placed next to existing landmarks, or they were marked with a float placed nearby. The exact locations of each meter and of a brick stretching a rope out from the meter stake were marked with GPS waypoints upon each deployment. Snagging the rope by dragging a hook between the marked waypoints from the boat proved to be an effective method of retrieving the instruments.

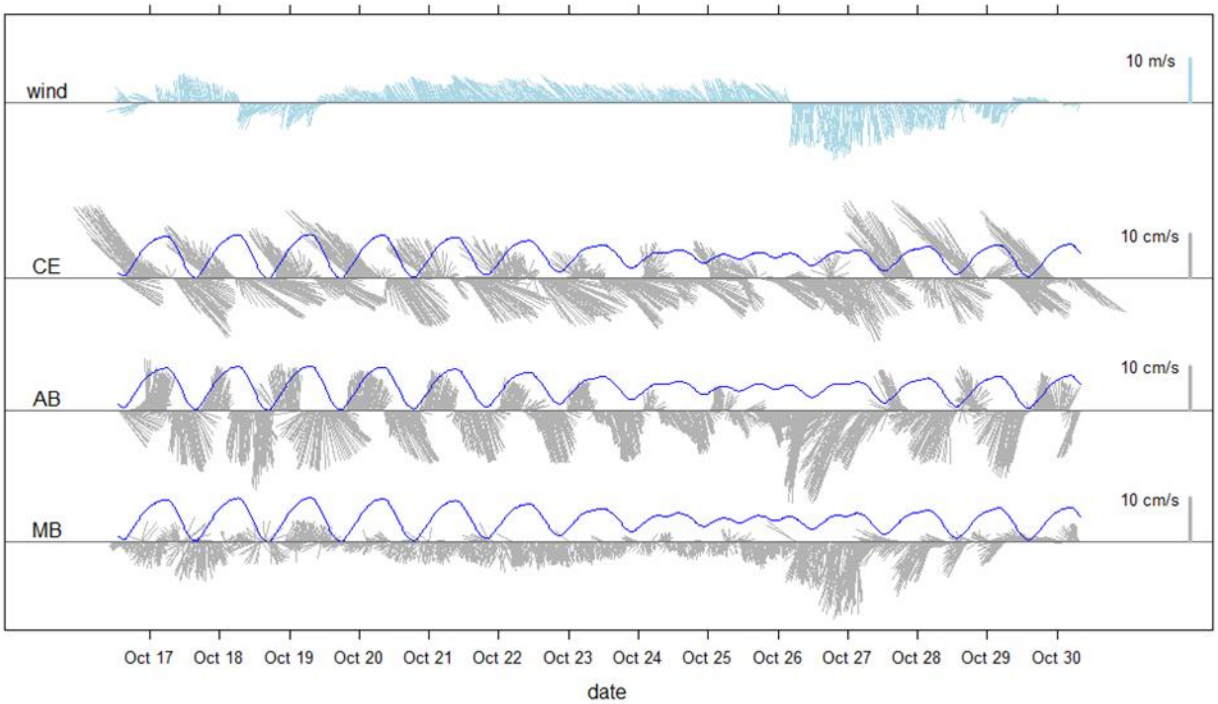


Figure 7. Stick plot of wind and water flow directions and velocities at three of the SWMP stations during a two week deployment in October 2012, where the length of each line represents the speed of flow towards the indicated direction. Wind data are from a Texas Coastal Ocean Observation Network (TCOON) station in Copano Bay. Relative tidal height data (blue) from the Copano TCOON station are overlain on the water current data.

To determine where in the estuary the meters should be placed, participants in the stakeholder meeting on May 30, 2012 were solicited for location suggestions. It was apparent that there were regions in which the locations clustered, indicating that a substantial number of the participants independently agreed on the importance of monitoring currents in those general regions. An attempt was made to capture the consensus by condensing the locations to a workable number of stations.

The suggestions of stakeholders at the May 30, 2012 meeting in Port Aransas and the information provided by local fishing guides at a December 6, 2012 meeting were taken into account while selecting 15 final locations for the first round of current meter deployments in Aransas and Mesquite bays (Figure 8A). Data was collected at these stations from June-November 2013. The tilt meters were redeployed at 11 stations in Mesquite Bay in March 2014, just prior to the start of work to reopen Cedar Bayou, so circulation patterns before and after the pass was opened could be compared (Figure 8B). Newer model tilt meters with built-in compasses were paired with the original instruments at these stations to help correct any direction alignment errors in previously gathered data.

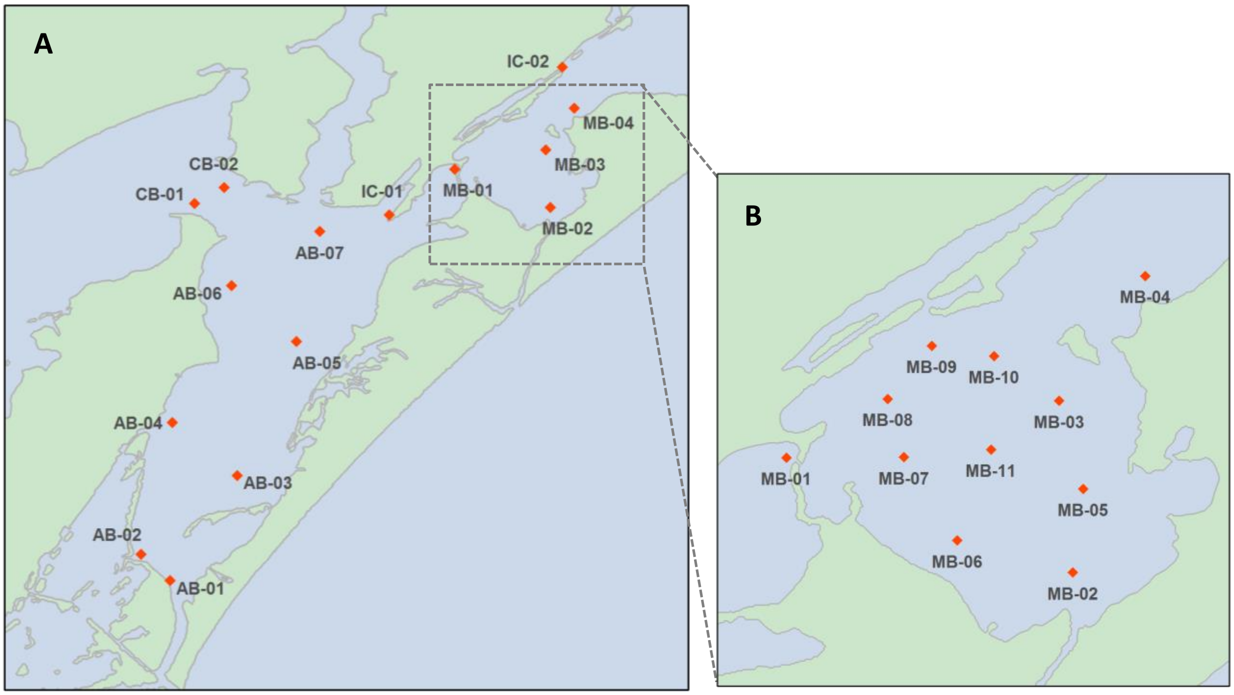


Figure 8. (A) Map of the 15 stations selected to deploy the tilt meters for the first round of data collection. (B) Map of the 11 stations in Mesquite Bay selected for the second round of data collection.

The tilt meters generate large amounts of data that are challenging to display in an informative way. To view time-series of current speed and direction data, stick plots are commonly used (Figure 7). While corresponding changes in currents between different stations can be seen on these plots, it is difficult to relate the patterns to where the stations are located relative to one another. To attempt to solve this problem, an animated plot was created to display the data for multiple stations over time on a map (Figure 9). In this plot, a blue arrow drawn at each current meter station on a map creates a snapshot of the directions and speeds of the currents at a single time-point. A red arrow representing wind speed and direction and a bar representing predicted tide direction are also shown. Underneath the map, the tide and wind time-series are plotted, and a vertical bar marks the point in time displayed. As the animation plays, the time-series plot scrolls and the arrows and bars on the map move, and relationships between the tides, wind, and currents at the different stations can be seen.

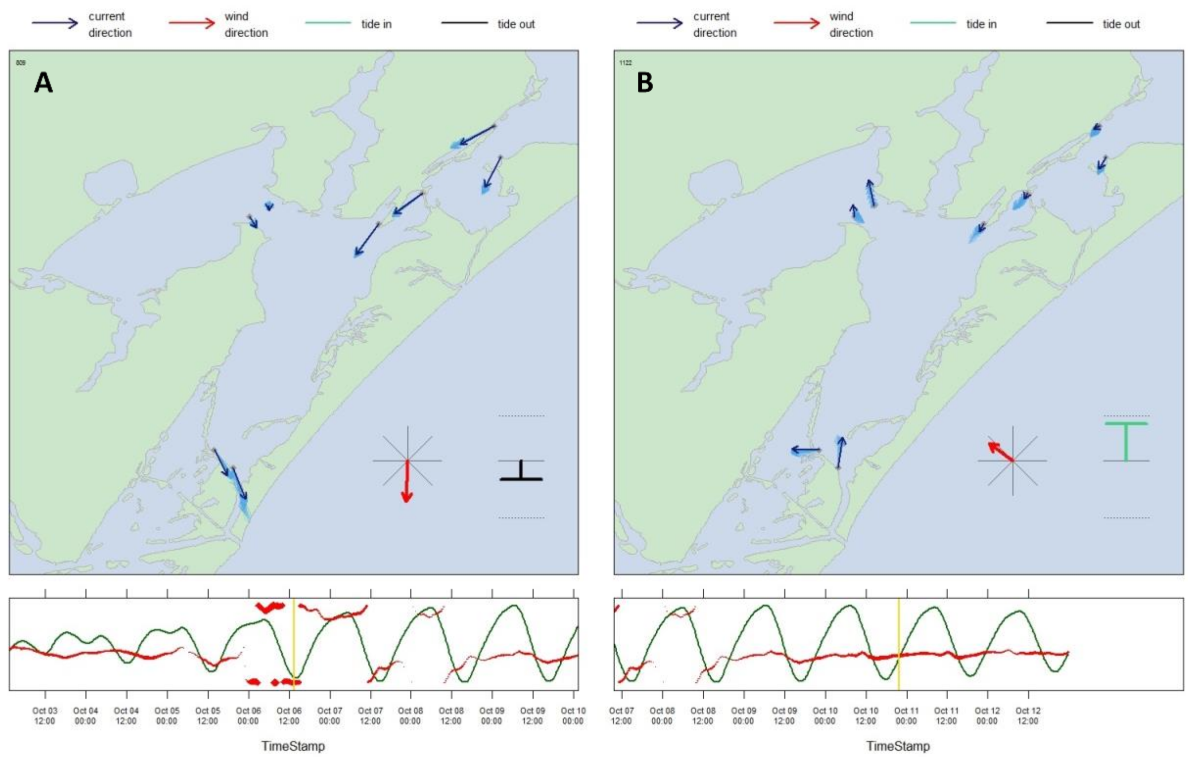


Figure 9. Frames from an animation of current data for eight of the 15 stations. (A) Snapshot of current directions during an outgoing tide with a southward wind. (B) Snapshot of current direction during an incoming tide with a northwestward wind.

Tidal and wind influences on currents were apparent in the data animations and were quantified for each station. When these results are displayed on a map, it is clear that tidal effects on currents are stronger closer to Aransas Pass, and wind is a more dominant factor farther from the pass (Figure 10). An analysis was conducted to assess whether an influence of current patterns on salinity in the bays could be detected. Salinity data from the MANERR SWMP stations was compared to the direction of water flow between Aransas and San Antonio Bays. Salinity at the Mesquite Bay SWMP station was most strongly related to current direction, with over 80% of the variance in salinity explained by the current meter data (Figure 11).

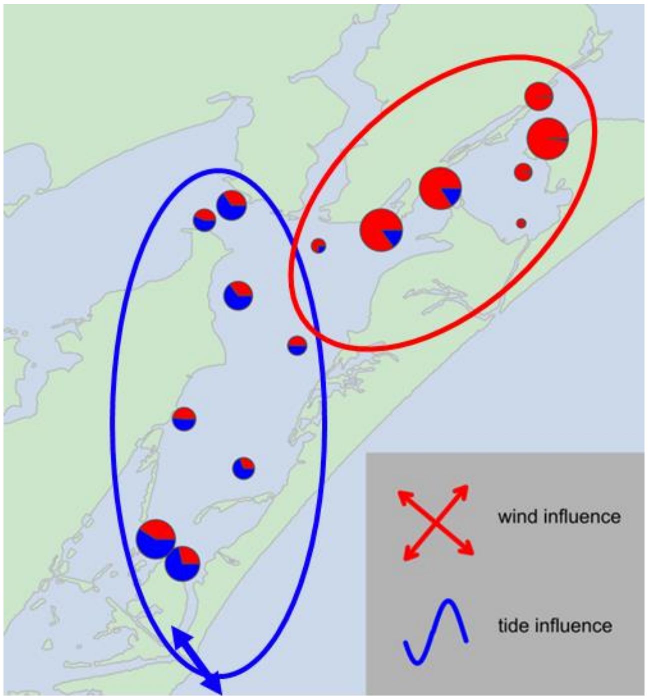


Figure 10. Pie charts indicating the relative influence of tides (blue) and wind (red) on current speed and direction at each station.

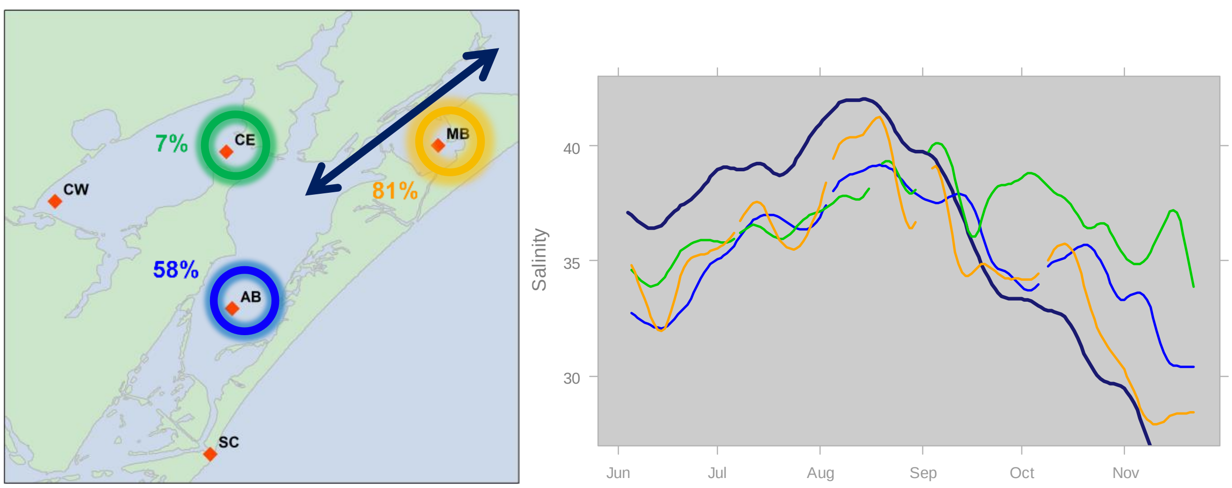


Figure 11. Map of the SWMP station locations and plot of the salinity time-series from the Aransas Bay (blue), Copano East (green), and Mesquite Bay (orange) SWMP stations. Direction of flow between Aransas and San Antonio bays is also indicated on the plot (black), where upward slope indicates flow up towards San Antonio Bay and downward slope indicates flow down towards Aransas Bay. The amount of variance in salinity at each station that is explained by the current direction is indicated on the map.

4. Shared Learning through Mediated Modeling

The fourth objective of the NERR Science Collaborative was improve access to freshwater management information, including products generated by this project, by developing shared systems of learning among the local stakeholders and scientists, and integrating that learning to construct a system dynamics model of the Guadalupe-San Antonio and Mission-Aransas estuaries.

To this end, the mediated modeling team (modeling team) facilitated collaborative modeling activities at each of the six workshops. The overall goal of these activities was to integrate knowledge and interests from all stakeholder groups, including the modeling team, into a collaboratively developed system dynamics model of the Guadalupe and Mission-Aransas estuaries. The formal model that emerged from these activities focused on estuary components of greatest interest to participating stakeholders. Workshops participants initially developed a conceptual model of the estuary system that was then formalized into a system dynamics model, using Netlogo software (http://ccl.northwestern.edu/netlogo/). Stakeholders then used the resulting model to experiment with various scenarios they envisioned for the estuary system. Drs. Grant and Peterson jointly led this process, with Dr. Peterson primarily responsible for eliciting the system dynamics that were of greatest interest to participants, and Dr. Grant primarily responsible for formalizing those system dynamics into a model that would allow participants to experiment with various scenarios. Chara Ragland, PhD student, facilitated most group activities, with assistance from Paulami Banerjee (PhD student), and Sarah Horn (MS student). Near the conclusion of the project, stakeholders were surveyed to enable the modeling team to learn which aspects of the workshop activities had contributed more and less to motivation for continued participation in this, and other collaborative conservation efforts.

Workshop participants followed a standard protocol (van den Belt, 2004) to construct conceptual models of the estuary (Figure 12). Working together in small groups, they attempted to 1) tell the story of the estuary as a system, 2) ask 3 basic questions about the system, 3) translate the questions into modeling language, 4) retell the story, using formal modeling language, and 5) revise the model to tell a more persuasive story. The modeling team used the conceptual model developed by workshop participants as the basis for developing a formalized system dynamics model. Over the next several workshops, stakeholders then experimented with the formal model, critiqued the results, and suggested additional changes each time they met (Thompson et al, 2010). A description of workshop results can be found in Appendix A.

Figure 12. Participants work on refining the conceptual estuary model.

The final discussion in May 2014 reviewed the overall collaborative process and looked toward the future. Participants have become more informed about the potential effects of land use and climate change on freshwater inflows; learned more about how currents, tides, and wind affect water movement in the estuary; learned more about blue crab and *Rangia* clam life history; and developed shared systems learning through construction of a system dynamics model.

To ground the discussion, the collaborative team offered a concept map by TIDES inter Abbie Sherwin (Figure 13) of the project as relates to the Texas SB3 process. Participants discussed how data currently being gathered on *Rangia* clams and knowledge learned about blue crabs might be useful to BBEST. They suggested that what has been learned from these meetings needs to be communicated to a wider audience. For example, participants expressed hope that suggestions based on science conducted by project research teams would be incorporated by the Texas Commission on Environmental Quality into standards suggested in reports prepared by the Guadalupe/San Antonio BBEST and BBASC.

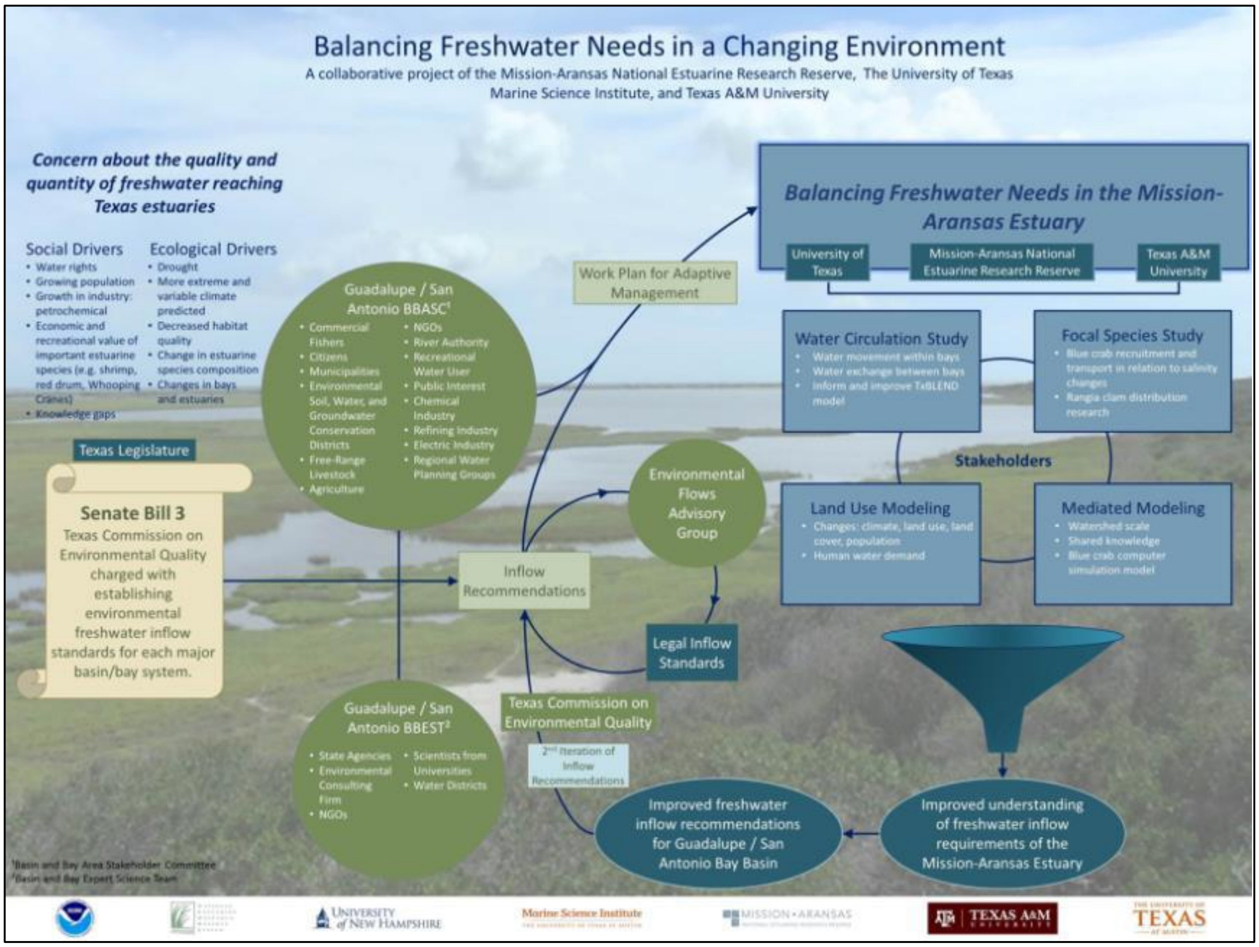


Figure 13. Concept diagram of Texas SB3 process.

To learn what motivated stakeholders who had participated in this multi-year process, the modeling team developed a 12 question survey. The survey asked stakeholders to identify the initial influences that led them to begin participating in the collaborative process, report on their goals and objectives for the process, and to identify and describe roles they believed were the most important to the success of the collaborative process. Finally, they were asked to explain their overall rationale for continued participation. This gave them an opportunity to further emphasize one of the topics they had already talked about, or to introduce topics that had not been included. The survey took approximately 20 minutes to complete, and included both multiple choice and open ended questions.

Participants were invited to provide their contact information at the completion of the survey should they wish to participate in an in-depth interview to be scheduled at a later date. Sarah Horn conducted five follow up interviews, using the same basic questions, but taking an informant-directed approach so that interviewees could direct the conversation toward topics of greatest interest to them. This provided greater richness and depth regarding participant motivations.

Survey and interview responses were both transcribed into digital format for analysis and qualitative textual analysis was conducted to identify themes and subthemes that emerged. To maintain participant confidentiality and fulfill IRB requirements (IRB2012-0187D), we removed names from our data.

Three themes emerged from the responses. Information sharing was the most frequently mentioned motivation for participation, and was often introduced in connection with other themes. The second theme participants identified was role playing. Stakeholders reported roles that facilitated information sharing as strong motivators for continued participation. The third theme identified by participants was a desire to contribute to closer connections between science and management of the estuarine system. Overall, participants were motivated by their hope of accomplishing three objectives through this collaborative process: 1) learning about estuaries and bays, and gaining exposure to current scientific practices; 2) communicating what they learned with each other and with those unable to participate, about what is learned; and 3) using science to make informed management decisions. These three objectives were closely interrelated with each other and with the themes of information sharing, role playing, and connecting science with management.

<u>Information Sharing:</u> The sense that participation in the collaborative process provided participants with access to management decisions provided the strongest motivation to participate. The hope that information sharing would provide them with access to the management process motivated people to begin participating and continue to participate over the multi-year project. Some stated that information sharing was most valuable when people shared their personal experiences with the group because it provided opportunities to engage all participants, to offer multiple perspectives, and to provide insight beyond the published literature. Participants believed that everyone gained from having multiple opportunities to share his/her own knowledge, and also to learn from other stakeholders.

One participant claimed that one of the most valuable aspects of the modeling process was “stakeholders providing their own knowledge/experience to help inform others”. Participants noted the value of the project’s iterative nature, explaining, “you can go to one [workshop], provide information, and then at the second one they'd show how they incorporated that into the project. Because lots of times you go to one or two day workshop and then you never see the results of it. So, when we were able to provide our information, it was used and that helped to improve the process". The possibility of sharing information outside the collaborative process also motivated continued participation because it provided an opportunity to further discuss information learned during workshops with a broader audience.

<u>Role Playing:</u> Stakeholders reported that performance of certain roles motivated them to continue participating in the collaborative process. Stakeholder responses indicated that the availability of those roles enabled them to achieve a sense of standing in the management process for the Mission-Aransas Estuary. Rather than referring to legal standing, we use the term in the broad sense articulated by Senecah (2004:24) as the "civic legitimacy, respect, esteem, and consideration that should be given to stakeholder perspectives." Participants tended to identify with one or two roles, most frequently as observers, information providers and liaison with non-participants. One participant noted that all participants got to play roles they did not normally play when participating in other workshops and meetings: "we were able to choose which indicators we thought were most helpful, crabs, oysters, things like that, and also where we wanted to put tide instruments [flow meters] to see circulation in the bays". Others noted that, even when it came to formal presentations, all stakeholders had opportunities to share in the role of information provider. Overall, stakeholders agreed that multiple roles were important for productive and accurate information sharing and contributed to the desirability of participating in the collaborative process.

<u>Connecting Management with Science:</u> The third theme was the desire to more closely connect science to management of the estuary. One participant stated they were motivated by the "unique" opportunity the workshops provided for "getting science to managers". This stakeholder believed participation in the collaborative workshops provided a direct vehicle for ensuring that managers had access to the most relevant science. Participants were motivated by opportunities to promote "improved freshwater inflow requirements for the estuary - i.e., have more information to justify the recommended inflow standards". All participants were unified in their overriding motivation to contribute to science-based management of the estuary.

<u>Opportunity to influence estuary management:</u> Stakeholder responses also revealed how the three themes interrelated to provide them with hope that, by participating in the NERR collaborative process, they could have an influence that would contribute to sustaining the Mission-Aransas Estuary. Participants demonstrated the interconnected motivational impacts of the three themes in several ways. One stakeholder highlighted theme 1 and 2 by self-identifying with the role of observer, which enabled him to "attend meetings and gain knowledge". He highlighted the importance of information sharing, which provided "a better understanding of how the estuaries work and how the system responds to a variety of external factors. He explained that his primary motivation was to "continue to gain knowledge and stay informed". Another participant emphasized themes one and three by saying, "I would like to hope that understanding more about how the estuaries are managed means you can make the science fit legally what is needed to protect the things that you want to protect". Another participant described "gaining exposure to new science" as a way to "advance/inform the decision making process regarding freshwater inflow needs". Their motivations for continued participation were based on the belief that knowledge gained from information sharing, both among and beyond those who participated in the collaborative process,

would lead to more scientifically informed policy decisions.

Retrospective

Overall, the project team found it very beneficial to build up on the work done by the BBASC/BBEST committees during the Senate Bill 3 process, but this did sometimes create some challenges for the collaborative aspects of the project. For example, at the beginning of the project, there was some confusion among stakeholders about how the GSA BBASC decisions would influence and drive the decision about what type of focal species project the Science Collaborative project team would undertake. It was reiterated several times to the GSA BBASC estuary subcommittee by multiple members of the project team that input from the BBASC (and BBEST) is very important, but the Science Collaborative project team priority or focal species project would be selected by a larger stakeholder audience.

Freshwater inflow is a challenging problem and our NSC project tried to address several components of the issue. It was often challenging to get stakeholders to understand how, seemingly different components worked together in the short amount of time available for meetings (without meeting burnout). We tried to address this by developing a better presentation and short activity to help alleviate this problem and provide connectivity. At a stakeholder meeting held in September, we added a facilitated discussion using the "web-of-life" game to explore how the project components (i.e., land use / climate modeling, current meters, blue crab research, and mediated model) affect decision-making related to freshwater inflows. In addition, our TIDES fellow, Abbie Sherwin, created a context map. This context map was presented at one of the stakeholder meetings, with the participants making suggestions on the placement of arrows and presentation.

The mediated model (using NetLogo software) was time consuming and a challenge to implement. The stakeholders may have gotten a better understanding of blue crab dynamics with a game combined with actual sampling.

Input from intended users influenced every applied science aspect of the project: (1) intended users helped select locations where current meters should be placed; (2) intended users helped define the parameters of the land use/climate change modeling scenarios; (3) intended users selected blue crab as the species of interest for additional research; and (4) intended users provided input to the development of the blue crab system dynamics in NetLogo. Some of the applied science objectives required continued input of intended users throughout the project, while others were limited to input at the beginning of the project. By continuing to involve intended users throughout the course of the project, the project team was able to cultivate an environment in which intended users felt invested in the project and desired to help the team improve the project. This was evidenced by the good attendance at workshops that spanned the entire course of the three-year project.

As the project team worked on the blue crab system dynamics model with stakeholders, it was decided that using NetLogo software would be beneficial for building the model and allowing stakeholders to interact with the model. As a result, an expert on NetLogo was invited to participate in the project to assist with the model development.

Conducting this type of collaborative research was much more time intensive than the project team had initially estimated – meetings occurred frequently and required a great deal of time to plan and prepare. Future proposals should incorporate additional salary support for staff to devote the necessary time required for this type of collaborative effort.

For the circulation portion of the project, devising a feasible deployment and retrieval method for the tilt current meters was more challenging than expected. The weighted cross-bases that were originally designed to moor the meters were too cumbersome and heavy to easily deploy and retrieve such a large number of meters regularly. Also, surface markers tended to be pulled up by boaters and could therefore not be attached directly to the meters, which made locating the instruments for retrieval more challenging. Collaboration with intended users was helpful in the initial selection of stations for tilt meter deployment, and the feedback provided and questions posed by the stakeholders throughout the project as new data were collected, spurred ideas for how the data could be analyzed.

Sharing your work with the Reserves and NOAA

The NERR Science Collaborative project was a huge catalyst for further scientific study and collaboration among scientists and resource managers within the surrounding watersheds.

Research:

Based on studies described in previous reports, the project team published the following manuscript: Bittler, K.M., L.P. Scheef, E.J. Buskey (2014) Freshwater inflows and blue crabs: The influence of salinity on selective tidal stream transport. Marine Ecology Progress Series 514: 137-148. Doi: 10.2254/meps10990

Dr. Edward Buskey and volunteer coordinator Colleen McCue applied for a grant from the Texas State Aquarium to continue the NSC blue crab studies, and received a $15,000 grant to continue these studies. The Texas State Aquarium project is expected to be completed in August 2015.

Drs. Ed Buskey, Lindsay Scheef and Jianhong Xue submitted a proposal to the Texas Water Development Board entitled "Assessing the effects of freshwater inflows and other key drivers on the population dynamics of blue crab and white shrimp using a multivariate time series framework" based on the results of studies funded under the NERR Science Collaborative project, and were awarded a grant of $150,000 to perform time-series analysis of the TPWD blue crab and white shrimp catch data. This project is expected to be completed by September 2015.

A second focal species that we have begun additional study with is the clam *Rangia*. Preliminary analysis of *Rangia* shells were conducted by Dr. Bryan Black to see if the annual growth rings on their shells (similar to the growth rings in tree trunks) would reflect periods of lower salinity waters, when they might grow faster and periods of higher salinity that might be less favorable for growth of this oligohaline species. Dr. Black was able to demonstrate that the annual growth rings in the shells of *Rangia* count be reliably measured, and preliminary analysis seemed to indicate that they would be good indicators of environmental conditions including salinity. As a result of these preliminary results, Drs. Ed Buskey and Bryan Black collaborated with scientist from the San Antonio River Authority to write a proposal to the Texas water Development Board to study the distribution of *Rangia* in Texas Bays and to further investigate the usefulness of the clam's growth rings for revealing salinity patterns. A subcontract of $90,000 was awarded for the *Rangia* growth studies.

Scientific presentations at national and regional meetings

Scheef, L.P., G. H. Ward and E. J. Buskey. April 2015. Water circulation in the Mission-Aransas Estuary: the effects of tides, winds and the opening of Cedar Bayou. Texas Bays and Estuaries Meeting, Port Aransas, TX.

Bittler, K.M., L.P. Scheef and E.J. Buskey. January 2015. Blue crabs (*Callinectes sapidus*) and Freshwater Inflows: A National Perspective. Southern Division American Fisheries Society, Savannah, Georgia

Scheef, LP, GH Ward, D Alonso, EJ Buskey. Monitoring current patterns within the Mission-Aransas and Guadalupe estuaries, Texas, with tilt current meters. 7th National Summit on Coastal and Estuarine Restoration, November 1-6, 2014, Gaylord National Conventional Center, Washington, D.C.

Weirich, C., C.M. McCue, L.P. Scheef, and E.J. Buskey. October 2014. The effects of tides and currents on blue crab (*Callinectes sapidus*) megalopae. Gulf Estuarine Research Society 2014 Meeting, Port Aransas, TX.

Bittler, K.M., L.P. Scheef and E.J. Buskey. May 2014. Freshwater inflows and blue crabs: can Texas megalopae find the estuary? Joint Aquatic Sciences Meeting, Portland, OR.

Bittler, K.M., L.P. Scheef and E.J. Buskey. March 2014. Blue crab megalopae go with the flow: How do currents affect estimates of abundance from Hog's Hair collectors? Benthic Ecology Meeting 2014. Jacksonville, FL

Stanzel, K. E.J. Buskey, S. Palmer, J. Xue and H. Wade. April 2014. Evaluating vulnerability of coastal ecosystem and communities using long-term data sets in the Mission Aransas Reserve. Texas Bays and Estuaries Meeting, Port Aransas, TX

Bittler, K. L. Scheef and E.J. Buskey. November 2013. Freshwater inflows and blue crabs: Can Texas megalopae find an estuary during drought? 22nd Biennial Coastal and Estuarine Research Federation Meeting, San Diego, CA.

Myers, J., R. Mooney and E.J. Buskey. November 2013. Using high spatial resolution sampling to validate the locations of permanent water quality monitoring stations within the Mission-Aransas Estuary. 22nd Biennial Coastal and Estuarine Research Federation Meeting, San Diego, CA.

Bittler, K., L. Scheef and E.J. Buskey. April 2013. To settle or not settle? Fickle megalopae may bias efficiency or hog's hair collector under environmental conditions. Texas Bays and Estuaries Meeting, Port Aransas, TX

Buskey, E.J., L.P. Scheef and G. Ward. Feb 2013. Monitoring current patterns within the Mission-Aransas estuary, Texas, with tilt current meters. ASLO 2013 Aquatic Sciences Meeting, New Orleans, LA.

Buchalski, C., S. Palmer, E.J. Buskey, K. Madden, T.R. Peterson and C. Ragland. Jan 2013. Bridge across the Mission: using a mediated modeling approach for mess management and moving forward, ASLO 2013 Aquatic Sciences Meeting, New Orleans, LA.

Palmer, S., K.M. Madden, E.J. Buskey, T.R. Peterson and G. Ward. Balancing freshwater inflows in a changing environment: collaborating for water conservation on the Texas coast. ASLO 2013 Aquatic Sciences Meeting, New Orleans, LA.

Workshops

Dr. Peterson worked with project manager Sally Palmer to initiate contact with leaders of the Wells NERRS to initiate a set of workshops to exchange the collaborative methodology used by the Mission Aransas NERR with that used by the Wells NERR. The effort was titled, Interdisciplinary Methods for Stakeholder Engagement and Collaborative Research: Lessons from the National Estuarine Research Reserve System (NERRS).

The project team that designed, implemented, and will evaluate the two workshops focused on sharing interdisciplinary methods for engaging stakeholders in collaborative research included:

- Christine B. Feurt (representing Wells NERR)
- Sally Palmer, Candace Peyton, and Colbi Gemmell (representing Mission Aransas NERR)
- Annie Cox and Kristin Ransom (CTP Coordinators)
- Verna DeLauer and Tarla Rai Peterson (collaborative leads and presenters)

The goal for this transfer project was to build capacity to understand and use different approaches to assess stakeholder understanding, foster the development of shared knowledge, and move diverse stakeholder groups toward mutually agreed upon improvements in management and policy. The team developed workshops to educate trainers, social scientists, and resource management agencies within the Mission-Aransas and Wells NERR watersheds and their surrounding regions in these approaches. To reach this goal, the team convened workshops at the Maine and Texas NERR sites. These workshops engaged subject matter experts in Collaborative Learning and Communications from the aforementioned Science Collaborative Projects and representatives of the intended user groups identified above.

The Maine workshop was held September 22-23, 2014 at the Wells National Estuarine Research Reserve. The Texas workshop was held January 14 and 15, 2015 at the Mission Aransas National Estuarine Research Reserve. Both workshops followed a similar pattern (Appendix D provides an example of the process agenda used for the workshops; Appendix E provides an example of the workbook provided to participants.). At the time of this report, evaluation of the workshops remained pending.

Anything else?

The project team was able to leverage several partnerships in order to expand the scope and range of several project objectives. For example, through collaboration with the NOAA Environmental Cooperative Science Center (ECSC), Reserve staff were able to survey the local estuary for Rangia clams. There were no funds directly in the project budget for a Rangia clam study, but since the intended users had expressed an interest in Rangia clam research, the Reserve was able to show its partner, ECSC, how beneficial this research would be to freshwater inflow stakeholders. The Reserve was also able to build upon its current meter study by partnering with the San Antonio Bay Foundation (SABF). SABF saw the benefit of installing current meters at areas outside of those covered by the current project. They purchased their own meters and installed them with assistance from the Reserve. This expanded coverage will further enhance efforts to understand circulation within and between bays and allow for improvements to be made to the TxBLEND model.

The networking opportunities provided by the collaborative nature of this project were very valuable in helping Reserve build new and stronger connections to local researchers and stakeholders. The benefit of this collaborative effort for the Mission-Aransas Reserve will go far beyond the successes seen in the workshops and in the management of freshwater inflows, but will allow us to continue working on important management issues from the numerous relationships developed with stakeholders throughout this process.

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APPENDIX A

Stakeholder Meeting Summaries

STAKEHOLDER MEETINGS 9.7.12 AND 9.10.12

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas, and Texas A&M University. Intended users of this project include stakeholders from the agriculture, commercial fishing, and recreation industries; municipalities; water resource agencies; and scientists.

For more information

WWW.MISSIONARANSAS.ORG/POST_SCIENCE_SCIENCECOLLABORATIVE.HTML

This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Workshop participants get to know each other during an "ice-breaker" activity.

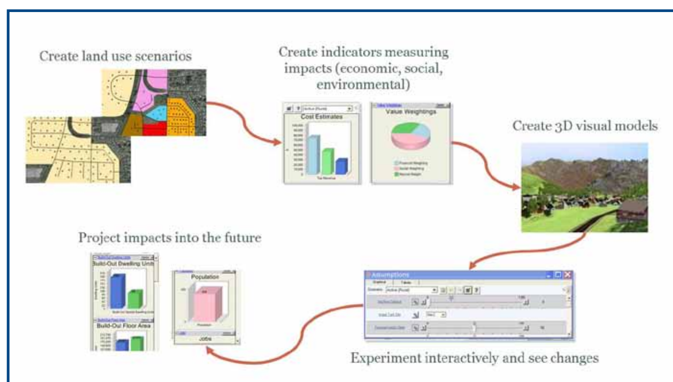
Executive Summary

The "Balancing Freshwater Needs in a Changing Environment" project held its second round of stakeholder meetings on September 7, 2012 in Seguin, Texas and on September 10, 2012 in Rockport, Texas. Two meetings were held in different locations because the project covers such a large area. Meeting participants included stakeholders from the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and interested citizens.

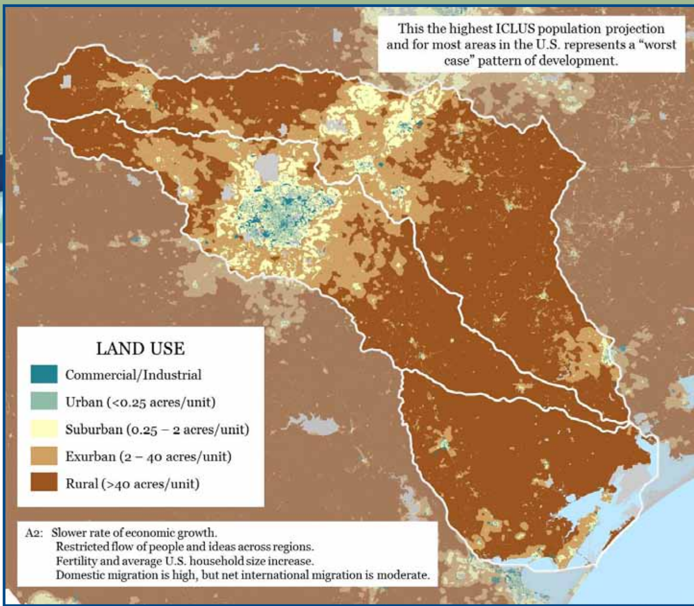
The purpose of these meetings was to present a summary of the initial meeting held in May, report on current research efforts, provide information on next steps, and begin developing a model of the system that participants can eventually use to improve freshwater inflow management decisions. Presentations during the meeting were provided for the four project objectives: 1) land use and climate change model, 2) water circulation data collection, 3) key species for research, and 4) system dynamics model.

LAND USE AND CLIMATE CHANGE MODEL

In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the effects of land use and climate change on water usage and runoff would greatly enhance environmental flow recommendations. To help address these issues, the project team will use mapping tools to examine various scenarios of future land use and climate to understand potential changes to future freshwater inflow volume. Dr. Kiersten Madden, Stewardship Coordinator for the NERR, provided an update on the land use and climate change modeling component of the project. During her presentation she (1) reviewed the conceptual model that has been developed for this component of the project, (2) presented results from breakout sessions at the first stakeholder workshop, (3) introduced the workshop participants to the Integrated Land Use and Climate Scenarios (ICLUS) project, and (4) showed participants how CommunityViz could be utilized to model future growth and water usage within the watershed.



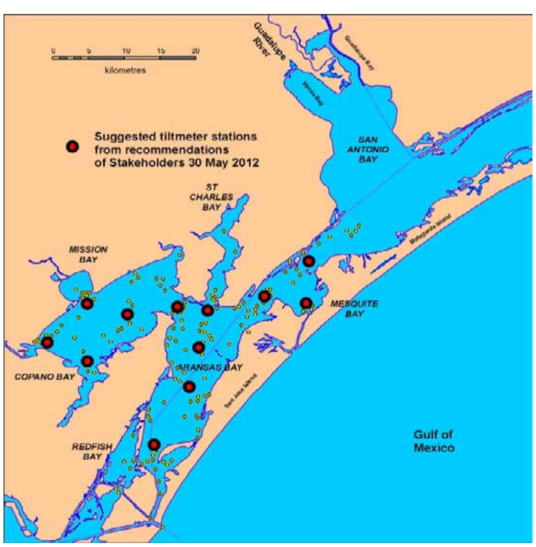
CommunityViz planning software is an extension for ArcGIS that is used by planners, resource managers, and local governments to model the implications of different plans and choices. It supports scenario planning, suitability analysis, growth modeling, and impact assessment. The image above shows how CommunityViz could be used in this project to model impacts from various watershed land use scenarios.



The EPA Global Change Research Program's Integrated Climate and Land-Use Scenarios (ICLUS) project developed future land-use projections that are based on the social, economic, and demographic storylines of the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) and adapted these to the U.S. ICLUS outputs are derived from a demographic model that generates population estimates and a spatial allocation model that distributes housing density across the landscape. The image above shows the 2080 housing density in the Guadalupe-San Antonio and Mission-Aransas estuary watersheds based on the A2 SRES storyline.

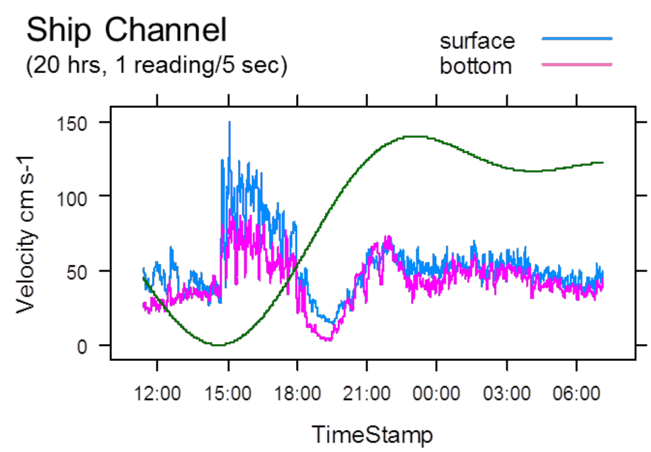
WATER CIRCULATION DATA COLLECTION

Dr. George Ward and Dr. Lindsay Scheef presented an overview of how Seahorse tilt current meters will be used to measure currents and estimate water exchange between the bays in the Mission-Aransas Estuary. These tilt meters work by using inclinometers to sense how far and in what direction the meter rod is leaning in a current. The angle and direction of the tilt can then be converted to current speed and direction. Stakeholders at the May 30th meeting in Port Aransas suggested many different locations for deployment of the meters. These suggested locations tend to be clustered in certain areas, and can therefore be consolidated into a more manageable number of stations.



Map of tiltmeter locations suggested by stakeholders at the May 30th meeting (yellow points), and consolidated locations (red points) based on spatial clustering of the recommended locations.

Test deployments of the current meters have been done in Mesquite Bay and in the Port Aransas Ship Channel to experiment with different deployment methods and to become more familiar with the data they collect. The meters appear to be providing data that indicate realistic current velocity patterns that are in agreement between simultaneously deployed meters (see graph below). However, refinements to the deployment methods must still be made that allow for easy deployment and retrieval from a boat without obvious surface markers. A method using a pole deployer and a hook retriever was suggested, but the best way to mark the locations of the meters is still unclear. Stakeholders were solicited for suggestions on how to mark moored meters for recovery while minimizing losses due to boaters and vandalism.



Smoothed current velocity versus time data gathered by two current meters deployed at the surface (blue line) and bottom (pink line) of the ship channel at the MSI pier for 24 hours. The green line indicates tidal levels (no scale) in relation to the current velocities.

KEY SPECIES FOR RESEARCH

During the September 7th meeting in Seguin, Dr. Ed Buskey gave a presentation on focal species research. Dr. Zack Darnell gave this presentation at the September 10th meeting in Rockport. These presentations briefly outlined the Senate Bill 3 process, the process through which blue crabs were chosen as a focal species for this project, and ongoing and future research projects. Informal discussions were held with the participants during breaks, outlining the ongoing megalopal sampling effort. In Seguin, participants asked if other life history stages would be included in the models, or if not, why we're focusing solely on megalopae. Participants were also interested in salinity effects on blue crab growth and development. In Rockport, questions focused primarily on the mechanisms of megalopal estuarine ingress in drought conditions, and there seemed to be agreement that this was an important issue.

SYSTEM DYNAMICS MODEL

Participants used three tools to further develop the qualitative model of the estuary. The first activity asked individuals to think about the estuary and identify their needs as well as their concerns about how these needs might be impacted in the future. They used this information to develop specific questions that the model might address.

The table below is organized around the questions that were asked about participants' wants/needs, as well as about their concerns/worries regarding the future fulfillment of those wants/needs. This table lists the most frequently offered answers to both questions and the total number of people that provided that answer. Individuals were then asked to identify one question, based on their wants/needs and concerns/worries, which they hoped the model would answer.

What do you want/need from the estuary?		What concerns/worries do you have about the estuary's ability to satisfy your wants/needs into the future?	
Category	**No.**	**Category**	**No.**
Sustainable Fisheries	16	Freshwater Inflows	22
Estuary Health	15	Estuary Health	14
Biodiversity	10	Human Impacts	14
Clean Water	7	Toxic Pollution	12

Next, participants worked in groups to synthesize how their individual questions related to model components that were suggested in the earlier May meeting. Groups of 4-6 people worked with a matrix of all of the components that had been suggested, as well as a picture (shown below) that summarized the May model. Groups then explored how their needs, concerns,

Workshop participants discuss components and dynamics of the Mission-Aransas estuarine system.

Meeting participants identify their needs of the estuary and how these needs could be affected in the future.

and questions could actually be mapped onto questions related to model components they (or other participants) had suggested during the May workshop. The needs and concerns (see table to the left) generated questions that can be clustered into four primary themes. These themes, from most to least mentioned, included freshwater inflows, estuary health, sustainable fisheries, and human impact. Examples of questions that could be drawn from these themes include:

• How much freshwater is needed to maintain estuarine health and sustainable fisheries (i.e., How many acre feet of freshwater are needed?)?

• What are the most important dynamics of freshwater inflow for estuarine health and sustainable fisheries (i.e., How do freshwater increases/decreases affect the food web dynamics?)?

• How do human impacts contribute to/detract from estuary health and sustaining estuarine fisheries (Are certain activities more/less influential?)?

• Which physical and ecological interactions are the most important determinants of estuary health?

We are using the results of these activities as the basis for developing a preliminary quantitative model. In the January 2013 Collaborative Workshop we will present the resulting model. After viewing the model and exploring how it works, participants will be asked to refine and change the model to make it more useful as an educational and management tool.

Presentations from the meeting, please go to www.missionaransas.org/post_science_sciencecollaborative.html. The next upcoming meeting will be held on January 17th in Port Aransas, Texas at the University of Texas Marine Science Institute. This meeting will provide an update on the research completed for each project objective, and continue development of the system dynamics model that participants can then use to improve freshwater inflow management.

STAKEHOLDER WORKSHOP 5.30.12

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas, and Texas A&M University. Intended users of this project include stakeholders from the agriculture, commercial fishing, and recreation industries; municipalities; water resource agencies; and scientists.

For more information

WWW.MISSIONARANSAS.ORG/POST_SCIENCE_SCIENCECOLLABORATIVE.HTML

This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Workshop participants talk about what areas of the estuary and watershed they identify with.

Executive Summary

The first of many meetings to come was held on May 30, 2012 to discuss the project entitled "Balancing Freshwater Needs in a Changing Environment." This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas, and Texas A&M University.

During this initial meeting, the project team and workshop participants began their development of a common knowledge base regarding the Mission-Aransas Estuary. The workshop included presentations by research team members, question/answer sessions, and small group activities. The group activities helped the project team 1) prioritize a key species for research, 2) define priority information for decision support tools, 3) propose appropriate locations for obtaining water circulation data for modeling, and 4) delineate the parameters for a collaboratively designed model of the estuary that can assist in better management of the system.

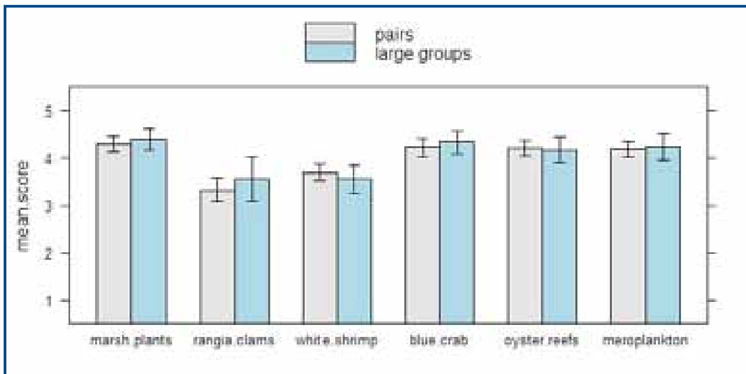
The group activity designed to help define priority information for decision support tools was preceded by a presentation of the effects of land use and climate change on freshwater inflows to the Guadalupe and Mission-Aransas Estuary. Workshop participants were then split into small working groups based on the areas within the watershed that they identified. These working groups then suggested locations future land use change and development. The suggestions will be used to help build land use and climate scenarios for the watershed. Following the workshop, the project team will continue to work with stakeholders to gather information from relevant data sources.

The group activity designed to help prioritize a key species for research was preceded by a presentation of the focal species for determining freshwater inflow needs of the Mission-Aransas Estuary. This presentation introduced the Bay and Basin Expert Science Team (BBEST) approach and the species recommended by that group in their adaptive management plan. Workshop participants were then split into small working groups that ranked the importance of marsh plants, rangia clams, white shrimp, blue crabs, oyster reefs, and meroplankton. Results from this group activity indicated that high importance was placed on marsh plants, blue crab, oyster reefs, and

Land use projections by workshop participants for areas of Aransas Pass, Bayside, Lamar Peninsula, Port Aransas, Refugio, Rockport-Fulton in 2060 (Group 2).

Turn over for more information ...

meroplankton, and slightly lower importance on white shrimp and Rangia clams. A word analysis of the written participant feedback in the surveys indicated that commercial value and trophic importance within the ecosystem were emphasized most frequently for species with higher ranking. These results, and the Guadalupe-San Antonio Bay and Basin Area Stakeholder's Committee's "Work Plan for Adaptive Management" will be used to choose the focal species for our study.



Mean focal species scores (±SE) from surveys completed by pairs and large groups.

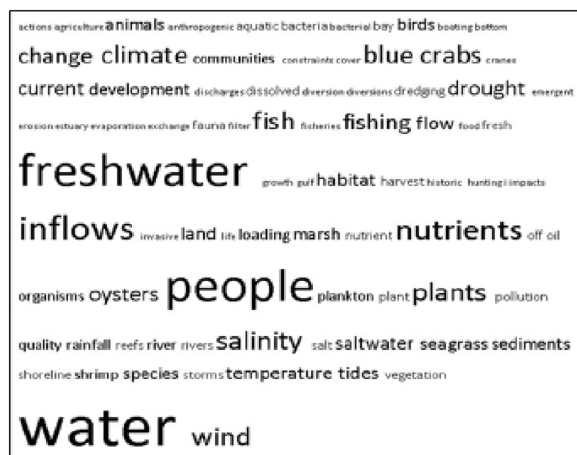
The group activity designed to help propose appropriate locations for obtaining water circulation data for modeling was preceded by a presentation of the importance and capabilities of current meters. Workshop participants were then split into small working groups that reviewed maps of the system and asked to indicate suggested locations of current meters and their rationale for placement. Results from this group activity indicated that participants independently agreed on the importance of monitoring currents in the mouths of the Mission and Aransas

Condensed suggested current meter locations. Red points indicate suggested locations for tiltmeters and the yellow point indicates a current meter station maintained by the Guadalupe-Blanco River Authority.

Workshop participants identify basic components and dynamics of the Mission-Aransas estuarine system.

rivers, Copano Pass, the entrance to St Charles Bay, the interior termini of Aransas Pass and Cedar Bayou, and the passage from San Antonio Bay into Aransas Bay through the Lines of Islands. These results and additional considerations will need to be brought in before a final selection is made.

The group activity designed to develop a common knowledge base was preceded by a presentation of systems dynamic modeling. Workshop participants were then split into small working groups to discuss the Mission-Aransas Estuary from a systems perspective begin to develop a system-dynamics model. In this exercise they were asked to 1) tell a story of the system, 2) ask 3 basic questions, 3) answer the questions & translate the questions into modeling language & answer them, 4) retell the story, using modeling language, with a model, and 5) revise the model to tell a more convincing story.



A word map of central components for the Mission-Aransas Estuary identified by stakeholders in the May 30, 2012 meeting.

For a more complete description of the meeting, please go to www.missionaransas.org/post_science_sciencecollaborative.html. The next meetings will be held on September 7th in Seguin, Texas at the Guadalupe-Blanco River Authority Building from 1-4 pm and on September 10th in Rockport, Texas at the Bay Education Center from 6-8 pm. These meetings will present the findings and summary of the initial meeting held in May, current research efforts, provide information on next steps, and continue development of a model of the system that participants can then use to improve freshwater inflow management.

STAKEHOLDER MEETING 1.17.13

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas, and Texas A&M University. Intended users of this project include stakeholders from the agriculture, commercial fishing, and recreation industries; municipalities; water resource agencies; and scientists.

For more information

WWW.MISSIONARANSAS.ORG/POST_SCIENCE_SCIENCECOLLABORATIVE.HTML

This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Workshop participants discuss model development.

Executive Summary

The “Balancing Freshwater Needs in a Changing Environment” project held its third stakeholder meeting on January 17, 2013 in Port Aransas, Texas at the Estuarine Research Center. Meeting participants included stakeholders from the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and interested citizens.

The purpose of this meeting was to report on current research efforts, provide information on next steps, and continue development of a model of the system that participants can use to understand and improve freshwater inflow management decisions. Presentations during the meeting were provided for the four project objectives: 1) land use and climate change model, 2) water circulation data collection, 3) key species for research, and 4) system dynamics model.

LAND USE AND CLIMATE CHANGE MODEL

In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the effects of land use and climate change on water usage and runoff will greatly enhance environmental flow recommendations. To help address these issues, the project team will be using modeling tools to examine various scenarios of future land use and climate in order to understand potential changes to future freshwater inflow volume.

Dr. Kiersten Madden, Stewardship Coordinator for the Mission-Aransas NERR, provided an update on the progress of the land use and climate change modeling component of the project at the stakeholder workshop. During her presentation she (1) reviewed the objectives for this component of the project, (2) presented stakeholders with future projections for land use and precipitation, (3) surveyed participants for input on scenario development, and (4) presented results from initial build out modeling for a county within the watershed. Stakeholders were surveyed twice during the presentation using keypad polling software.

The goal of the surveys was to gather input from the stakeholders on the types of scenarios that they would like to see included in the modeling. This will help ensure that stakeholders benefit from the models results and can use the information in their decision-making. Each table below shows the percentage of stakeholders that voted for the different options for each of the three questions related to scenario development.

Question 1: What time horizon(s) would you like to see included in the land use and climate change modeling?

Year	Survey 1	Survey 2
2020	**32%**	**32%**
2040	**28%**	23%
2060	25%	**34%**
2080	4%	6%
2100	11%	5%

The two highest percentages for each question are indicated in bold. Based on these results, the modeling scenarios will include the following aspects: time horizon = 2020 and 2060; approach = monthly, seasonal, and annual; and

Question 2: Which of the following approaches would you prefer to see used for the land use and climate modeling?		
Approach	**Survey 1**	**Survey 2**
Monthly	3%	3%
Seasonal	9%	9%
Annual	6%	0%
Monthly & Seasonal	11%	16%
Monthly & Annual	9%	3%
Seasonal & Annual	**34%**	**50%**
Monthly, Seasonal, & Annual	29%	19%

Question 3: Which climate change scenario(s) would you like to see used for climate change and land use modeling?		
Year	**Survey 1**	**Survey 2**
A2 (High)	6%	6%
A1B (Medium)	**26%**	18%
B1 (Low)	3%	3%
A2 & B1 (High & Low)	11%	21%
All Three	**54%**	**53%**

emissions scenarios = A2 (High), A1B (Medium), and B1 (Low). Depending on the time that it takes to run the models, it may be necessary to eliminate some of the choices listed above. Dr. Madden will continue to update stakeholders as the modeling progresses and the final scenarios are developed.

WATER CIRCULATION DATA COLLECTION

Dr. Lindsay Scheef presented an update of how Seahorse tilt current meters will be used to measure currents and estimate water exchange between the bays in the Mission-Aransas Estuary. These tilt meters work by using inclinometers to sense how far and in what direction the meter rod is leaning in a current. The angle and direction of the tilt can then be converted to current speed and direction. The suggestions of stakeholders at the May 30th meeting in Port Aransas and the information provided by local fishing guides at a December 6th meeting were taken into account while selecting the approximate locations for the first round of current meter deployments in March (Figure 1). These stations are primarily in Aransas and Mesquite bays, but as flow patterns under different wind and tidal conditions are determined for those locations, the meters will be redistributed to stations throughout the estuary. Test deployments of the current meters have been done at four of the NERR System Wide Monitoring Program (SWMP) stations to help us become more familiar with the type of data that the loggers record and allow us to experiment with different deployment methods. The meters appear to be providing data that, when smoothed over time, represent realistic current directions and velocities (Figure 2). A deployment method using a pole deployer and a hook retriever has been developed and successfully implemented. Stakeholders had no suggestions for further refinement of this method.

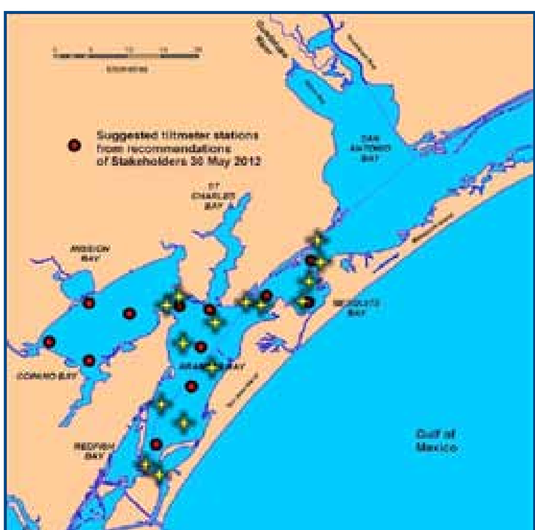


Figure 1. Map of tilt meter locations suggested by stakeholders at the May 30, 2012 meeting (red points), and the locations selected to deploy the meters for the first round of data collection (yellow stars).

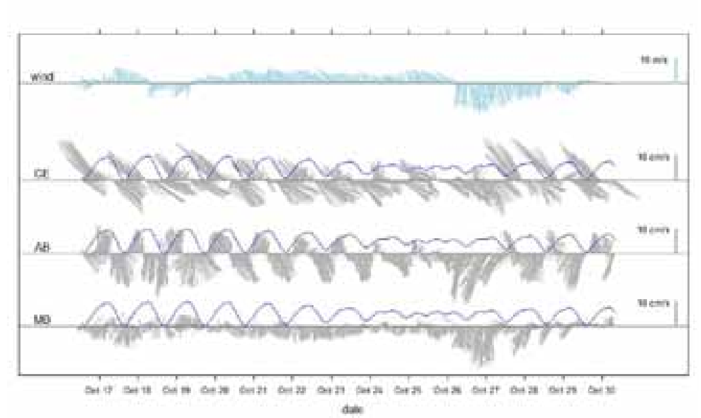


Figure 2. Stick plot of wind and water flow directions and velocities at three of the SWMP stations during a two week deployment in October 2012, where the length of each line represents the velocity of flow towards the indicated direction. Wind data are from a Texas Coastal Ocean Observation Network (TCOON) station in Copano Bay. Relative tidal height data (blue) from the Copano TCOON station are overlain on the water current data.

KEY SPECIES FOR RESEARCH

Dr. Zack Darnell presented on current blue crab research. Blue crabs were chosen as the primary focal species for the project due to their economic and ecological importance in Texas estuaries. Current research is focused on understanding (1) how recruitment of megalopae into the estuary is affected by environmental forcing, (2) how behavioral responses of crab megalopae to changes in salinity affect transport into the estuary, and (3) what nursery habitats are important for juvenile blue crabs and during what stages are they reaching the upper estuary. Zack gave an overview of research progress to date and anticipated timelines for these projects over the next several months. Participants asked whether the opening of Cedar Bayou would

benefit crab populations. Dr. Darnell pointed out that this is one of the questions that our current research will allow us to address, but that more data are needed.

SYSTEM DYNAMICS MODEL

We began this workshop with "A Few Thoughts about Models and Modeling" from Dr. Bill Grant of Texas A&M University. He cautioned us not to expect to be able to predict (with absolute certainty) the future using the system dynamics model. We should hope to project, with some degree of uncertainty, possible alternative futures under certain restrictive assumptions. A model will provide new knowledge that will help us reduce uncertainty with which we view the future of our system-of-interest. That is, we should expect to gain knowledge from our simulations that will allow us to discard as highly unlikely some system futures that previously seemed quite plausible. The relative amount of knowledge we gain depends in large part on the current level of knowledge about the system-of-interest. Logically, the less we currently understand about the system, the more we are likely to learn. The fact that we are using the systems approach and simulation to solve our problem implies that we are dealing with a system for which we have relatively few data and, quite likely, a relatively low level of understanding.

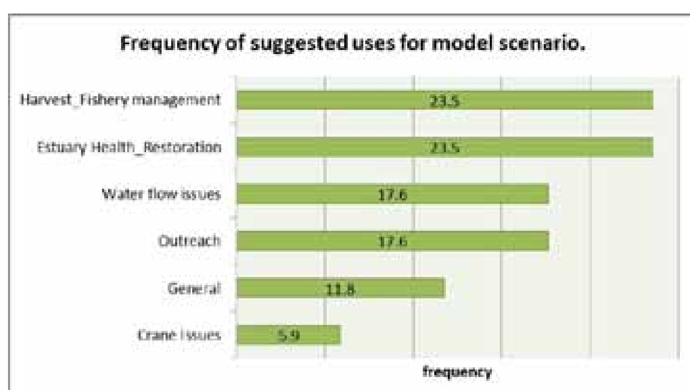
Workshop participants practice manipulating model.

The information gained from qualitative systems modeling in the first two meetings led to development of a quantitative model exploring the possible effects of changes in salinity on the population dynamics of blue crabs in Aransas Bay and Copano Bay. Dr. Grant designed this model using NetLogo software. At the January 17, 2013 meeting, participants spent several hours testing various scenarios of altered freshwater flow affecting salinity and temperature in the Mission-Aransas and Copano estuaries.

Meeting participants provided feedback on ways to improve the model, ways to use the model, and their confidence in the model. Participants liked having a model that showed visual movement of crabs through various life stages as well as quantitative output regarding population fluctuation. The primary complaints, which will be addressed in future versions, regard increasing the size of the estuary picture and making the 'save' function more user friendly. Everyone was excited to have something to work with and offered a number of suggestions for improvement.

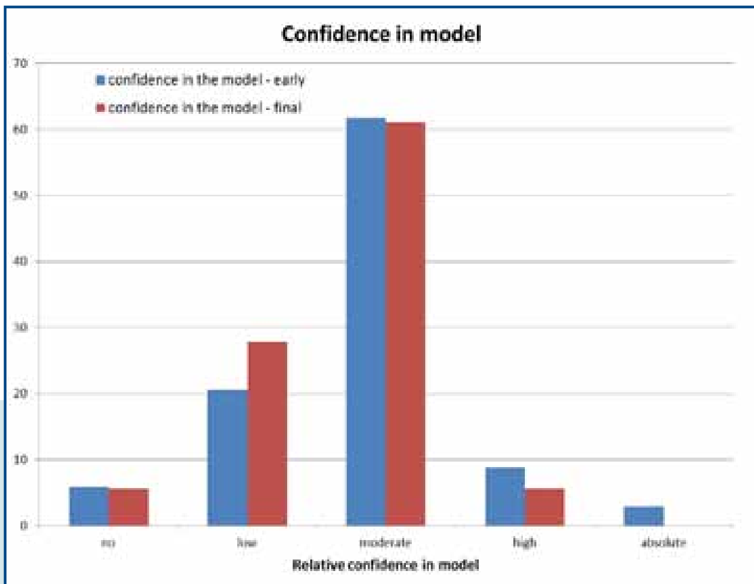
Among the constructive comments for making the model more useful was a suggestion by many groups to incorporate crab harvest data into the model. Another suggestion was to provide greater detail in the changing salinity as a result of freshwater inflow. Both crab harvest and more detailed salinity changes will likely be added to future versions of the model. We also hope to be able to 'manage' the freshwater inflow variation better in future models so that users will be able to manipulate this to mimic either actual or proposed freshwater inflow regimes.

Participants were asked how model results might be useful. The chart below summarizes the feedback from this question. Note that the two most frequent ways this might be useful were to address harvest and fishery management and estuary health/ restoration. Future versions of the model will focus on these areas.



SYSTEM DYNAMICS MODEL continued

Keypad polling (a fun new toy for many) was used to gauge opinions quickly. Each participant had a ‘clicker’ with which they could answer specific questions regarding scenario expectations and confidence in the model. We were pleased to find that the majority of the group had confidence in the model, and that after using the model, those who were initially very confident became more skeptical. Why would this be good? We think that a bit of skepticism is a good thing, helping people think critically about the interactions that are important in the estuary system. The table below summarizes the survey results from asking the question: How much confidence do you have in the results generated from the simulation?



This short summary cannot list all of the great suggestions participants made at the last meeting, but we are using them to improve the next version. We welcome any comments and feedback that you may have after reading this summary, so please let us know what you want to see in the next version via email: MissionAransas@gmail.com

Announcements

Karen A. Bishop with Texas Sea Grant - Potential funding opportunity: Sea Grant and the NOAA Restoration Center have partnered up to collect information about restoration projects that remove or modify anthropogenic barriers to restore historic tidal estuarine and freshwater exchange to benefit coastal and marine fisheries habitat. Projects can cost up to $5 million. For more information or to share a project idea, please contact: Karen A. Bishop at (210)557-6795 or karen.bishop@tamu.edu.

Dan Alonso with San Antonio Bay Foundation (SABAY) – SABAY is working with Texas Water Development Board to purchase and install 10 Sea Horse inclinometers. They are also conducting monthly water quality sampling. SABAY is also assisting UT, Dr. Jeff Paine with LIDAR ground truthing.

James Dodson with San Antonio Bay Partnership (SABP) – Completed conservation plan for San Antonio Bay that identified ~60 needed project s (I.e. restoration, acquisition etc…). SABP is in discussion with Texas Sea Grant about hydrological restoration projects. Working on a public access plan for San Antonio Bay and build upon current plan developed for Calhoun County.

Steve Raabe with San Antonio River Authority (SARA) – SARA has piloted a model that identifies and improves salinity dynamics predictions in the tidal areas. They are working on refining the model and part of that process will involve stakeholder input and they are working with SABP to host workshops to gather input.

Richard Gonzales – Science & Spanish Club is hosting World Seagrass Day on March 8, 2013. Contact Richard at richard@gulfmex.org for more information.

The next upcoming meeting will be held on April 16th in Port Aransas, Texas at the University of Texas Marine Science Institute. This meeting will provide an update on the research completed for each project objective, and continue development of the system dynamics model that participants can then use to improve freshwater inflow management. Presentations from the meeting, please go to www.missionaransas.org/post_science_sciencecollaborative.html.

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

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This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Workshop participants discuss model development.

Executive Summary

The "Balancing Freshwater Needs in a Changing Environment" project held its fourth stakeholder meeting on April 16, 2013 in Port Aransas, Texas at the Estuarine Research Center. Meeting participants included stakeholders from the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and interested citizens.

The purpose of this meeting was to report on current research efforts, provide information on next steps, and continue development of a model of the system that participants can use to understand and improve freshwater inflow management decisions. Presentations during the meeting were provided for the four project objectives: 1) land use and climate change model, 2) water circulation data collection, 3) key species for research, and 4) system dynamics model.

LAND USE AND CLIMATE CHANGE MODEL

In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the effects of land use and climate change on water usage and runoff would greatly enhance environmental flow recommendations. To help address these issues, the project team will be using modeling tools to examine various scenarios of future land use and climate in order to understand potential changes to future freshwater inflow volume. Due to time limitations, Dr. Madden was forced to shorten her presentation and was only able to share with the participants a list of the scenarios that are being analyzed for this component of the project. These 20 scenarios are based on stakeholder input at a previous workshop, as well as user knowledge about the time constraints of the modeling software.

The two highest percentages for each question are indicated in bold. Based on these results, the modeling scenarios will include the following aspects: time horizon = 2020 and 2060; approach = monthly, seasonal, and annual; and emissions scenarios = A2 (High), A1B (Medium), and B1 (Low). Depending on the time that it takes to run the models, it may be necessary to eliminate some of the choices listed above. Dr. Madden will continue to update stakeholders as the modeling progresses and the final scenarios are developed.

Scenario 1 A2 (High) 2020 Annual	Scenario 2 A2 (High) 2020 Fall	Scenario 3 A2 (High) 2020 Winter	Scenario 4 A2 (High) 2020 Spring	Scenario 5 A2 (High) 2020 Summer
Scenario 6 A2 (High) 2060 Annual	Scenario 7 A2 (High) 2060 Fall	Scenario 8 A2 (High) 2060 Winter	Scenario 9 A2 (High) 2060 Spring	Scenario 10 A2 (High) 2060 Spring
Scenario 11 B1 (Low) 2020 Annual	Scenario 12 B1 (Low) 2020 Fall	Scenario 13 B1 (Low) 2020 Winter	Scenario 14 B1 (Low) 2020 Spring	Scenario 15 B1 (Low) 2020 Summer
Scenario 16 B1 (Low) 2060 Annual	Scenario 17 B1 (Low) 2060 Fall	Scenario 18 B1 (Low) 2060 Winter	Scenario 19 B1 (Low) 2060 Spring	Scenario 20 B1 (Low) 2060 Spring

Figure 1. Scenarios that are being evaluated for land use and climate effects on freshwater inflows.

WATER CIRCULATION DATA COLLECTION

Dr. Lindsay Scheef presented an update on how Seahorse tilt current meters will be used to measure currents and estimate water exchange between the bays in the Mission-Aransas Estuary. The tilt meters work by recording how far and in what direction the meter rod is leaning in a current, and those values are later converted to current speed and direction. Fifteen stations in Aransas and Mesquite bays for the first deployment of the meters have been scouted to assess depth, substrate type, and the presence of landmarks (Figure 2).

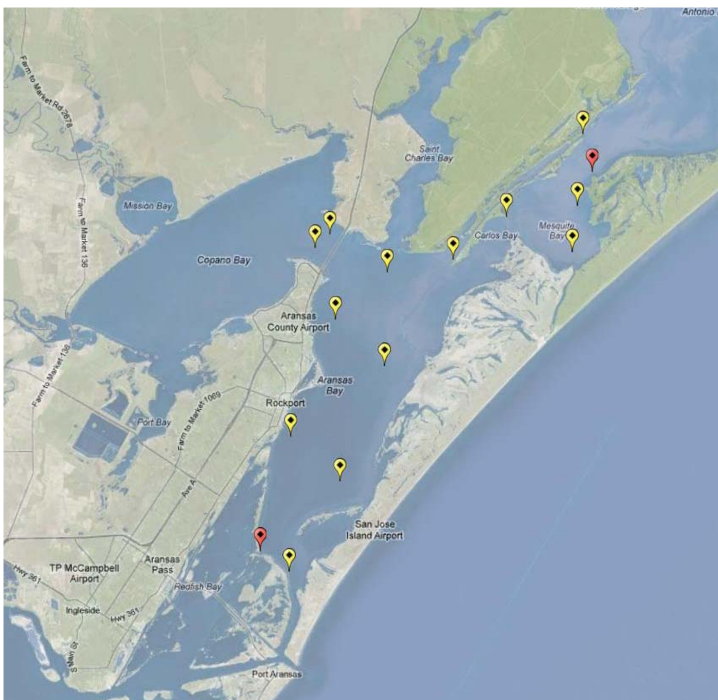


Figure 2. The final stations selected for the first deployment of the tilt current meters. Stations marked in yellow have already been assessed for the presence of landmarks, depth, and substrate type.

Stations without existing landmarks will be marked with floats that are not attached to the meters to prevent loss if the markers are pulled up. A final summary of the data from a series of test deployments of the current meters at four of the NERR System Wide Monitoring Program (SWMP) stations was presented. The meters are able to sense clear tidal current patterns at the two stations closest to the Aransas Ship Channel, but tidal influences are less obvious at the more remote stations (Figure 3). The current data recorded by the meters correspond well to tidal predictions and wind data for the area.

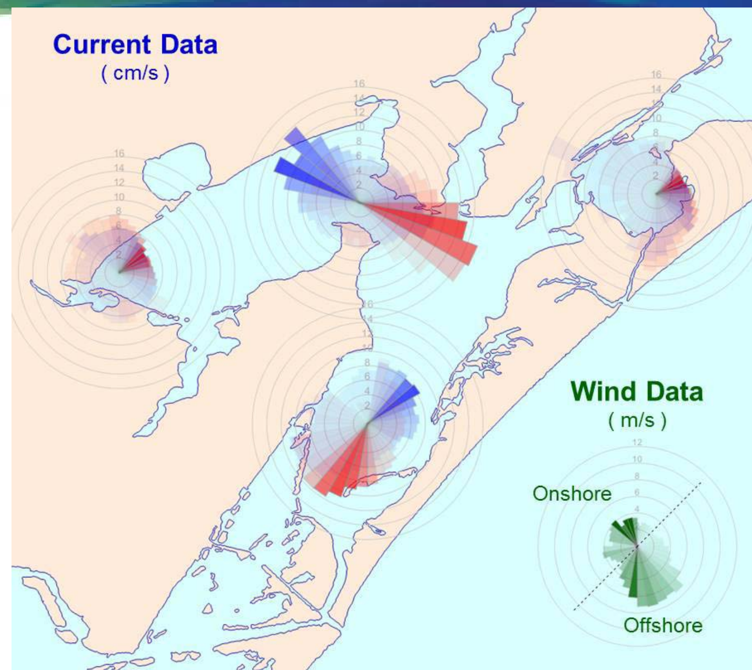
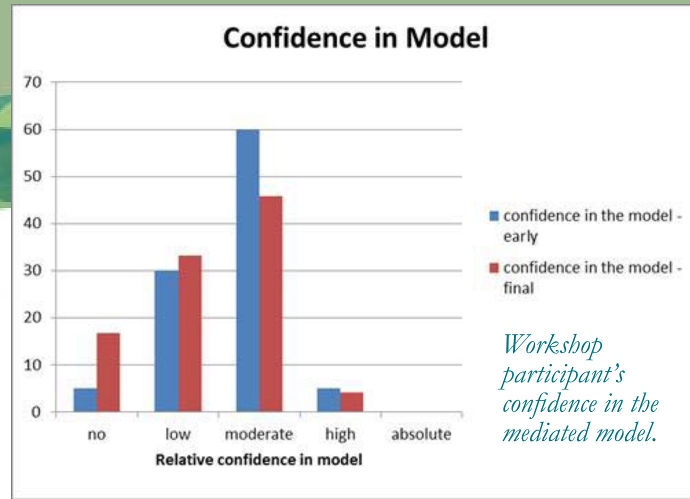


Figure 3. Current velocities and directions at four of the Reserve SWMP stations, where the length of each bar indicates current speed and the darkness of each bar represents the number of observations made for the direction. Observations made during the incoming and outgoing tides are shown in blue and red, respectively. Wind speed and direction data recorded during the sampling period are also shown in green.

KEY SPECIES FOR RESEARCH

Dr. Zack Darnell presented on blue crab research that is ongoing within the Reserve. This presentation focused on two primary research areas: (1) blue crab recruitment dynamics in the Mission-Aransas estuary and (2) determining critical life history parameters for inclusion into Dr. Bill Grant's individual-based model. Recruitment dynamics are being studied through a citizen-science megalopal monitoring project, Kimberly Bittler's study of behavioral responses to changes in salinity, and Dr. Darnell's study of juvenile blue crab abundance and distribution in the estuary. Life history parameters are being studied through experiments examining environmental (temperature and salinity) control of growth and maturity as well as spatial and time-series analyses of existing datasets. These datasets include the TPWD fishery-independent survey program and the Southeast Area Monitoring and Assessment Program conducted by the Gulf States Marine Fisheries Commission. All projects are ongoing, and this summer's results will be presented at the next meeting on September 12, 2013.



Workshop participant's confidence in the mediated model.

SYSTEM DYNAMICS MODEL

In this workshop, participants tested a revised system dynamics model of the Mission-Aransas and Copano Bay estuaries, and began generating ideas about how their model might contribute to future management decisions regarding the estuaries. Prior to the workshop, participants had provided the basic structure for a system dynamics model by developing concept maps of the estuary system, identifying critical questions about estuary function, and testing a preliminary model that was designed to explore the question: How do freshwater inflows influence blue crab populations in the Mission-Aransas and Copano Bay system? For the April 16th meeting, the modeling team used participant recommendations to revise the preliminary model adding additional information on commercial and recreational harvest, increased options for users to simulate freshwater inflow changes, and more detail in salinity changes over the course of a year.

Workshop participants practice manipulating model scenarios.

Workshop participants spent much of two hours simulating different scenarios, evaluating simulations, and discussing their results. Although some participants favored introducing additional variables, there was general consensus that the model is sufficiently complex. Most participants were fully engaged in these activities, and as one person commented, "using the model is relatively easy, comprehending is harder." This was echoed in suggestions to provide additional documentation that further explained the assumptions and limitations of the model as a means of enhancing understanding and increasing confidence in the model. The modeling team committed to add this documentation before the next workshop in September.

Some participants expressed frustration that Whooping Crane predation did not have a measurable effect on crab populations. The group discussed the possibility that the model may be demonstrating that, although crabs may be fundamentally important to the health of the crane population, this may not be a reciprocal relationship: cranes may or may not be especially important to the health of the crab population. To help users understand the model results better, participants requested user friendly model output that indicates salinity and trapping changes during scenario runs, data output starting after initial model calibration, and the ability to save each scenario data set for subsequent analysis. These output and informational changes may increase the understanding of and confidence in the model.

Keypad polling was again used to gauge participants' perspectives on model functionality and model evaluation. Each participant had a 'clicker' to answer questions regarding scenario expectations and confidence in the model. The majority of the group expressed some confidence in the model but model confidence did decrease during this workshop. We interpret this skepticism as a good thing because it reflects critical thinking. Polling results show that 70% of participants increased their understanding of freshwater inflows important in the estuary system. The chart summarizes the results from asking the question: How much confidence do you have in the results generated from the simulation?

Participants were asked how model results might be useful. The most frequent response was "for long term planning for drought and freshwater inflow changes". This response addresses concerns about upstream freshwater release and timing as it affects the estuarine system, guiding water permits, and crab harvest.

This short summary cannot include all the great suggestions from workshop participants, but we are using them to improve the model. We welcome any comments you may have after reading this summary. Please email us at: MissionAransas@gmail.com

The next upcoming meeting will be held on September 12th in Port Aransas, Texas at the University of Texas Marine Science Institute. This meeting will provide an update on the research completed for each project objective, and continue development of the system dynamics model that participants can then use to improve freshwater inflow management. Presentations from the meeting, please go to www.missionaransas.org/post_science_sciencecollaborative.html.

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas, and Texas A&M University. Intended users of this project include stakeholders from the agriculture, commercial fishing, and recreation industries; municipalities; water resource agencies; and scientists.

For more information

WWW.MISSIONARANSAS.ORG/POST_SCIENCE_SCIENCECOLLABORATIVE.HTML

This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Executive Summary

The "Balancing Freshwater Needs in a Changing Environment" project held its fifth stakeholder meeting on September 12, 2013 in Port Aransas, Texas at the Estuarine Research Center. Meeting participants included stakeholders from the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and interested citizens.

The purpose of this meeting was to report on current research efforts, provide information on next steps, and continue development of a model of the system that participants can use to understand and improve freshwater inflow management decisions. Presentations during the meeting were provided for the four project objectives: 1) land use and climate change model, 2) water circulation data collection, 3) key species for research, and 4) system dynamics model.

Workshop participants discuss blue crab model development.

LAND USE & CLIMATE CHANGE MODEL

In a state where population growth and water demand are not equally distributed throughout the watershed, an increased understanding of the effects of land use and climate change on water usage and runoff would enhance environmental flow recommendations. To help address these issues, the project team will be using mapping tools to examine various scenarios of future land use and climate in order to understand potential changes to future freshwater inflow volume. Dr. Kiersten Madden, Stewardship Coordinator for the Mission-Aransas NERR, provided an update on the progress of the land use and climate change mapping component of the project. During her presentation she (1) reviewed the 20 scenarios that are being analyzed for this part of the project, (2) discussed a simplified approach for using CommunityViz software to model future growth and water usage, (3) presented initial results of water use indicators developed in CommunityViz, and (4) discussed next steps and future modifications.

The EPA's Integrated Climate and Land Use Scenarios were used to generate maps of future land use/land cover for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries.

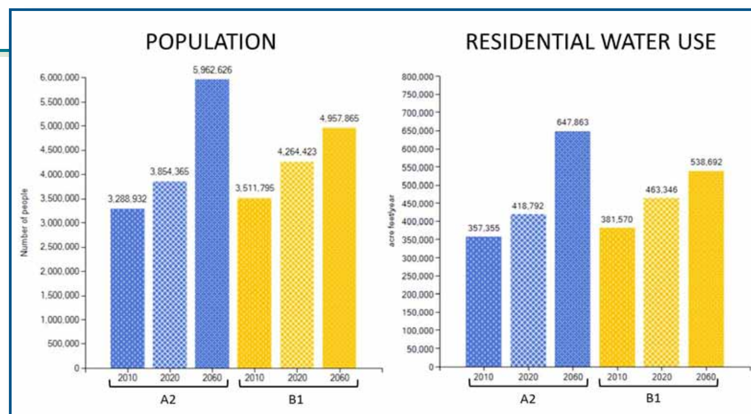


Figure 1. Graphs show estimates of population and residential water use for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries. Results are shown for multiple time points (2010, 2020, 2060) and multiple climate change emissions scenarios (A2 = blue, B1 = yellow). Residential water use estimates represent totals for the entire watershed for a full year and are based on the assumption of 97 gallons of water used per person per day.

Information about parcel size, size of dwelling units, and average household size was used to estimate future population within the watershed for each scenario (Figure 1). Assumptions about the amount of water used per person per day were applied to calculate residential water use (also Figure 1). By changing the assumption about the amount of water used per person, it is possible to see how water conservation efforts could affect residential water use (Figure 2). Future land use/land cover scenarios were also used to estimate how the amount of cultivated cropland would change over time and how this would affect the amount of water used for irrigation (Figure 3). By changing the assumption about how much water is used to irrigate an acre of cropland, it is possible to see how improvements in irrigation efficiency could affect future irrigation water use (Figure 4). Similarly, by changing assumptions about the amount of cropland being irrigated, it is possible to see how changes in the number of irrigated acres (due to increasing drought, changes in crop type, etc.) could affect future irrigation water use (Figure 4). These are a few examples of the types of scenarios and modifications that are being developed with this model. Additional scenarios are being developed based on participants feedback. If you have additional questions or information needs about this project component, please email missionaransas@gmail.com.

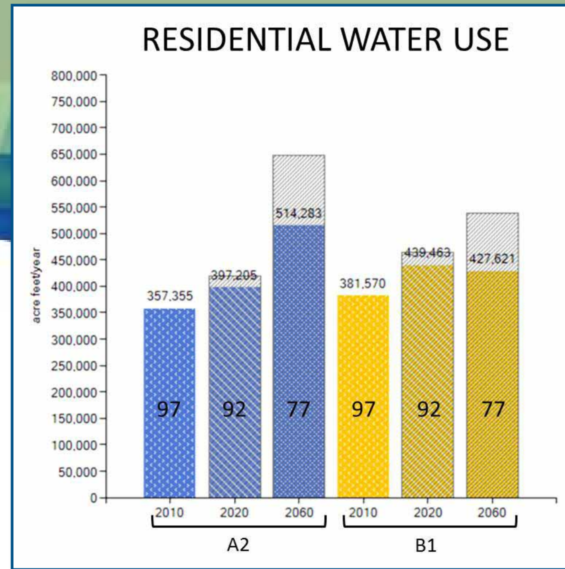


Figure 2. Graph shows estimated residential water use for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries. Results are shown for multiple time points (2010, 2020, 2060) and multiple climate change emissions scenarios (A2 = blue, B1 = yellow). Residential water use estimates represent totals for the entire watershed for a full year and are based on the assumption that water use per person per day decreases over time (i.e., 2010 = 97; 2020 = 92; 2060 = 77). Grey hatched lines provide a comparison to previous values that are based on the assumption of 97 gallons per person per day.

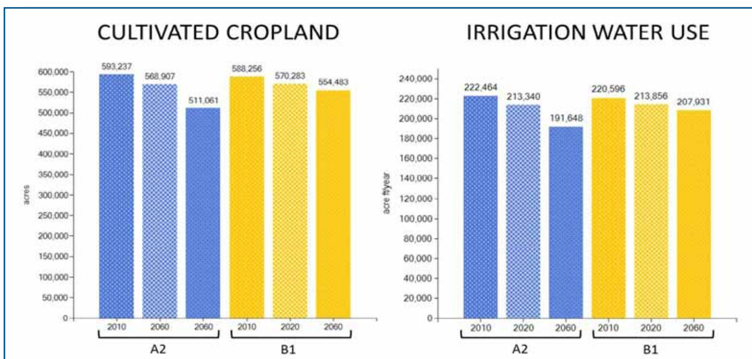


Figure 3. Graphs show estimates of acres of cultivated cropland and irrigation water use for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries. Results are shown for multiple time points (2010, 2020, 2060) and multiple climate change emissions scenarios (A2 = blue, B1 = yellow). Irrigation water use estimates represent totals for the entire watershed for a full year and are based on the assumption that 18 inches of water is used per acre per year and 25% of the cropland acres are irrigated.

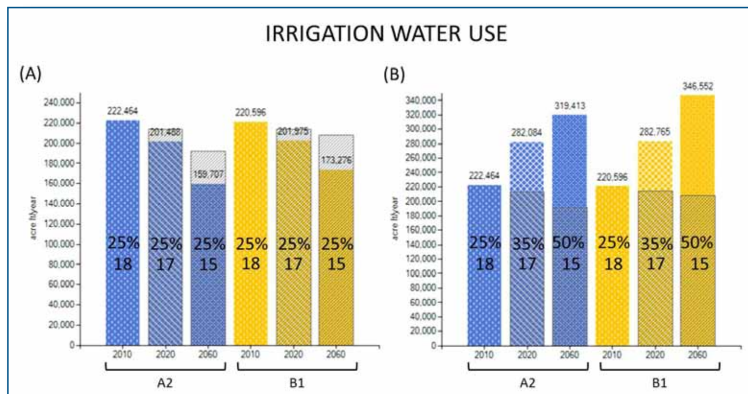


Figure 4. Graphs show estimates of irrigation water use for the watersheds of the Mission-Aransas and San Antonio-Guadalupe estuaries. Results are shown for multiple time points (2010, 2020, 2060) and multiple climate change emissions scenarios (A2 = blue, B1 = yellow). Irrigation water use estimates represent totals for the entire watershed for a full year. (A) Estimates are based on the assumption that the amount of cropland irrigated remains constant over time (i.e., 25%) but the amount of water used to irrigate each acre decreases over time (i.e., 2010 = 18, 2020 = 17, 2060 = 15). Grey hatched lines provide comparison to previous values which are based on the assumption of 18 inches of water per acre per year. (B) Estimates are based on the assumption that the amount of cropland irrigated increases over time (i.e., 2010 = 25%, 2020 = 35%, 2060 = 50%) and the amount of water used to irrigate decreases over time (i.e., 2010 = 18, 2020 = 17, 2060 = 15). Grey hatched lines provide comparison to previous values which are based on the assumption that a consistent amount of acres are irrigated but the amount of water used for irrigation decreases over time.

WATER CIRCULATION DATA COLLECTION

Dr. Lindsay Scheef presented an update of how Seahorse tilt current meters are being used to measure currents and estimate water exchange between the bays in the Mission-Aransas Estuary. The tilt meters use inclinometers to sense how far and in what direction the meter rod is leaning in a current. The angle and direction of the tilt can then be converted to current speed and direction. Early in June 2013, the meters were deployed at 15 stations that were selected based on stakeholder suggestions and information provided by local fishing guides (Figure 5). These stations are primarily in Aransas and Mesquite bays, but as flow patterns under different wind and tidal conditions are determined for those locations, the meters will be redistributed to stations throughout the estuary. The meters generate large amounts of data that are challenging to display in an informative way. A circular histogram was presented as a way of summarizing all the data gathered at each individual station (Figure 6A). An animated map was presented as a way to display the data for multiple stations over time (Figure 6B). Additional meters, which have built-in compasses and larger memory, are being purchased. All current data gathered will be used to improve inputs to the TxBLEND salinity model.

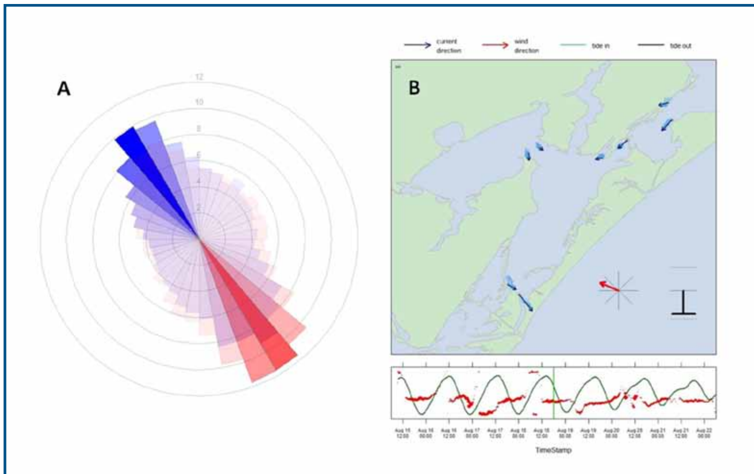


Figure 6. (A) Circular histogram summarizing all current data gathered so far for one of the 15 stations. The length of each bar represents the average current speed (cm/s) in the respective compass direction, the darkness of each bar represents the number of values for that direction, and the color of each bar indicates the predicted direction of the tide (blue = incoming, red = outgoing). (B) A frame from an animation that shows current data for eight of the 15 stations over time. The blue arrows on the map are a snapshot of the directions and speeds of the currents at a single time-point. The direction and speed of the wind (red arrow on map and red dots on plot), as well as the direction of the tide (black bar on map and dark line on plot), are also depicted. An animation of the data was created and can be requested by emailing missionaransas@gmail.com.

KEY SPECIES FOR RESEARCH

Dr. Ed Buskey, Research Coordinator, presented an update on focal species for determining freshwater inflow needs of the Mission-Aransas Estuary. The priority research issues for the Adaptive Management Plan Priority Tier 1 were reviewed, which include *Rangia* clam investigations and life cycle, habitat, and salinity studies for blue crabs. Two undergraduate students from Texas A&M University-Corpus Christi made a presentation on their field work in the Mission and Aransas Rivers to locate populations of *Rangia*, with the help of Dr. Wes Tunnell and Shanna Madsen, the Reserve's Environmental Cooperative Science Center Coordinator. Dr. Buskey then presented some preliminary research on *Rangia* from Dr. Bryan Black, who is investigating the growth rings on *Rangia* shells

Figure 5. Map of the 15 stations selected to deploy the tilt meters for the first round of data collection.

to determine if they would be useful for calculating the age of *Rangia* and the effects of salinity on their growth patterns. These studies could provide additional evidence of the usefulness of *Rangia* as a focal species for freshwater inflow studies.

Kimberly Bittler then presented a summary of her Master's thesis research on the role of salinity signals in recruitment of blue crab megalopae larvae into the Mission-Aransas Estuary. She is investigating the effects of salinity changes on the selective tidal stream transport behavior of blue crab megalopae. These larval blue crabs use the increase in salinity at night to signal the time to swim up into the water column so that flood tides will transport them further into the estuary. Experimental studies showed that blue crab larvae from Texas were more sensitive to small changes in salinity than larvae from North Carolina, where similar studies were previously performed, and where freshwater inflows are generally greater and have lower salinities than Texas estuaries. This makes Texas blue crab larvae better adapted for the higher salinities often found in Texas estuaries, but may still make it difficult for larvae to recruit to the estuary from the Gulf of Mexico when the estuary is hypersaline during periods of extended drought. Dr. Buskey then reviewed the results from the Citizen Science Project, where volunteers help collect crab larvae at several locations near the entrance to the estuary. These data provide an estimate of the number of blue crab larvae recruiting into the estuary and how this recruitment varies in space and time. Finally, Dr. Buskey provided a short summary of The Aransas Project verses TCEQ lawsuit, charging that the Endangered Species Act had been violated through the mismanagement of environmental flows into San Antonio Bay, which may have reduced food supply for the Whooping Cranes (including wolfberries and blue crabs).

SYSTEM DYNAMICS MODEL

Participants in this workshop ran simulations of the updated version of the system dynamics model of the Mission-Aransas Estuary. The model was developed to simulate population dynamics of blue crabs in response to selected environmental and management variables identified by participants at previous meetings. The weekly water temperatures and salinities used in this model are based on data collected from 2007-2012 at Mission-Aransas NERR System-Wide Monitoring Program stations. As temperature tended to be homogeneous throughout the bays during any given week, and seasonal patterns were quite similar from year to year, a single water temperature for each week of the year as a weekly mean was assigned to all cells in the model.

Salinity exhibited spatial and temporal variability, so we calculated a different time series of weekly salinities for each grid cell for years representative of (1) high freshwater inflows (based on data from 2007 and 2010), (2) low freshwater inflows (based on data from 2009, 2011, and 2012), and (3) normal freshwater inflows (based on all data from 2007 to 2012). Blue crab population levels fluctuate as the result of weekly changes in rates of recruitment, growth, movement in and out of the bays, natural mortality, and fishing mortality. The effect of salinity is implicit in the model in the rules that govern migration of adult females toward the open Gulf. This is based on available scientific data. Detailed information regarding the model is available at: http://www.missionaransas.org/pdf/Blue_Crab_Model_Documentation_2_online_draft.pdf

Participants ran the model first under normal salinity and temperature regimes (Scenario 1) and then under variable regimes of their choosing (Scenario 2) to examine how crab populations responded to changes in salinity over time. We gathered written feedback as to (1) confidence in the model for both scenarios, (2) useful information provided by the model, (3) expectations, and (4) implications of model use for estuary management. Figure seven summarizes the results from asking the question: How much confidence do you have in the results generated from this simulation? As in previous workshops, low confidence increased and moderate confidence decreased. We interpret this skepticism as indicating critical thinking about model use.

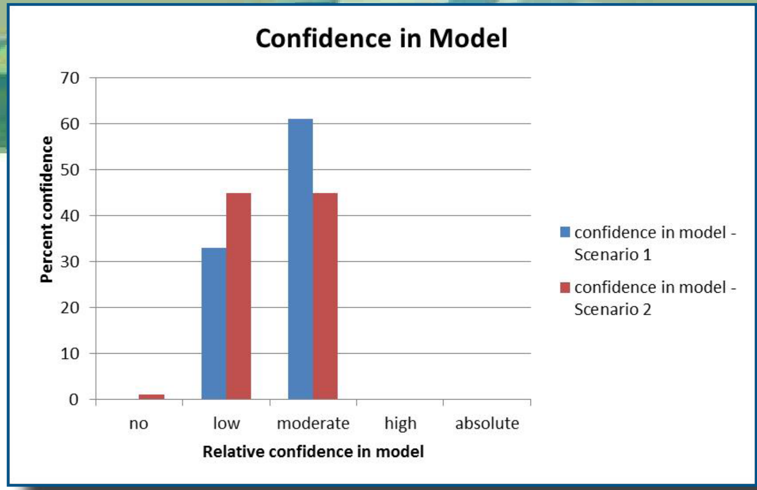


Figure 7. Workshop participant's confidence in the mediated model.

When asked how this model might be useful, several participants suggested that they need more information from the model for it to be useful, specifically about the effects of freshwater inflow changes (i.e. salinity) on other organisms within the estuary and bays. Others suggested that the model might be useful for managing crab harvest.

In later discussion, participants reflected that they intend to communicate what they have learned about the connections and parameters that are important in the estuary to peers and family as well as through educational outreach. They want to change attitudes of "people and water providers" to realize the important connections in the system. Participants also feel that this workshop series has stimulated ideas and raised questions about knowledge gaps regarding the estuary system. One concern expressed by several is that human influence has been largely left out of discussions and needs to become a part of the conversation in future meetings.

We welcome any comments you may have after reading this summary. Please email us at: MissionAransas@gmail.com

Figure 8. Workshop participants conduct a web-of-life game to further explore the connections in the Estuary.

SAVE THE DATE FOR THE NEXT MEETING

When: April 10, 2014
Where: Mission-Aransas NERR Headquarters
Estuarine Research Center
750 Channel View Dr.
Port Aransas, TX 78373

This meeting will provide an update on the research completed for each project objective.

STAKEHOLDER MEETING 4.10.14

BALANCING FRESHWATER NEEDS IN A CHANGING ENVIRONMENT

About this project

This project is a collaboration of the Mission-Aransas National Estuarine Research Reserve (NERR), the University of Texas at Austin, and Texas A&M University. Intended users of this project include stakeholders from the agriculture, commercial fishing, and recreation industries; municipalities; water resource agencies; and scientists.

For more information

WWW.MISSIONARANSAS.ORG/POST_SCIENCE_SCIENCECOLLABORATIVE.HTML

This project is funded by the National Estuarine Research Reserve System Science Collaborative, a partnership of the National Oceanic and Atmospheric Administration and the University of New Hampshire.

Executive Summary

The "Balancing Freshwater Needs in a Changing Environment" project held its sixth stakeholder meeting on April 10, 2014 in Port Aransas, Texas at the Estuarine Research Center. Meeting participants included stakeholders from the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and interested citizens.

The purpose of this meeting was to report on current research efforts, provide information on next steps, and continue development of a model of the system that participants can use to understand and improve freshwater inflow management decisions. Presentations during the meeting were provided for the four project objectives: 1) land use and climate change model, 2) water circulation data collection, 3) key species for research, and 4) system dynamics model.

Workshop participants work on a participant motivation survey.

LAND USE & CLIMATE CHANGE MODEL

Population growth and water demands are not equally distributed throughout the San Antonio and Guadalupe watershed. Increased understanding of the effects of land use and climate change on water usage and runoff will Improve environmental flow recommendations. To help address these issues, the project team are using mapping tools to help stakeholders begin to examine how various scenarios of future land use and climate might affect future freshwater inflow volume. Dr. Kiersten (Madden) Stanzel, Research Associate with the Mission-Aransas NERR, provided an update on the progress of the land use and climate change mapping component of the project. During her presentation she (1) reviewed the 20 scenarios that are being analyzed for this part of the project, (2) discussed the use of Open N-SPECT (or Non-Point Source Pollution and Erosion Comparison Tool) to examine changes in runoff volume, (3) presented initial results of runoff analyses, and (4) discussed next steps and future modifications.

Open N-SPECT is a broadly applicable tool developed by the NOAA Coastal Services Center to help planners and managers understand potential water quality impacts from development and climate change. For the purpose of this project, digital elevation maps (USGS National Elevation Dataset), soils data (NRCS Soil Survey Geographic Database), land use maps (USGS National Land Cover Data, EPA Integrated Climate and Land Use Scenarios), and precipitation information (PRISM; Climate Wizard) were used to estimate runoff volumes. However, due to processing limitations of the tool, analyses could not be performed for the entire watershed of the Mission-Aransas and San Antonio-Guadalupe estuaries. Analyses were restricted to two sub-basins, one which represented a rural portion of the watershed (Mission Sub-Basin) and one which represented an urbanized area (Upper San Antonio Sub-Basin).

Open N-SPECT results allow for visualization of runoff volumes within the two sub-basins (see Figure 1 for example results). They also allow for comparison of multiple scenarios to examine potential changes in runoff volume over time (see Figure 2 for example comparisons). Although work is still underway, initial results indicate that the geographic scale and timeframe of the scenarios chosen for this project do not show major differences between the A2 and B1 emissions scenarios. Results also show that when precipitation varies significantly with season, it may be more important to look at seasonal runoff, rather than annual averages.

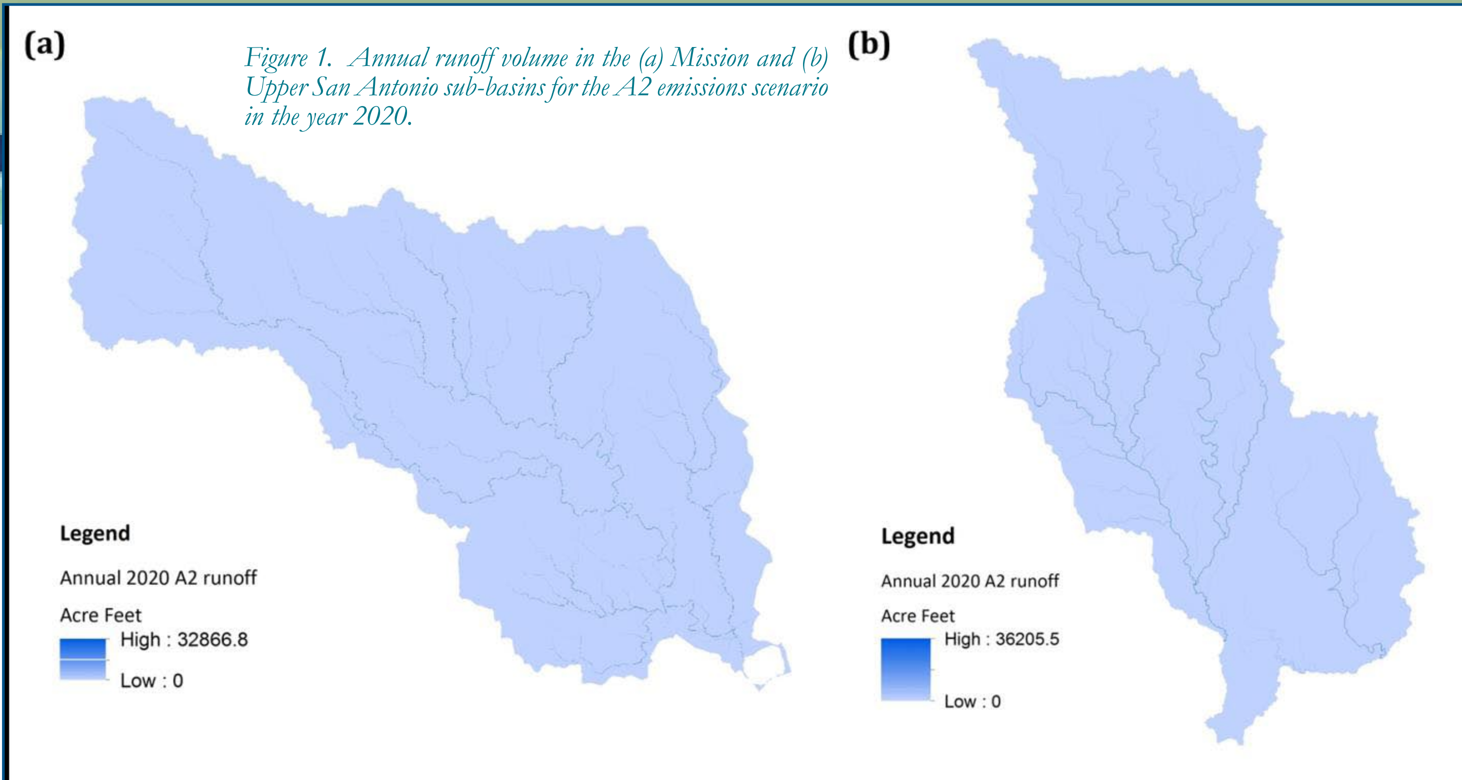


Figure 1. Annual runoff volume in the (a) Mission and (b) Upper San Antonio sub-basins for the A2 emissions scenario in the year 2020.

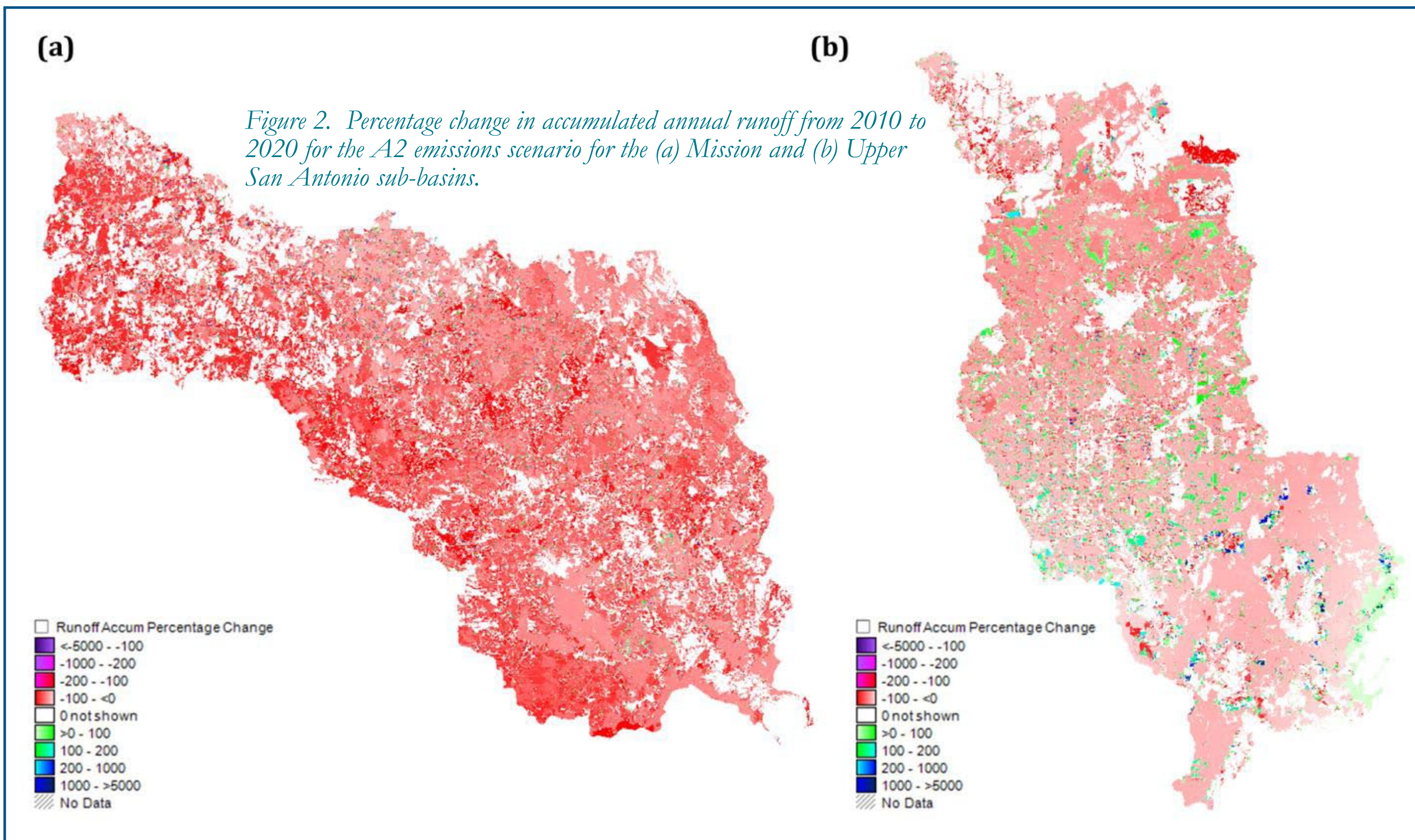


Figure 2. Percentage change in accumulated annual runoff from 2010 to 2020 for the A2 emissions scenario for the (a) Mission and (b) Upper San Antonio sub-basins.

Land use change does appear to have some effect on future runoff volumes, but at a very local scale, and changes in precipitation are going to be the major driving factor in future runoff volume. Finally, results indicate that runoff volumes could be impacted by the way in which precipitation is delivered in the future (i.e., less frequent, larger volume rainfall events verse more frequent, smaller volume rainfall events). Next steps include developing additional baseline scenarios (i.e., annual and seasonal averages) for comparison with future scenarios, and if time allows, additional analyses will be conducted to explore impacts of land use and climate change on nutrient and sediment loads.

WATER CIRCULATION DATA COLLECTION

Dr. Lindsay Scheef presented an update on the tilt current meter circulation study. To date, six months of data at 15 stations in Aransas, Copano, and Mesquite bays have been gathered. The meters generate large amounts of data that are challenging to display in an informative way, but circular histograms and animated maps are effective ways of visualizing patterns in the data over space and time. Tidal and wind influences on currents are apparent in the data animations and were quantified for each station. When these results are displayed on a map, it is clear that tidal effects on currents are stronger closer to Aransas Pass, and wind is a more dominant factor farther from the pass (Figure 3). An analysis was conducted to assess whether an influence of current patterns on salinity in the bays could be detected. Salinity data from the NERR SWMP stations was compared to the direction of water flow between Aransas and San Antonio Bays. Salinity at the Mesquite Bay SWMP station was most strongly related to current direction, with over 80% of the variance in salinity explained by the current meter data (Figure 4). With work to open Cedar Bayou now underway, the tilt meters have been moved to 11 stations in Mesquite Bay so circulation patterns before and after the pass is opened can be compared. Additional meters, which have built-in compasses, are being used to correct any direction alignment errors in the data gathered so far. All current data gathered will ultimately be used assess the performance of the TxBLEND salinity model.

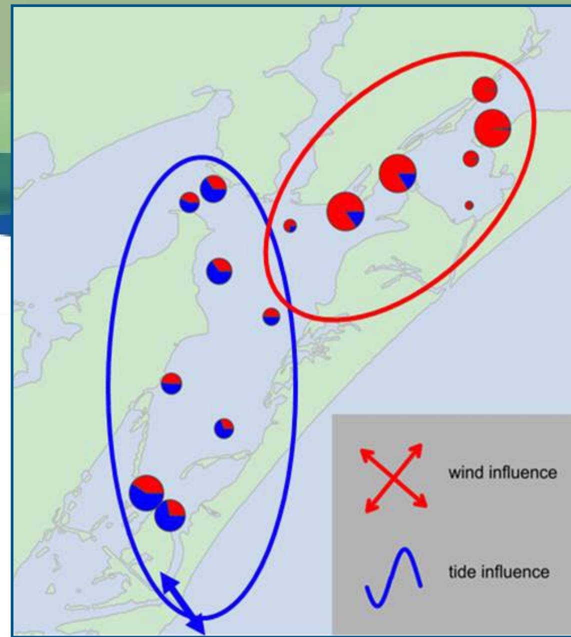


Figure 3. Pie charts indicating the relative influence of tides (blue) and wind (red) on current speed and direction at each station.

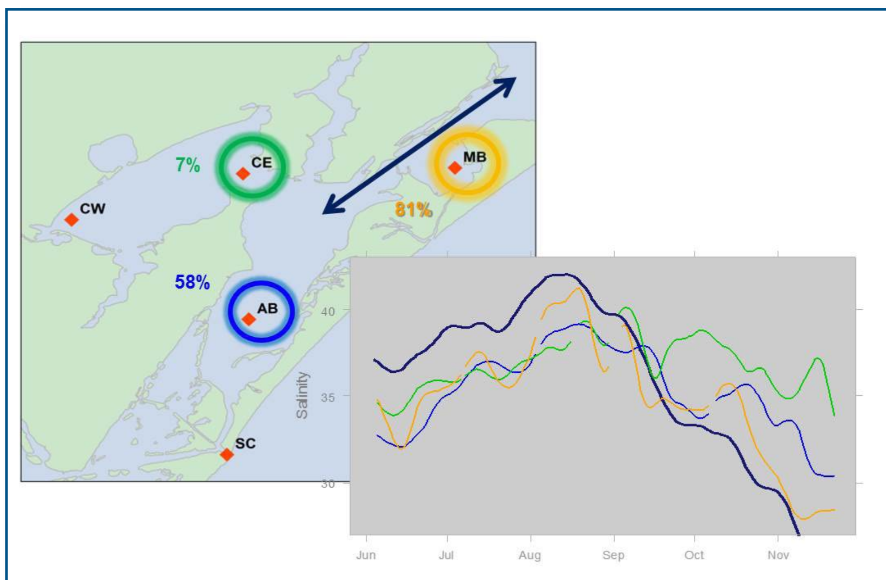


Figure 4. Map of the SWMP station locations and plot of the salinity time-series from the Aransas Bay (blue), Copano East (green), and Mesquite Bay (orange) SWMP stations. Direction of flow between Aransas and San Antonio bays is also indicated on the plot (black), where upward slope indicates flow up towards San Antonio Bay and downward slope indicates flow down towards Aransas Bay. The amount of variance in salinity at each station that is explained by the current direction is indicated on the map.

KEY SPECIES FOR RESEARCH

Dr. Ed Buskey, Research Coordinator

Scientifically valid demonstrations of the importance of freshwater inflows to estuarine dependent species are challenging. There is often anecdotal evidence for estuarine species of commercial or recreational value being more abundant or productive in years of higher freshwater inflow. However, scientific and statistical validation of these observed trends requires long term data sets, and most available data sets do not include all critical life history stages of the species of interest. Sessile species provide the advantage that they remain in one location and experience salinity changes at that location, whereas motile species may select for other habitat characteristics in addition to salinity.

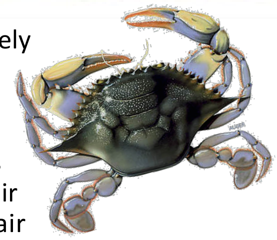
Two focal species considered in studies of the Mission-Aransas NERR Science Collaborative include blue crabs and *Rangia* clams. Blue crabs are both ecologically and economically important. They possess complex life histories which make interpretation of their responses to freshwater inflows challenging. The Texas Parks and Wildlife Department (TPWD) trawl data has a long time series of blue crab abundance, but only adult crabs and larger juveniles are collected by this method. *Rangia* clams are known to require low salinities during at least their early life history stages, however they are at best an incidental catch in the TPWD data.

Graduate student Kimberly Bittler studied several aspects of the relationships between freshwater inflow and blue crab biology, and results of her studies were briefly summarized. The general consensus is that juvenile blue crabs prefer lower salinity estuaries, since these regions tend to have lower predation and parasitism rates for blue crabs. Adult female blue crabs seek higher salinity waters to release their planktonic larvae, and blue crab larvae use tidal currents and salinity signals to locate estuaries and get transported back into estuaries.

Kimberly performed a “data mining” meta-analysis of existing long term data sets on blue crab abundance from throughout the US. This analysis included 30 estuaries from New Jersey to Texas, and time series of 5 to 36 years. Statistical analysis of this data revealed a subtle but significant relationship between salinity and crab abundance with maximum abundance predicted for salinities of about 10 ppt.

A study was also performed of the behavioral response of blue crab larvae to changes in salinity. The Mission-Aransas Estuary, Texas, experiences extreme year to year variation in freshwater inflows and salinity regimes due to drought, climate change, and human diversions. Previous studies have suggested that freshwater inflows affect populations of the commercially and ecologically important blue crab, possibly during recruitment into estuaries via Selective Tidal Stream Transport (STST) after they have completed larval development offshore. Blue crab megalopae use increases in salinity as a cue to differentiate between flood and ebb tides, swimming up with an increase in salinity on the flood tide, which carries megalopae to favorable nursery habitats within the estuary. However, in drought years when the estuary becomes hypersaline, an increase in salinity occurs on the ebb tide, potentially transporting megalopae away from the estuary. We re-examined the role of salinity in flood tide transport behaviors of megalopae from the Mission-Aransas Estuary, and use a simple model to show how this behavior could lead to year class failures of blue crabs when a threshold is crossed.

A study was also performed on the efficiency of “hogs hair” collectors for blue crab larvae. Blue crabs spawn at the mouths of estuaries, larvae develop offshore, and return to the estuary as a postlarval megalopae stage. Hog’s hair collectors are simple artificial settlement substrates that have been widely used to quantify the abundance and supply of megalopae recruiting back into estuaries. Despite their broad application in over 30 studies on blue crab, few studies have quantified the efficiency of hog’s hair collectors. The efficiency of hog’s hair collectors was calculated by comparing megalopae settlement to their planktonic abundance and current speed in the field. A flume experiment was also performed, where the settlement behaviors of megalopae interacting with the substrate under various flow conditions was examined. Interactions between megalopae and a scaled-down hog’s hair collector were filmed, and the small scale flows around the collector were quantified using tomographic PIV (particle imaging velocimetry). Relationships between flow velocity, megalopae abundance, and megalopae settlement were interpreted using an encounter rate model framework. A new model was created that accounts for the non-linear impact of current speed on settlement behaviors, which can be used to estimate either supply or abundance of megalopae using hog’s hair collector data.



Results of some preliminary studies on the possibility of studying the effects of freshwater inflow on *Rangia* clams were also presented. Most mollusks change the rate at which they grow new shell material over annual patterns, and they produce annual “rings” similar to those found in tree trunks. The width of these rings may reveal climate patterns, such as temperature and salinity. Dr. Bryan Black has collected some *Rangia* shells and found them amenable to growth increment studies. Their life span is only about 10-15 years, but the annual growth increments are well defined, so growth chronologies can be developed. It remains to be determined if growth rate is strongly affected by salinity.

PARTICIPANT MOTIVATION SURVEY

Participants in this workshop were asked to take part in a survey regarding their participation in the NERR Collaborative, specifically, why they have chosen to participate. Participants were asked about the number of meetings they have attended, their initial influences in participating, things they feel are important to accomplish through this process, the roles they perform and other participants perform, and their continued motivation to participate. Understanding these stakeholder motivations is important for ensuring their needs and desires are met through this collaborative process. As well, the results can be used moving forward in the NERR Collaborative and in the planning processes of any future management efforts because the stakeholders’ voices are being heard. From this survey, we hope to gain an understanding of how participants perceive the collaborative process and their involvement in NERR. Stakeholder involvement can have positive outcomes for individuals and the group: the more participants can learn, the better able they are to know their opinions, and ultimately, the more confident they can be sharing their knowledge and opinions to make informed decisions regarding freshwater inflow recommendations.

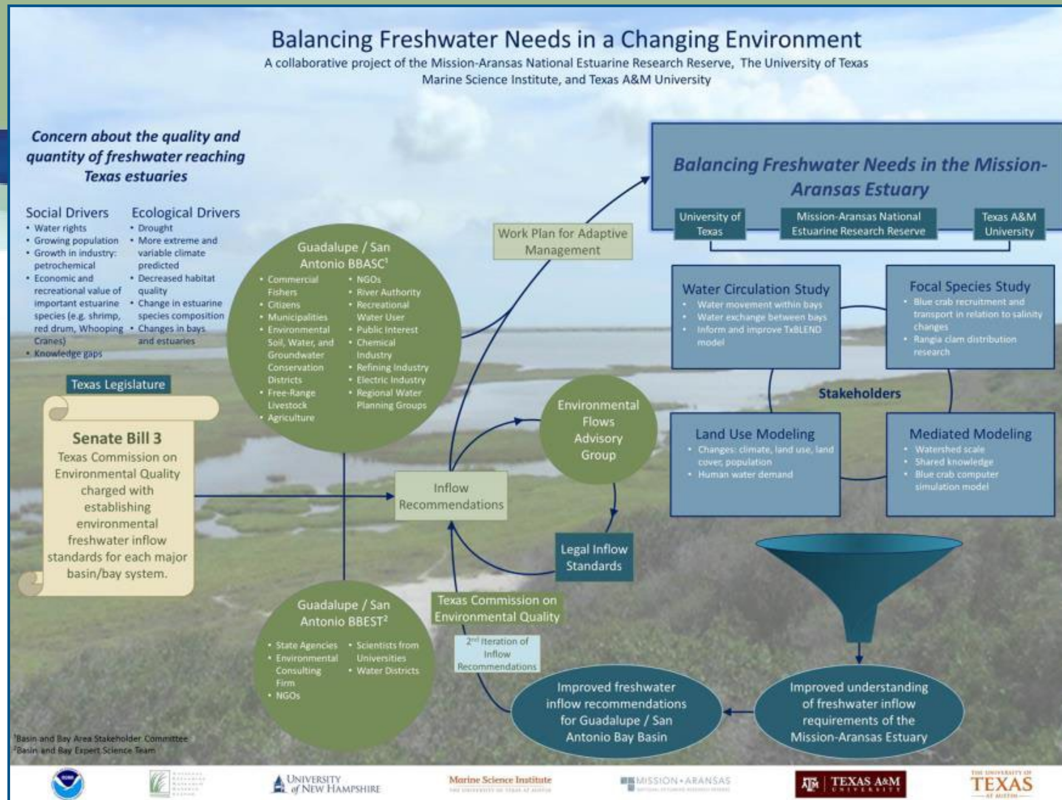


Figure 5. Context map used in the facilitated discussion to help participants think and work through project connections. (Courtesy of Abbie Sherwin)

MEDIATED MODELING

We reviewed the development of the system dynamics model of the Mission-Aransas and Copano Bay estuaries during previous meetings. We then ran simulations of the model in normal and high flow scenarios. Participants had questions regarding the data used in this model. Dr. George Ward pointed out that much of the adult crab data has been checked against data from Texas Parks and Wildlife. Detailed information regarding the model is available at: http://www.missionaransas.org/pdf/Blue_Crab_Model_Documentation_2_online_draft.pdf

Discussion centered on the use and limitations of the model. The model does not show dramatic responses of crab populations to periods of higher salinity as have been the experience of several participants. There is speculation that factors other than salinity may indirectly affect crab populations in these estuaries. As data becomes available, future iterations of the model might include the hypersaline estuary fringes (currently available data is restricted to sampling stations located in the bay proper) and newer data on megalopae movements. Several participants commented that this model presented an opportunity to learn what we know and what we don't know to further refine existing knowledge gaps.

Workshop participants discuss the project and related connections.

FACILITATED DISCUSSION: Next Steps

The final discussion in this meeting looked towards Next Steps for the Collaborative. While this is not a decision-making process, participants have become more informed about the effects of land use and climate change on freshwater inflows; learned more about how currents, tides, and wind affect water movement in the estuary; focused research efforts on blue crab and *Rangia* spp. clam life history; and developed shared systems learning through construction of the system dynamics model. The discussion was an opportunity to communicate about best practices and policy regarding freshwater inflows.

To ground the discussion, we provided a context map of this project in relation to the Texas SB3 process (Figure 5). Participants expressed hope that the knowledge gained from 'Balancing Freshwater Needs in a Changing Environment' might be incorporated by the Texas Commission on Environmental Quality into standards that have been created from the Guadalupe / San Antonio BBEST and BBASC recommendation reports. Specific questions were asked about how data such as the information currently being gathered on *Rangia* clams and knowledge learned about blue crabs might be useful to BBEST. Participants suggested that what has been learned from these meetings needs to be communicated to a wider audience.

We welcome any comments you may have after reading this summary. Please email us at: MissionAransas@gmail.com

SAVE THE DATE - FINAL MEETING

When: October 16, 2014
Where: Mission-Aransas NERR Headquarters
Estuarine Research Center
750 Channel View Dr.
Port Aransas, TX 78373