
Final Report

# Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes

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# Executive Summary

*Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes*

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<u>Introduction</u>

From 2002 through 2009, faculty and students from the Department of Wildlife and Fisheries Sciences at Texas A&M University conducted field, laboratory, and modeling studies to investigate the diet, behavior, and habitat of the whooping crane (*Grus americana*) at Aransas National Wildlife Refuge (ANWR), Texas. During this period the research team also conducted complementary studies of environmental conditions in San Antonio Bay. The project was called the San Antonio Guadalupe Estuarine System (SAGES) project, and was funded primarily by the Guadalupe Blanco River Authority and the San Antonio River Authority, with additional support provided by the San Antonio Water System and the Texas Water Development Board. The U.S. Fish and Wildlife Service provided in-kind support through lodging, the use of boating facilities, and other logistics.

The overall goal of the SAGES project was to use empirically-generated and existing available data to evaluate the relationship between freshwater inflows feeding San Antonio Bay and the health of the endangered whooping crane population at ANWR. Field research included several studies of wetland processes, plant ecology, and the abundance and distribution of blue crabs in the salt marshes of ANWR. Investigations also focused on the behavioral responses of whooping cranes to changes in abundance and distribution of foods (blue crab [*Callinectes sapidus*], wolfberry fruit [*Lycium carolinianum*], and others), abiotic factors, and human-induced disturbances within and adjacent to ANWR. Finally, empirical findings were integrated to produce a simulation model with the capabilities of predicting crane response to changes in food supply, temperature, salinity, and water levels in and around the ANWR salt marsh. The study design was guided by inputs from the project sponsors, State of Texas agencies with knowledge of how freshwater inflows can impact estuarine ecology, and a team of experienced scientists from throughout the U.S. and whose expertise included most aspects of crane and estuarine ecology.

As essentially nothing was known about the effects of freshwater inflows on crane ecology, the SAGES team chose to focus on two primary areas of study. The first area of study was the ecology of key crane foods, namely blue crabs and wolfberries. The primary study objective was to determine how environmental parameters influenced the abundance and distribution of these foods. The second area was on the behavioral ecology of cranes. The main objectives here were to document the food habits and time-activity budgets of cranes, as well as investigate the effects of abiotic conditions, food abundance, and human disturbance on the crane's energy balance. The team anticipated that these areas of study would allow for substantial gains in knowledge of whooping cranes, but also recognized that the limited duration of the SAGES project would not allow for a totally comprehensive evaluation of the effects of altered freshwater inflows.

<u>The Studies</u>

Figure 1 is a map of San Antonio Bay and the Blackjack Peninsula showing three whooping crane territories that were intensively studied by the SAGES team. The hydrology and food abundance research was conducted in the Boat Ramp Channel, Pump Canal and Middle Sundown Bay territories; crane behavior was observed in two additional territories at the south end of Blackjack Peninsula. A brief synopsis of the field and laboratory studies follows. Please see Appendix A for a more thorough description of each study.

**Core SAGES Studies**

1. *J. Bryan Allison* characterized sediment movement in tidal creeks and concluded that wave action from barge traffic can affect tidal-creek hydrodynamics.
2. *Rachel Butzler* studied space and time patterns of wolfberry plants in the territories and documented that peak berry abundance generally occurred at the same time as crane arrival in the fall and that the berry supply was exhausted by the end of December.
3. *Carrie Miller* studied pond algal and nutrient dynamics and contributed to the understanding of how water levels impact marsh inundation and hydrologic connectivity.
4. *George Gable* examined relationships between water quality and plankton communities and, among other outcomes, determined that Cedar Bayou has a limited effect on ecological conditions in Mesquite Bay.
5. *Matthew Driffill* studied the relationship between water levels in tidal creeks and adjacent marshes and quantified how inundation connects marshes to the bay and creek system.
6. *Christopher Llewellyn* conducted a laboratory study that showed wolfberries are less productive in saline water during mid-summer. Also, inundation regime had no apparent effect on productivity during this same period.

7-9. *Danielle Greer* was responsible for a series of studies relating to the foraging behavior and diet of whooping cranes and the larval settlement, juvenile recruitment, and juvenile and adult abundance patterns of blue crabs. Shallow bays adjacent to mature salt marshes functioned as both terminal settlement habitat and critical nursery habitat. Additionally, water temperature during spawning/larval export best predicted settlement of larval crabs. While shallow bays provided important nursery habitat for young blue crabs, interior marsh ponds were important habitats for dispersing juvenile and adults crabs. Overall benefits of foraging differed among foods in the crane's diet, depending on the resource targeted, and food abundance patterns during winter; wolfberry fruits, snails, and insects were of particular importance to cranes.

10. *Kristin LaFever* observed whooping crane behavior and found that foraging is the dominant activity among territorial birds and that human activities at ANWR did not have a detrimental impact on territorial cranes.
11. *Karine Gil de Weir* developed a model that simulated population dynamics of the whooping crane and predicted substantial continued growth of the ANWR flock.
12. *William Grant and Todd Swannack* developed a spatially-explicit hydrological connectivity model using light detection and ranging (LIDAR) and environmental data that simulates patterns of water level changes and connectivity within ANWR.

**Complementary SAGES Studies**

13. *Stephen Davis et al.* found that plankton dynamics were driven by seasonal and freshwater inflow effects. The United States Geological Survey funded this complementary project.
14. *Stephen Davis et al.* conducting intensive spatial surveys, found that estuarine-wide water quality and circulation patterns are driven to a great extent by variations in freshwater inflows. Texas Sea Grant funded this complementary project.

**Non-SAGES, ANWR Studies**

15. *Steven Zeug et al*. compared the ecology of natural and created marsh and observed that blue crabs have a consistent role in the food chain regardless of their size.
16. *David Hoeinghaus and Stephen Davis* used stable isotope analysis and found that larger size classes of blue crabs were more associated with "connected" pond edge habitats in ANWR marshes than the smaller ones.
17. *Katherine Roach et al.* defined the importance of connectivity in shaping aquatic food webs in ANWR marshes.

Access to the theses, dissertations and publications from these studies may be found at http://sages.tamu.edu.

San Antonio Bay

The team's studies show a clear effect of river inflows on water quality patterns across the greater bay ecosystem. However, during periods of low inflow, the impacts of factors such as wind and tides became more noticeable. Pass Cavallo represents the major source of Gulf of Mexico inputs into the bay. Further, the data indicate that Cedar Bayou represents a minor exchange path for Gulf water into the estuary, as the water quality signature of inputs from Cedar Bayou diminishes within a short distance of the bayou. Freshwater inflows to the bay tended to flow in a southwest direction along Blackjack

Peninsula and along the estuarine marshes at ANWR. Not surprisingly, patterns of salinity in San Antonio Bay were strongly correlated with those in tidal creeks of Blackjack Peninsula.

ANWR Marsh and Vegetation

Given the higher elevation of the marsh relative to mean sea level, the ANWR salt marsh is infrequently inundated, typically a result of spring high tides, storm surges, and high-water periods. The team estimated high year-to-year variability in marsh inundation, which governs the frequency and duration of surface water connections between tidal waters (*i.e*., creeks and bays) and marsh ponds. These surface water connections are the path for aquatic organisms to migrate between bays and ponds. With extended periods of marsh exposure and disconnection, marsh ponds can completely dry out—leading to death of resident aquatic organisms—or the resident aquatic organisms can be sufficiently depleted by wading birds (*e.g*., whooping cranes) and other consumers. Either way, prey items in these ponds are replenished through subsequent inundation and connection events.

The ANWR marsh vegetation community is comprised of a mixed, high-marsh plant community. Wolfberry plants had a frequency of occurrence at the three sites of about 30% and were most productive in early spring and late summer, prior to flowering and fruiting in fall. Peak wolfberry fruit abundance coincided with crane arrival in October each year. Based on the team's observations and those from other studies in the region, salinity immediately prior to and leading up to the late summer leafing period may be an important factor in fruit production. Berry density at the ANWR marsh sites was negatively correlated with bay water salinity, thus when salinity is high, berry density is low. Soil porewater salinity correlated with surface water salinity at these sites, but we had less than one year of reliable soil salinity data. Future effort should be made to focus on the relationship between surface water salinity and soil salinity across the ANWR marshes, as well as on the effects of local precipitation.

Blue Crab Settlement, Recruitment, and Abundance Patterns

The team found that developing crabs were significantly influenced by the following abiotic factors: water temperature, precipitation, water level, and wind speed and wind direction. We were not able to define significant relationships between settlement or recruitment rate and juvenile or adult abundance.

We believe this particular field study is one of the first studies to have sampled blue crabs (*e.g.* nekton) within habitats of interior salt marsh and is believed to be the first study to examine patterns of crab abundance in a mature salt marsh where emergent vegetation is dominated by high-marsh halophytes. We found that shallow bay habitats were important nursery habitats for young blue crabs and interior marsh ponds were important habitats for dispersing juvenile adult crabs. Small crabs were more typically found in submerged vegetation and algae-dominated bay waters. Larger crabs were found proportionately more often in pond-edge habitats, and the largest crabs were found in open-water pond habitats of the interior marsh. These connected, interior marsh ponds were significant contributors to total numbers and standing stock of crabs.

Whooping Crane Behavior

Whooping cranes spent 65% of daylight hours foraging. While in the salt marsh their diet consisted of wolfberry fruit, blue crabs, clams, snails, insects, fiddler crabs (*Uca spp*), snakes, and fish. Wolfberry fruit and snails and insects were consumed in the highest quantities, required the least effort during foraging, and generally were associated with the most efficient foraging behavior. Blue crabs were the most optimal food in relation to protein, and clams were a significant source of biomass. Whooping cranes foraged most efficiently during the winter of 2005-2006 when water levels were lowest.

A diversity of human activities occurred in the vicinity of crane territories. The most common type of human activity was motor boating, representing 50% of all human stimuli that occurred during the study. Other relatively common disturbance stimuli that occurred in the vicinity of crane territories were barges, shrimp boats, air boats, tour boats, airplanes, and helicopters. Both positive and negative responses to human stimuli were observed for crane family groups. The effects of human activities in the vicinity of ANWR did not appear to detrimentally affect crane energetics.

The Model

The team developed a quantitative simulation model as a tool to aid in assessing the potential impact of changes in freshwater inflow into San Antonio Bay on whooping cranes. The final form of the quantitative model evolved from the team's initial conceptualization of the San Antonio Bay-ANWR salt-marsh ecosystem, which views the ecosystem as being influenced by regional environmental factors that affect hydrology and landscape features within the marsh. These factors, in turn, affect the abundance of the two most important food resources (wolfberry fruits and blue crabs) within whooping crane territories and, as a result, may have an impact on the energy budget of the cranes. The model consists of three equations derived from our empirical studies and three equations taken from the scientific literature. The team does not view its quantitative model as all-inclusive, but rather, as a useful simplification of a complex system that focuses attention on evaluating the most likely links between freshwater inflow and whooping crane ecology that could be explored with the resources at the team's disposal.

Despite these limitations, the model does suggest relationships that are of potential importance to assessing crane ecology and that may be relevant to evaluation of future freshwater diversions. These relationships include the following:

- The food supply for cranes appears to be more than adequate to meet their energy needs. None of the study results indicated that habitat conditions at Blackjack Peninsula are marginal for crane survival and well-being.

- Bay salinity is demonstrably higher when freshwater inflows are low; however, the relationship between salinity and crane energetics is still uncertain.
- Wolfberry abundance is lower when bay salinity is high. The team does not know the extent to which marsh salinity is dependent on bay salinity, nor does the team understand the interactive effect of bay salinity and marsh inundation patterns on marsh soil salinity.
- Consistent with prior studies, blue crab abundance tends to increase with bay salinity.

Summary

The team found that the diet of the whooping crane is varied and included blue crabs, wolfberry fruit, clams, snails, and insects. The dominant food resources (blue crabs and wolfberries) are affected by several factors: freshwater inflow, bay salinity, tides, and temperature. Simulation results for the 11-year period of 1997-2007 found that the metabolic energy present in wolfberry fruit and blue crabs, and in blue crabs alone, always exceeded the estimated daily energy requirements of four adult cranes in each of the three representative crane territories, except under extreme marsh environment conditions. In nearly all conditions simulated, the food supply for whooping cranes appears to be more than adequate to meet their energy needs.


Figure 1. Map of San Antonio Bay and Blackjack Peninsula.