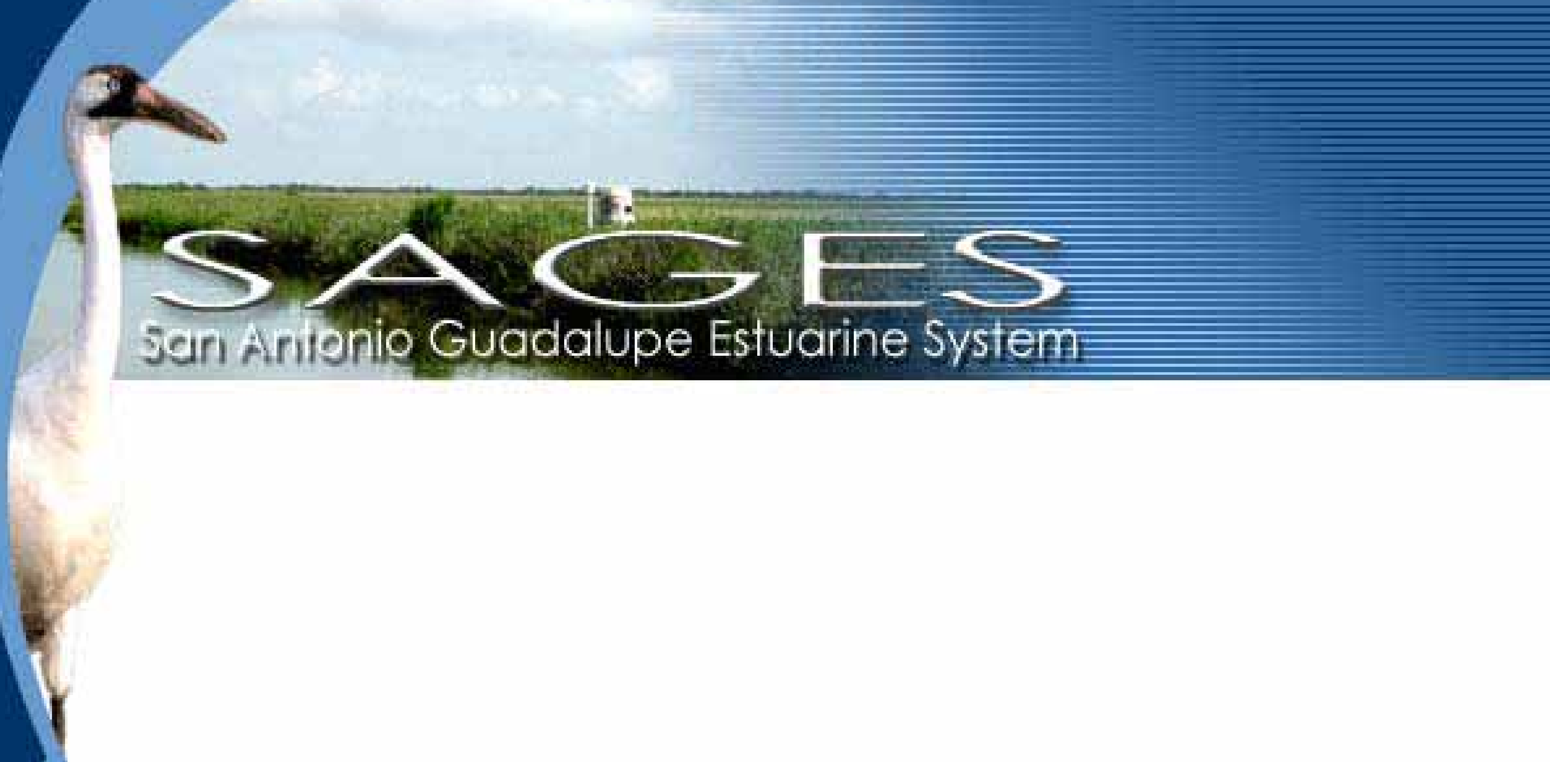


# Comments on SAGES Final Report

## From: Mr. Tom Stehn, of U.S. Fish and Wildlife Service

June 5, 2009

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Dr. Slack,

I am writing to provide comments on the draft SAGES report presented in Seguin, Texas on April 29, 2009. Your study has provided valuable new information on some topics including wolfberry production and blue crab recruitment. However, I disagree with your conclusions about the relationship of inflows, blue crabs and whooping cranes. I find the SAGES study very misleading mainly because it contains false assumptions and does not properly account for existing knowledge in the scientific literature.

My comments are presented numerically, with supporting material in 4 appendices.

1. **The SAGES study results are contrary to what I have observed during 28 years at Aransas monitoring the whooping crane population.**

Data collected at Aransas National Wildlife refuge indicates a relationship between marsh salinities, blue crab populations, and whooping crane survival. In general, when inflows are high and bay and marsh salinities are low, blue crab populations do well, and whooping crane mortality is low. With reduced inflows and high marsh and bay salinities, crabs do poorly and whooping crane mortality rises dramatically. This higher mortality makes sense since blue crabs make up 80-90% of the whooping crane diet when crabs are available (Chavez-Ramirez 1996) and are the predominate food of whooping cranes (Stevenson and Griffiths 1946, Allen 1952, Blankinship 1976, Hunt and Slack 1987, Nelson 1995, Chavez-Ramirez 1996).

Observations from weekly aerial survey whooping crane distribution data, monthly surveys initiated in the 1990s of blue crab, wolfberries and salinities in the bays and marshes, as well as observations of experienced personnel, were compiled to characterize what habitats the cranes were using throughout the winter which relates to general patterns of food consumption. Variables monitored were characterized in comparison with other winters as high, medium or low for either the entire winter or portions of the winter. Whooping crane mortality was detected on weekly aerial census flights (Stehn and Taylor 2008).

Data for the past 21 winters separated into winters of high (> 1.5%) whooping crane flock mortality (Table 1), and low (<1.5%) whooping crane flock mortality is shown below (Table 2). Annual flock mortality is provided in Appendix 1.

In the last 21 winters, whooping crane mortality was high (> 1.5%) in 7 of those winters. For the 7 winters with the highest whooping crane mortality; all but one (winter of 1993) had high salinities for much of the winter. For the winters with crab populations monitored, all (n=5) had low blue crab populations. Five of 6 had notably high levels of upland use. Wolfberry production ranged from abundant to low, and the amount of clamming and acorn levels differed depending on the winter. When in a winter of high salinities and low blue crab populations, this long-term data anticipates that whooping crane mortality will be high. In the winter of 2008 with high salinities, blue crabs and wolfberries, the two major foods of whooping cranes, were both extremely low and 23 whooping cranes died (8.5% of the flock), the highest winter mortality recorded in the past 21 years.

**Table 1. Habitat conditions associated with high mortality winters (>1.5%) for whooping cranes at Aransas, 1988-2008.**

| Winter | % Mortality | Salinities | Crane Use of Freshwater | Blue Crab | Wolf-Berry | Use of Clams | Acorns | Upland Use |
|---|---|---|---|---|---|---|---|---|
| 1988 | 4.3% | High | High | -[1] | - | - | High | High |
| 1989 | 3.4% | High | High | Scarce | - | - | High | High |
| 1990 | 7.8% | High thru Jan. Lower Feb-Apr. | High thru Jan. Lower Feb-Apr. | - | - | - | High | High |
| 1993 | 4.9% | High, 14-26 ppt[2], though usually<23ppt in connected ponds | Only seen in December | Low, small crabs re-populated marsh starting in late Feb. | Abundant | Little observed | low | Low, but moderate use following burns |
| 2000 | 3.3% | High thru Dec. Low Jan.-April. | High thru Dec. Low after Dec. | Scarce, especially in mid-winter | Moderate, but still notable part of diet | Use noted | scarce | High |
| 2005 | 2.7% | High | Use occurred, especially 2nd half of winter | Low | High | High | scarce | Some use on burns |
| 2008 | 8.5% | High | High | Low | Low | High | scarce | High, especially on M.I. |

1. Blue crabs were not monitored until 1992 when Chavez-Ramirez started his study. Refuge personnel continued monitoring blue crabs after his study was completed in 1993.

2 Parts per thousand (ppt)

A typical pattern of habitat conditions present during all 7 high mortality winters was apparent as follows;

- Blue crabs were in short supply.
- Salinities were high forcing the cranes to seek out fresh water to drink except in 1993 when salinities were high but generally stayed below the threshold that forces cranes to seek out fresh water to drink.
- Considerable crane use foraging on clams and invertebrates in open bay habitat was documented, with some exceptions.
- Considerable foraging occurred on uplands.

In an average winter, blue crabs and wolfberries are readily available when the cranes return to Aransas in the fall. High tides in late September/early October have inundated the marshes and allowed crabs to disperse into connected and unconnected ponds. Starting in October, wolfberries are flowering and fruiting into December. Usually sometime in December, the cranes have consumed many of the blue crabs in the marshes, and the wolfberry crop is well past its peak and over by the end of the year. Starting in late-November, low pressure systems that reach the coast lower temperatures and bring north winds that blow the bay waters out into the Gulf. Tides are lowered dramatically. Blues crabs tend to move from the marshes into the open bays as marsh water levels and temperatures drop. Many crabs seek out deeper water which tends to be warmer than the shallow marsh waters. Whooping crane food habits shift dramatically to foraging in open bay habitat for clams and invertebrates in the substrate. During this mid-winter period, much crane upland use may occur, especially immediately after prescribed burns that provide animal matter killed in the fire (snakes and insects) or makes acorns on the mainland readily available when the mast crop is sufficient. Upland use also occurs on barrier islands following prescribed burns, as well as on disturbed soils mostly rooted up by feral hogs with the cranes foraging on tubers including nutsedges and ground cherries. In late winter, as temperatures and tide levels increase, blue crabs start moving back into the marshes, and whooping cranes go back to feeding on crabs. Fiddler crabs may become a larger part of the diet as spring days become warmer and the fiddler crabs are higher in their burrows due to the higher marsh water levels.

A correlation has been noted between the winters of high whooping crane mortality (1988, 1989, 1990, 1993, 2001, 2005, 2008) and low river flows on the Guadalupe below the level of 1.3 million acre-feet recommended by TPWD required for a health bay/estuary system (R. Sass, Professor of Natural Sciences, Emeritus, Rice University, unpublished data). Dr. Sass came to the following conclusions:

"*1. A high (whooping crane) mortality rate is always accompanied by a low river flow and the resulting high salinity.*

*2. A whooping crane response to low river flow (high salinity) is one of excess stress. This condition does not necessarily lead to death but may be manifested as lack of sufficient bodily fat and protein that will be exhibited during the spring migration and subsequent poor reproductive behavior...*

*3. Complete and accurate data on environmental stress that is manifested by poor migratory and reproductive behavior is hard to generate but may well be a major part of the story on salinity-diet relationships…"*

For the 14 winters with low whooping crane mortality < 1.5%, all had high blue crab populations except during mid-winter periods. Blue crab populations always decline in late fall and into the winter due to consumption by whooping cranes, the draining of the marshes from low pressure systems that bring northerly winds that lower marsh water levels dramatically as bay waters are blown out into the Gulf, and crabs moving to deeper water to find warmer and deeper water. Thus, blue crab levels are always lower during mid-winter. SAGES should have focused on crab movements in and out of the marshes since without regular replenishment of blue crabs in the marsh from crab movements, the cranes will consume most of their available food supply.

**Table 2. Habitat conditions associated with low mortality winters (<1.5%) for whooping cranes at Aransas, 1988-2008.**

| Winter | % Mortality | Salinities | Crane Use of Freshwater | Blue Crab[1] | Wolf-Berry | Use of Clams | Acorns | Upland Use |
|---|---|---|---|---|---|---|---|---|
| 1991 | 0.8% | Low | Low | - | very high | Low | High | high |
| 1992 | 0.0% | Moderate (10-20 ppt[2]) | Low | High | High | Low | High | high |
| 1994 | 0.0% | High thru mid-Dec., then lower | Medium | High into Jan., then low | High | Medium | Low | Low |
| 1995 | 0.6% | high | High | High in fall, low in Jan-Feb, medium in spring | Abundant | Moderate | Moderate | high |
| 1996 | 0.0% | High until mid-March rains | High thru mid-Jan., then moderate | High in fall, moderate mid-winter | High | Low | High | Moderate |
| Winter | % Mortality | Salinities | Use of freshwater | Blue crab | Wolfberry | Use of clams | Acorns | Uplands use |
| 1997 | 0.5% | Low | None | High in fall, then moderate | High | Moderate use mid-Dec to mid-Feb. | High | Some use on burns and hog rootings |
| 1998 | 0.0% | Low | Very low | High except in mid-winter | Moderate+ | Low | moderate | Moderate |
| | | | | | | | | |
| 1999 | 0.5% | High | High | High in fall, but then scarce | Moderate to high | High | High | High |
| 2001 | 1.1% | Moderate | Low | High in fall, then medium | High | High | moderate | Moderate |
| 2002 | 0.5% | Moderate | None | High | High | Low * | High | Low |
| 2003 | 0.5% | Moderate | Moderate | High in fall, low Jan-Feb. high mid-March | High | Low | High | Low, moderate on burns |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2004 | 0.9% | Low | Low | High in fall and spring, low mid-winter | High | Low to moderate | Low | Low except moderate on burns |
| 2006 | 0.0% | High first half of winter, then dropping below 23 ppt | High through Dec., low after mid-Feb. | High in fall, then moderate | High | moderate | High | Moderate |
| 2007 | 0.0% | Low first half of winter, increase to 20 ppt by spring | Moderate | High except mid-winter | High | Moderate in mid-winter but very high on March 5 census | - | Moderate on burns, high on M.I. uplands/burns |

[1] Blue crabs were not monitored until 1992 when Chavez-Ramirez started his study. Refuge personnel continued monitoring blue crabs after his study was completed in 1993.

[2] Parts per thousand (ppt)

The correlation between increased whooping crane mortality occurring when blue crab populations in the marshes are low invalidates the SAGES conclusion "that food is not an issue for whooping cranes except in the most extreme conditions." Without blue crabs and wolfberries available, cranes are forced to eat other foods. These other foods are not as good at meeting the energy and nutritional needs of wintering whooping cranes (Nelson 1995). If other foods such as clams, insects, tubers and snails provided everything the whooping cranes needed, then high levels of mortality would occur in both high and low blue crab winters. My observations support the observations of other researchers that the key to whooping crane well-being during winter are adequate blue crab population.

SAGES should look at flock dynamics and habitat conditions at Aransas over more than 2 decades and compare them with inflow data including possible time lag affects.

**2. The SAGES study results fail to account for the conditions observed during the 2008 winter at Aransas.**

The conclusions of the SAGES study fails to account for the record level of whooping crane mortality during the 2008 winter (8.5%). Neither of the crane winters in which the SAGES project collected blue crab data were anything near as bad for the cranes compared with 2008.

CHARACTERIZATION OF THE 2008 WINTER AT ARANSAS

The fall of 2008 had the worst crop of wolfberries I had ever observed at Aransas in the past 28 years. Data from a transect walked on November 10th, 2008 found only 12 wolfberry fruits and no wolfberry flowers on one transect about 150 meters long that we have been monitoring for years. The previous November, on the same transect, we had counted 416 flowers and 60 fruits. The SAGES study concludes that wolfberry production is negatively affected by high summer salinities, which fits in this case since the area experienced an extreme drought and salinities were high. The cranes did not get much benefit from the wolfberry crop in the fall of 2008. Moderate numbers of blue crabs were available when the cranes first arrived, but numbers quickly tapered after the cranes started feeding on the crabs. Commercial whooping crane boat captain Tommy Moore emailed me on November 11th:

> "There are no wolfberries. It is like that all over the marsh. I have been watching the cranes' feeding habits and only every once in a while do I see one pluck a wolfberry from the vegetation. They are mostly digging for fiddler crabs is my guess. I have not seen a blue crab consumed this year (on 4 trips). We did see a snake eaten on Ayres Island. Looks like a tough year."

A food survey done by refuge personnel on December 1, 2008 found only one blue crab and 2 wolfberries. Salinities were measured at 30 parts per thousand (ppt) at the refuge boat ramp and 43 in unconnected ponds at the refuge boat ramp marsh. The same day, an emaciated subadult crane unable to stand was picked up near the refuge boat ramp. The next blue crab survey on December 30th found zero blue crabs, and that finding was replicated on monthly surveys the remainder of the winter.

On January 7, 2009, I spoke with Karen Meador of Texas Parks and Wildlife Department (TPWD), Rockport. She stated that ongoing bay sampling was finding low numbers of blue crabs, but not at alarmingly low levels. However, commercial blue crab harvest was very low and crabbing pressure was down. Salinities were very high, measured at 30 ppt in Copano Bay.

From my aerial census flight report on January 8, 2009 I wrote …"Although the Tour Boat Captains occasionally see cranes catching a crab, many of the birds have switched to eating razor clams in open bay habitat. The increased amount of crane use in open bay habitat on the flight (n=79 out of 228) is indicative of the food stress the population is facing."

Monthly crab surveys done the rest of the winter and spring also failed to find any blue crabs. Although the whooping crane tour boat captains would occasionally find a whooping crane eating a large blue crab, the overall consumption of blue crabs was way below the norm and extreme low. The very low availability of blue crabs and wolfberries during the 2008 winter for the cranes was correlated with record high mortality. Seventeen juveniles and 6 white-plumaged birds died, a record total of 23 cranes (8.5% of the flock).

Information on specific causes of mortality was obtained on the two intact carcasses recovered. The first bird captured live died as it was being transported to medical help. A necropsy done by the National Wildlife Health Lab in Madison, Wisconsin showed the bird was extremely emaciated and only found an injured knee that could have contributed to the bird's death. A white-plumaged bird had been seen limping with restricted foraging ability in Saskatchewan in the 2008 fall migration. It is possible that was the same bird as the one picked up live at Aransas and had been unable to get enough food over an extended period of time. The low levels of food availability at Aransas were presumably too much for the bird and it continued to weaken until it could no longer stand.

The second whooping crane carcass recovered was a juvenile that was observed being aggressively picked on by a territorial male on January 13, 2009. Since the juvenile's parents flew off during the territorial encounter, I postulate that the juvenile was too weak to fly off. It was predated with 48 hours of its encounter with the territorial male. A strain of infectious bursal disease (IBD) was isolated from the carcass, the first time IBD has ever been isolated from a crane. Very little work has been done on IBD in cranes, so the disease presumably may have been epizootically affecting whooping cranes at Aransas over a long period of time. IBD has been documented in whooping cranes and other birds including wild turkeys in Florida (Candelora et al. 2008), and may be present at captive whooping crane breeding facilities. One of the symptoms of IBD is emaciation, even when the bird is receiving adequate food supplies. However, the particular strain of IBD isolated from the Aransas whooping crane is different from other known strains, so how it affected the crane is speculative.

IBD mainly affects juvenile cranes since the virus grows in the bursa, an out pocket of the cloaca that is not present in white-plumaged cranes. Thus, the 7 mortalities of white-plumaged cranes at Aransas in the 2008 winter probably hadhad anything to do with IBD. The loss of even 7 whooping cranes ranks 2008 as a high mortality winter.

Field observations in the 2008 winter showed a correlation between low blue crab populations and high whooping crane mortality. Food supply can often be a limiting factor for wildlife populations. It makes sense that whooping cranes are going to do better when food supplies are adequate versus when food supplies are limited. SAGES seems to be denying this by suggesting food supplies are more than sufficient in crane territories. The fact that whooping crane territories appear to be approaching minimum sizes (Stehn and Prieto, In Review) suggests that territorial whooping cranes must defend a large enough area to maintain an adequate food supply for the territorial pair and their young of the year. With territories reaching minimum sizes and not observed to be getting smaller suggests that food is becoming limiting. If the wintering grounds were chock full of food for the cranes annually and that food was not a limiting factor in all but the most extreme winters, as stated by the SAGES report, I would expect to be seeing whooping crane territories continuing to get smaller and smaller until food becomes a limiting resource. Since territories are at or close to minimum sizes already, this provides evidence that food may be limiting. This is a far different conclusion than that described in the SAGES report. The inverse relationship between blue crab population size and whooping crane mortality shown by Pugesek et al. (2008) also provides evidence that food is a limiting factor (see below). I therefore do not see the relevance of the analysis done on p. 55 that hypothetically "shrinks" the size of whooping crane territories since there is evidence that this is not happening at Aransas as the cranes continue to slowly expand their range rather than increase the density of wintering cranes.

3. **SAGES study results are contrary to the conclusions of Pugesek et al. (2008). The SAGES report should attempt to explain this difference.**

For an eight-year period starting in 1993, intensive surveys were done by Pugesek et al. (2008) to estimate the number of blue crabs available to whooping cranes. The winters of 1993 and 2000 were poor crab years; the remaining six winters all had adequate numbers of blue crabs present. During the two winters with poor crab numbers, seven and six whooping cranes died respectively. In all six other winters, either zero or one whooping crane died. This showed a statistically significant inverse correlation between blue crab abundance and adult whooping crane mortality (Pugesek et al. 2008).

The SAGES report needs to explain why findings from the SAGES study which collected blue crab data only in 2 winters differs from the findings of the 8-year data set of Pugesek et al. (2008). It is a critical oversight not to have even mentioned the Pugesek et al. (2008) manuscript anywhere in the SAGES report even though I had emailed the manuscript to SAGES team members. This oversight seems to be characteristic of the SAGES study in failing to thoroughly review existing literature on many topics of the study including the relationship between inflows and blue crabs.

4. **Study results from SAGES about whooping crane foods seem in direct conflict with previous crane research. The discussion section found in scientific manuscripts that should attempt to relate current findings with previous research is missing in the SAGES report. Please discuss what field data you collected to come to different conclusions from previous studies.**

Numerous studies have found blue crabs to be an important food resource for wintering whooping cranes (Allen 1952, Stevenson and Griffiths 1946, Blankinship 1976, Hunt and Slack 1987, Nelson (1995), Chavez-Ramirez 1996). When blue crabs are scarce, the whooping crane population is under stress and does poorly (Nelson 1995, Chavez-Ramirez 1996, Pugesek et al. 2008). Allen (1952) found the diet in fecal samples to be 85% blue crab. Chavez-Ramirez (1996) found that when available, blue crabs can make up 80-90% of the diet of whooping cranes. An individual crane can consume up to 80 crabs per day. Blue crabs appear to be the most important source of energy for wintering whooping cranes contributing between 62% and 97% of overall energetic intake during different months (Chavez-Ramirez 1996). He did note that blue crabs may become a limited resource in some years. In October through December 1993, the second winter of his study, a lack of blue crabs which was only partially offset with an increase in wolfberry consumption, affected the potential for energy storage throughout the wintering period resulting in negative energy balances through the first half of the 1993-94 winter (Chavez-Ramirez 1996). Studies by Nelson (1995) of whooping crane food items (crabs, clams, wolfberry, acorns) showed that blue crabs were the highest in protein and nutrition for the whooping cranes. When crabs are not available, whooping cranes will switch to other foods, but because of the poor nutritive value of these alternate foods, whooping cranes may actually burn up fat reserves and have a net loss of energy for periods of the winter (Chavez-Ramirez 1996). Nelson (1996) noted an apparent instance of food shortage contributing to higher whooping crane mortality from late fall of 1993 to fall of 1994. This negative energy balance may also have manifested itself in greater than normal over-winter mortality and reduced nesting effort in the subsequent nesting season where 37% of the adult pairs failed to nest (B. Johns, Canadian Wildlife Service, unpublished data). This was unusual since normally just about all pairs attempt to nest annually. In addition, production was reduced from the pairs that did nest (B. Johns, Canadian Wildlife Service, personal communication). This was believed to have resulted from their reduced fat reserves that had not built up sufficiently during the previous winter.

A statistically significant inverse correlation between blue crab numbers and increased adult whooping crane mortality has been documented (Pugesek et al., 2008). It is well known that whooping cranes will eat other food items when blue crabs are not available, but energy content studies done by Nelson (1996) showed that blue crabs were higher in protein and lipids than other foods sampled. During most mid-winter periods when cranes switch their diet to eat clams, Nelson (1996) found that *Rangia cuneata* was a suboptimal energy and nutrient resource since it was low in gross energy and protein compared with the other crane foods studied.

From observations made over many winters, I can estimate food availability throughout the winter based on distribution of the cranes observed on aerial census flights as described by Chavez-Ramirez (1996). For example, severe food shortages in the 2008 winter changed crane distribution dramatically with greatly increased amounts of upland use observed, cranes utilizing game feeders, and increased clamming in open bays. These levels of use are not observed when blue crabs and/or wolfberry are available to the cranes, an indication that these other foods are suboptimal foods.

The first winter (2004) of the Sages study that did intensive blue crab sampling was a low whooping crane mortality winter (0.9% of the flock). The second and final winter (2005) of the SAGES study that did intensive blue crab sampling was a high mortality winter with 6 whooping cranes dying out of a flock of 220 (2.7%). There were noticeably more crabs present in 2004 compared to 2005. Walking surveys (n=6) found an average of 48 crabs/hour in 2004 and 38 crabs/hour in 2005 (T. Stehn, USFWS, unpublished data). Crab surveys done on 3 consecutive days in March following the methodology of Pugesek et al. (2008) who found that the March surveys were the best reflection of overall winter crab levels, recorded 3.22 crabs/100 meters in 2004 and 1.43 crabs/100 meters in 2005. Crabs were notably scarce in the second half of the 2005 winter and the crane population was under stress, a notable difference from the second half of the 2004 winter. The SAGES report fails to account for this difference and SAGES researches did not detect the way the whooping cranes were impacted differently in these two winters. Instead, the SAGES report on page *vi* states "None of the study results indicated that habitat conditions at Blackjack Peninsula are marginal for crane survival and well-being".

**5. The SAGES study fails to analyze existing data sets.**

The SAGES study collected two years of field data on crane foods. Existing multi-year data sets should be analyzed as follows:

a) Analyze inflow data and bay salinities in relation to whooping crane mortality.
b) Analyze inflow data in comparison with TPWD fisheries blue crab sampling data from Aransas and San Antonio bays.
c) Analyze inflow data in comparison with commercial crab harvest data.

**6. The SAGES study model assumes that blue crab numbers are directly correlated with rising salinities up to 30 ppt. This assumption is based on laboratory studies and is false!**

With the blue crab well documented as the primary food of whooping cranes, one of the most crucial objectives of the SAGES study was to determine how blue crab numbers in the crane marshes were related to salinities. Page 42 of the SAGES report states; "*In the model we selected, crab density was positively correlated with salinity, which agrees with Cadman and Weinstein 1988*". On p. *vi*, the SAGES report states; "Consistent with prior studies, blue crab abundance tends to increase with bay salinity." Instead of objectively leaving the relationship between blue crabs and salinities as an unknown and collecting all possible sources of data to shed light on this relationship, the SAGES study **assumed** that more crabs were present when salinities were higher. This assumption was based on laboratory studies (Cadman and Weinstein 1988) and does not fit field conditions observed in the winter range of the whooping crane nor data collected by Texas Parks and Wildlife Department (Longley 1994, M. Fisher, TPWD, personal communication). **This assumption made by SAGES is false and pervades and invalidates the entire SAGES model and study.** Neither Longley (1994) or Mark Fisher (unpublished data) found that blue crabs were more abundant in higher salinities as assumed by the SAGES study. Texas Water Development Board (TWDB)/TPWD model results for the Guadalupe Estuary predicted a harvest of 255,500 pounds under MinQ and 379,900 pounds under the higher inflows and lower salinities of MaxH (Longley et al. 1994). The SAGES assumption did not hold true for all the drought winters I have observed when blue crabs were scarce. Field sampling shows that blue crab populations usually crash in periods of drought. Examples of this were the winters of 1989, 1993, 2000, 2005 and 2008. The assumption needs to be changed in the SAGES model. I expect this would drastically change the conclusions of the SAGES study.

On October 28, 2004 I talked with Dennis Pridgen, TPWD fisheries biologist in Rockport, Texas. He noted how zoeal and megalopal stages of blue crabs need high salinities (> 25 ppt) for high recruitment with much of the spawning occurring in the Gulf of Mexico. After successful development of megalopae, survival of early crab stages is complicated, based on synergistic effects of salinity, temperature, pollutants, predation, disease, habitat and food availability. The first blue crab stage (2 ½ mm) and subsequent stages show the best abundance and growth when salinities are intermediate (10-20 ppt) (D. Pridgen, TPWD, personal communication). He also stated that "*Inflows between April and July will influence crab survival positively. If inflows are high during this period, the blue crab population will do well. Thus, April to July inflows are very important to the whooping crane food base.*" Notes I took from the conversation with Mr. Pridgen that were proof-read and edited by him for accuracy are provided as Appendix 3. Tom Wagner (TPWD Fisheries biologist, Rockport) in an email written to me January 5, 2005 noted "increased spring salinities will reduce juvenile blue crab growth, thus reducing energy available to cranes".

Scientific research in other estuarine systems in general demonstrates a positive relationship between inflows and blue crab populations. The SAGES study needs to exhaustively research the literature on this relationship, account for this knowledge in their report, and relate it to their field data collected on blue crabs in 2005 and 2006. Guillory et al. (2000) stated that "juvenile blue crabs are most abundant in low to intermediate salinities characteristic of middle and upper estuarine waters". Rounsefell (1964) found "low salinity marsh is an important nursery habitat for juvenile blue crabs and increased salinities may adversely impact the species" (as cited in Guillory et al. 2000). Guillory et al. (2000) found "*a blue crab recruitment index as correlated with lagged summer/early fall Mississippi River discharge (positively) and salinity (negatively), whereas commercial harvests were significantly correlated with unlagged Mississippi River discharge (positively) and salinity (negatively). They also state that the effects of discharge and salinity on blue crab recruitment and abundance were probably manifested indirectly through biotic mechanisms such as predation*".

Longley (1994) analyzing a long-term data set reported an inverse relationship between salinities and blue crab numbers. This totally disagrees with the SAGES assumption in the model that blue crabs prefer higher salinities, an assumption that is not based on field data collected by SAGES. TPWD data shows that more blue crabs are generally found not in the highest salinity areas in the estuary but in more moderate salinity areas of 5-15 ppt (Longley 1994).

Others have written about the implications of a causal relationship between inflows and high blue crab numbers. (Kretzschamer 1990) calculated that by the year 2040, due to anticipated diversions, a predicted decrease of 555,000 acre-feet of gauged inflows in an average year into the crane's winter range was projected to cause an 8% decline in blue crab populations (Texas Department of Water Resources 1980), but could have a much larger impact in drought years (N. Johns 1994).

Texas Water Development Board data indicate natural droughts already threaten the Guadalupe ecosystem. Without sufficient inflows, wildlife resources, including fish, crabs, and shrimp, all decline. The 1.15 million acre-feet figure derived by TPWD is often quoted as an amount needed to maximize harvest of 9 marine species of commercial interest in the bays and estuaries. In the case of blue crabs, more than 1.15 million acre-feet is needed to produce high blue crab populations. TPWD data clearly show that increased water inflows result in higher blue crab numbers (Mendoza 2001). Crab survival of all life stages increases when salinities are generally below 20 ppt. Blue crabs were found to be more abundant in the Guadalupe Estuary in salinities averaging between 10-25 ppt. A simple inverse relationship exists between blue crab catch rates and mean salinity within an estuary (Longley 1994). Peak crab counts in the bays occur following periods of flooding. In San Antonio Bay, the 3 highest blue crab harvest years were all having inflows greater than 3 million acre-feet annually. Thus, to maximize blue crabs for whooping cranes to eat, managers should maximize freshwater inflows on the Guadalupe River. Providing for guaranteed minimum inflows to the bay is essential.

**7. The SAGES study needs to comment on how marsh salinity levels could impact growth of sea grasses and algae in marsh ponds.**

Blue crab survival in the marshes is dependent on habitat in which they can hide from predators. Vegetated habitats are favored by blue crab over un-vegetated habitats (Rozas and Minello 1998). Many of the ponds at Aransas seem to have little aquatic vegetation growing in them except for algae. I have observed increased growth of seagrasses and algae during low salinity years in the ponds. Thus, reduced inflows could increase marsh salinities, reduce growth of seagrasses, and thus limit blue crab populations.

**8. The SAGES study needs to relate reduced inflows with the increased time periods that salinities in unconnected marsh ponds in the crane winter range would exceed 30 ppt.**

Long-term crab sampling data compiled in May, 2009 shows blue crab bag seine catch per unit effort in San Antonio and Aransas bays per salinity zone showed no differences for salinities below 30 ppt, but showed declining blue crab populations in salinities greater than 30 ppt (Mark Fisher, Texas Parks and Wildlife Department, unpublished data). If one assumes this to also hold true in the salt marshes, I have observed multiple drought years at Aransas when marsh salinities in unconnected ponds greatly exceed 30 ppt. Crabs presumably are avoiding these hypersaline ponds, thus greatly lowering the carrying capacity of the salt marshes to sustain blue crab populations. I recommend that the SAGES study look at how often reduced inflows would increase marsh salinities in unconnected ponds above 30 ppt and how that would lower the blue crab carrying capacity of the marsh.

**9. The SAGES study misuses data on the smallest age classes of blue crabs.**

Whooping cranes generally do not eat the smallest size classes of blue crabs (<30 mm). This needs to be factored in to the energetic model. Whooping cranes do not eat blue crabs 11 mm or smaller. I would also estimate that blue crabs 20 mm or smaller probably don't make up a significant part of the whooping crane diet either. Whooping cranes are normally seen eating crabs something at least as large as a fiddler crab, or blue crabs 30 mm in size or greater. Crab densities used in the SAGES model (crabs per square meter) should exclude all blue crabs <30 mm since they are basically not used by whooping cranes. Although the smallest sized blue crabs may presumably be a good indication of subsequent recruitment into the larger size classes, many other bird species prey on very small crabs, and many of these small blue crabs will die at Aransas during summer when much of the marsh at Aransas dries up.

With blue crabs > 30 mm the main food of the whooping crane, it is essential that the SAGES model be able to successfully reflect many aspects of blue crab biology. Especially important would be how blue crab availability for whooping cranes changes during the course of the winter due to many factors including consumption of crabs by whooping cranes and other wildlife species, movements of blue crabs in and out of the marshes, and differential availability of blue crabs during periods of colder temperatures as noted by Chavez (1996). Yet on p. 108, the Sages report states: "Model selection procedures used to explore the density of blue crabs > 30 mm in size often resulted in non-convergence or excessively large dispersion estimates".

Danielle Greer also failed to sample crabs in some key "bayou" habitat at Aransas. These bayous consist of very narrow channels that interconnect marsh ponds. On one blue crab survey in particular, I remember walking the marsh for over an hour and the only place I finally found crabs was in a bayou too narrow to be sampled using Danielle's methods.

**10. The important role of sediments, nutrients and organic matter brought by inflows to the Guadalupe Estuary is not accounted for in the SAGES study that seems focused on a salinity-based model only.**

Blue crabs and bay and marsh productivity are impacted by sediments, nutrients, and organic matter that are brought to the estuary by inflows (Longley 1994). For SAGES to be making public statements that inflows can be reduced 90% without hurting the food base of the whooping crane based on their salinity-based model that does not properly account for the importance of sediments, nutrients, and organic matter in maintenance of bay productivity is very misleading.

**11. The SAGES study fails to show the temporal aspects of whooping crane food availability.**

Page 70 of the SAGES report states:

> "*The food supply for cranes appears to be more than adequate to meet their energy needs during the time period simulated. None of the study results indicated that habitat conditions at Blackjack Peninsula are marginal for crane survival and well-being. Simulation results for the 11-year period of 1997-2007 found that the metabolic energy present in wolfberry fruit and blue crabs together and in blue crabs alone, always exceeded the estimated daily energy requirements of four whooping cranes in each of the three crane territories, except under extreme marsh environment circumstances.*"

The SAGES study does not account for seasonal periods of stress for the whooping crane that occur nearly every winter. Chavez-Ramirez (1996) found major stretches of the 1993 winter when cranes used up existing energy reserves due to inadequate availability of quality foods. With blue crabs and wolfberries well documented as the preferred foods of the species, both of these items are normally in short supply in January and February. The cranes switch to foraging on clams and other benthic invertebrates. Clams and invertebrates had been present earlier in the winter but were not selected by the cranes. Therefore, one assumes that they do not "prefer" those foods. Nelson (1995) found these foods to be lower in caloric value and protein compared to blue crabs. Thus, the SAGES calculations measuring total crane food supply are meaningless when key foods are not available to the cranes for significant stretches of most winters.

On p. 147-148, the author Danielle Greer noted the change in food habits from wolfberry fruits and blue crabs to razor clams in mid-winter "*when overall food abundance was presumably low*". She noted during the second half of her final field season that cranes were not able to find blue crabs and switched their food habits to clams and insects. However, she failed to recognize how atypical this was compared to winters when whooping crane foods are sufficient and failed to correlate the stressful conditions with the death of 6 whooping cranes during her second season of field sampling.

**12. The SAGES study concludes erroneously that a reduction in wolfberry production will not harm whooping cranes, with SAGES reasoning that cranes will opportunistically forage on other foods of sufficient nutrition that are present in adequate numbers in all but the most extreme winters.**

The SAGES study correlates increased summer salinities in the marsh with reduced levels of wolfberry production in the fall. Wolfberries are fed on heavily by whooping cranes because of their high caloric value and because they are easily obtained. A reduction in the wolfberry crop due to decreased inflows and higher marsh salinities could negatively impact significantly the food base available for whooping cranes since wolfberries are a key component of the whooping crane diet in the fall. In 2008 with the lowest wolfberry crop I have observed in the past 21 years, the cranes had only limited numbers of wolfberries to consume. The cranes initially fed on blue crabs in the fall. As more and more crabs were consumed and crab numbers declined, the species was in trouble. Continued food stress from the extreme low levels of wolfberry and blue crab were correlated with the highest flock mortality (8.5%) documented in the last 21 years.

The SAGES model when looking at the density of wolfberry fruits needs to estimate and take into account other wildlife species including sandhill cranes and raccoons that eat large quantities of wolfberries. In fact, the only time sandhill cranes forage extensively in salt marsh is when wolfberries are available. Thus, other wildlife species may significantly lower the quantity of wolfberries available to the whooping cranes.

**13. The SAGES study fails to analyze the energetic costs of cranes being forced to leave the salt marsh to drink.**

Cranes are observed leaving the marsh to seek out freshwater to drink when salinities approach or exceed 20 ppt. When marsh and bay salinities exceed 23 parts per thousand (ppt), whooping cranes are forced to make daily flights to freshwater to drink (Allen 1952, Hunt 1987). Flights are presumably made several times a day, although the number of times a whooping crane must drink fresh water daily has not been quantified. I have observed cranes on San Jose Island flying 3 miles to find the nearest fresh water. These flights use up energy, reduce time available for foraging or resting, and could make the cranes more vulnerable to predation on the uplands (Tom Stehn, USFWS, Austwell, Texas, personal communication). Thus, inflows are crucial in keeping salinity levels below the threshold of 23 ppt in coastal marshes used by whooping cranes.

Inflows which mix with Gulf waters help keep salinity levels moderate. The SAGES study should assess how reduced inflows would increase the energy demands for cranes forced to seek out freshwater sources. There could presumably also be detrimental physiological aspects for whooping cranes spending the winter in highly saline environments.

**14. SAGES should analyze the spike found in blue crab recruitment in relation to inflow data.**

A potentially very significant spike was found by SAGES in blue crab recruitment. Blue crab larval movements into the marshes were low except during the spikes. The study should comment on what factors may have caused this spike to occur.

**15. Peer review of the SAGES study was inadequate.**

The technical advisory committee convened by SAGES in 2003 and 2004 was never consulted again after those early stages of the study. Thus, the SAGES study received no technical guidance during much of the study's duration and especially during the wrap-up. Not knowing who peer-reviewed the draft report, I doubt if anyone knowledgeable about whooping cranes such as a member of the Whooping Crane Recovery Team was asked to review the final report before it was released in April, 2009.

**16. The report contains errors and inconsistencies, some of which are noted below.**

p. 26 - Figures 2.1 and 3.1 are very different even though the text states they are identical. Figure 3.1 which is wrong shows no link between inflows and whooping crane foods.

p. 43 – Sages assumed that "wind speed was a proxy for water turbidity". In the multiple surveys done by Mike Baldwin for the Pugesek et al. (2008) study, and the multiple walking surveys I have conducted, turbidity in the narrow bayous seemed mostly related to schools of fish that would stir up the bottom sediments and cloud the water.

p. 44 – I do not understand why "the sample grid for Boat ramp did not include the large lake within that territory." The territorial Boat ramp cranes spend extensive periods every winter foraging in that large lake known as Redfish Slough.

p. 54 – The date selected by SAGES for whooping crane arrival (October 16) is actually the average date for the first whooping crane of the fall to arrive (T. Stehn, USFWS, unpublished data). The date of April 7 assumed by SAGES to be the average departure date is actually about when 50% of the flock has started the migration. Thus, there is inconsistency in what the two dates selected represent. If SAGES wants to choose a date when 50% of the cranes have arrived in the fall, I would choose approximately November 4th.

p. 108 – "*Model selection procedures used to explore the density of blue crabs > 30 mm in size often resulted in non-convergence or excessively large dispersion estimates*". With blue crabs > 30 mm the main food of the whooping crane, it is essential that the SAGES model be able to successfully reflect many aspects of blue crab biology. Especially important would be how blue crab availability for whooping cranes changes during the course of the winter due to many factors including consumption of crabs by whooping cranes and other wildlife species, movements of blue crabs in and out of the marshes, and differential availability of blue crabs during periods of colder temperatures as noted by Chavez (1996).

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**Appendix 1. Mortality in the Aransas-Wood Buffalo whooping crane population 1989-2008.**

High crane mortality winters at Aransas are designated by red text.

| Year | Flock Size In April | Apr-Nov Mortality | Apr-Nov % Loss | Winter | Winter Mortality | Peak Winter Flock Size | % Winter Mortality | 12-Month Mortality | 12-Month Mortality (%) |
|---|---|---|---|---|---|---|---|---|---|
| 2008 | 266 | 34[A] | 12.8 [A] | 2008-09 | 23 | 270 | 8.5% [A] | 57 | 21.4% [A] |
| 2007 | 236 | 9 | 3.8 | 2007-08 | 0 | 266 | 0% | 9 | 3.8% |
| 2006 | 214 | 22 | 10.3 | 2006-07 | 0 | 237 | 0% | 22 | 10.3% |
| 2005 | 215 | 25 | 11.6 | 2005-06 | 6 | 220 | 2.7% | 31 | 14.4% |
| 2004 | 192 | 10 | 5.2 | 2004-05 | 2 | 217 | 0.9% | 12 | 6.3% |
| 2003 | 184 | 15 | 8.2 | 2003-04 | 1 | 193 | 0.5% | 16 | 8.7% |
| 2002 | 174 | 5 | 2.9 | 2002-03 | 1 | 185 | 0.5% | 6 | 3.4% |
| 2001 | 174 | 13 | 7.5 | 2001-02 | 2 | 176 | 1.1% | 15 | 8.6% |
| 2000 | 187 | 16 | 8.6 | 2000-01 | 6 | 180 | 3.3% | 22 | 11.8% |
| 1999 | 183 | 11 | 6.0 | 1999-00 | 1 | 188 | 0.5% | 12 | 6.6% |
| 1998 | 181 | 16 | 8.8 | 1998-99 | 0 | 183 | 0% | 16 | 8.8% |
| 1997 | 160 | 8 | 5.0 | 1997-98 | 1 | 182 | 0.5% | 9 | 5.6% |
| 1996 | 157 | 13 | 8.3 | 1996-97 | 0 | 160 | 0% | 13 | 8.3% |
| 1995 | 133 | 3 | 2.3 | 1995-96 | 1 | 158 | 0.6% | 4 | 3.0% |
| 1994 | 136 | 11 | 8.1 | 1994-95 | 0 | 133 | 0% | 11 | 8.1% |
| 1993 | 136 | 9 | 6.6 | 1993-94 | 7 | 143 | 4.9% | 16 | 11.8% |
| 1992 | 131 | 10 | 7.6 | 1992-93 | 0 | 136 | 0% | 10 | 7.6% |
| 1991 | 135 | 11 | 8.1 | 1991-92 | 1 | 132 | 0.8% | 12 | 8.9% |
| 1990 | 141 | 9 | 6.4 | 1990-91 | 11 | 146 | 7.5% | 20 | 14.2% |
| 1989 | 132 | 7 | 5.3 | 1989-90 | 5 | 146 | 3.4% | 12 | 9.1% |
| **20-Year Average** | | **12.8** | **7.2 %** | | **3.4 (1.3%)** | **182.6** | **1.8%** | **16.3** | **9.0%** |

[A] worst loss in past 20 years.

**Appendix 2. Winter notes on habitat conditions during high whooping crane flock mortality taken from unpublished file reports written annually by T. Stehn.**

**1962-63 winter** - 4 birds lost, highest as of that date.

**1988-89 winter –** 6 losses out of 138 (4.3%), the highest ever recorded as of that date.

The winter was notable for the amount of crane use in upland areas and freshwater ponds. Freshwater sources, mostly dugouts, provided sufficient drinking water for the cranes. Salinities in the salt marsh exceeded 23 ppt for much of the winter. An abundant acorn crop attracted numerous cranes to feed on the uplands. On the refuge, upland use totaled 17.2% of all aerial locations. In November, interior marsh pond salinities ranged between 40 and 52 ppt. Readings in the marshes on Matagorda Island were as high as 70 ppt. Salinity measurements in early December found readings in the GIWW and adjacent bays between 32-35 ppt. These bay levels were extraordinarily high, a result of the continued drought in South Texas and the resultant lack of freshwater inflows from river systems. San Antonio Bay at the refuge picnic area was 26 ppt, the lowest level documented. After heavy rains in January, marsh salinities averaged 19 ppt and the GIWW 23 ppt. The whoopers were observed no longer making flights to fresh water to drink. The lack of rain in February and March raised salinities, measured March 28 at 25 ppt in the GIWW and bays and an average of 33 ppt in the marshes. Cranes at freshwater were first observed on March 18. Such visits continued into April.

Some upland use was documented on 12 out of 22 aerial census flights conducted during the winter. Upland use was observed on all flights between Nov. 21 and March 8. On the refuge, 17.2% of all aerial locations were on uplands. With an excellent acorn crop, the cranes found an abundant food source. The census flight on March 8 noted the lowest tides of the winter. Fifty-six of the 124 cranes were located in the bays, presumably eating clams.

**1989-90 winter** 5 lost out of 146 (3.4%), second highest losses to date.

The winter was notable for the amount of crane use in upland areas for foraging and freshwater ponds for drinking. Marsh salinities were recorded as high as 46 ppt. An abundant acorn crop attracted numerous cranes to feed on the uplands. Blue crabs were scarce. A news article in mid-September indicated that the 1989 commercial harvest of blue crabs was down 80% compared with the previous year. Wolfberry plants on the refuge appeared stressed in summer, 1989, many without leaves. Cranes were seen at freshwater sources throughout the winter.

There was evidence of avian tuberculosis in subadult captured in 1989 winter, and similar disease in chick that died at Aransas in 1982 winter. Increased levels of oversummering whooping cranes occurred (1 in 1988, same bird again in 1989, 1 in 1991with bird dying during the summer) that could indicate disease issues. Analysis of winter mortality between 1980 and 1990 indicated higher mortality when the marshes are salty and when the cranes utilize uplands more to feed on acorns.

**1990-91 winter** 11 lost out of 141 (7.8%).

In August,1990 a red tide outbreak occurred in the bay but there was no evidence of a connection with subsequent winter mortality of whooping cranes. Losses were estimated at 3 adults, 3 subadults and 5 juveniles. Most losses (8 out of 11) occurred during a bad weather stretch in late December through early January along an 8-mile stretch of the refuge. Three of the losses involved chicks that had at Aransas separated from their parents. One carcass was found, but the cause of death was not determined.

Lots of upland use and use of freshwater ponds was observed. However, little upland use occurred on Matagorda Island. Lots of acorns were present on refuge uplands. Much upland use occurred through December, but cranes also were observed catching crabs. No crab counts were done. High marsh salinities < 37 ppt were recorded. Marsh salinities were lower during Feb-April with cranes drinking directly from marsh.

**1993-94** 7 lost out of 143 (4.9%).

Five juveniles and 2 white-plumaged birds were lost. One juvenile had separated from its parents and showed abnormal behavior prior to predation by a bobcat.

Blue crab numbers were down notably compared with the previous winter, but small blue crabs re-populated the marsh starting in late February that the cranes quickly took advantage of. Small crabs through March provided limited food for the cranes. Commercial size blue crabs were so scarce in the spring that crab fishermen removed their traps from Sundown and Dunham bays. Acorn use was low and little clamming was documented. Marsh salinities were somewhat elevated. Wolfberry crop was abundant. Winter weather was generally mild.

This was the second winter of field work by Chavez-Ramirez and crabs were at very low levels and the cranes overall lost energy reserves during much of the winter. Food resources were considered marginal. 37% of the adult pairs failed to nest in the summer of 1994.

Salinities were higher than the previous winter and were measured between 14 and 26 ppt. Summer drought raised salinities measured in the marsh at 23-26 ppt in early October, but bays were around 15 ppt. High October tides flooded the marshes and lowered marsh salinities. Marsh salinities dropped below 19 ppt by early November and stayed below the threshold of 23 ppt throughout the winter when cranes are forced to seek out fresh water to drink. Only occasional use of cranes drinking freshwater at dugouts was documented in December. Salinities that averaged 19-21 ppt in mid-January and 18-19 ppt in February dropped to 14 ppt in March. The winter report written by T. Stehn indicated the lack of blue crabs seemed to be the most significant factor related to crane winter mortality.

**2000-01** 6 lost out of 180 (3.3%).

Four adults and 2 juveniles died during the winter. Also possibly one subadult died. Only 1 old carcass was found.

Red tide was documented close to crane areas at the end of October.

Food sources were considered poor during the winter. It was a bad blue crab winter for the whooping cranes. Drought the previous spring and summer with lowered inflows had perhaps lowered blue crab production. Blue crabs were never abundant and were believed to make up only a small part of the whooping crane diet. Mike Baldwin walking 3 transects each 1000 meters long found a maximum of 23 crabs over a 3-day period until mid-April when he counted between 30 and 40 crabs per day. Blue crab numbers recorded by Baldwin were the worst since 1997-98, measured at only 0.24 crabs per 100 meters. They were at low levels all winter, but really scarce in mid-winter. Almost no crabs were available in December and January, resulting in more cranes foraging on upland areas. Crabs showed a slight increase in numbers at the end of February and March as tides rose slightly, but crab counts at the end of March indicated only low numbers present. The cranes spent considerable time off of their traditional territories and moved extensively in search of food, foraging in uplands or open bays. The amount of upland use was notable. Cranes were observed in unusual locations including uplands and game feeders, including a San Jose family that came over to Lamar, presumably influenced by feeders. These alternate foods were not as nutritious as blue crab (Nelson 1995).

A most unusual occurrence of 18 whoopers spent considerable time at Willow Creek and an adjacent game feeder. This unusual location was considered related to the lack of blue crab food resources. Wolfberries were available in November and December. Although not quantified, wolfberries were less abundant than in some winters, but still made up a notable part of the whooping crane diet. Use of open bays was observed January through March. Few acorns were available due to a poor mast crop. Refuge burns received heavy use initially, but use tapered off.

For the first half of the winter, salinities were high so that crane use of fresh water sources occurred on a daily basis. March salinities in October were measured at 30-35 ppt. Refuge rainfall totals in November, January and February equaled 12.29 inches and lowered marsh salinities enough so that few cranes were observed at freshwater sources Jan-April, 2001. March salinities during mid-February crab counts averaged 22.6 ppt but ranged between 15 and 46 ppt.

Data shows that when blue crab populations are low, the cranes do not do well. Blue crabs are believed to be the key whooping crane food as shown by Chavez-Ramirez (1996). The highest mortality has occurred in the two winters when the least number of crabs were present (7 died in 1993-94 and 6 in 2000-01).In all other winters 1992-93 to 2000-01, with more blue crabs available, whooping crane mortality was either zero or one. There is a correlation between low blue crab numbers and high whooping crane mortality. This makes sense since blue crabs can make up 90% of the crane diet when available (Chavez-Ramirez 1996).

**2005-06** 6 lost out of 220 (2.7%).

One adult and 5 juveniles were lost, but no carcasses were recovered. Mortality was higher than average and was correlated with the shortfall of blue crabs.

Wolfberries were available in November and December with a crop rated as excellent. Quality food resources were considered good throughout the fall, but declined into winter and were scarce Jan.-April, 2006. Overall, the winter was rated as fairly poor for blue crab abundance. No spring influx of blue crabs occurred. Drought started in December, 2005 and continued into spring, 2006. Use of clams and invertebrates such as mud shrimp or blood worms in open bay habitat was observed frequently as tides remained low for extended portions of the winter. Some upland use was made of prescribed burns, but acorns were scarce.

Salinities started the winter at 16 ppt as measured on Oct. 20th. That was the lowest reading of the winter. Bay salinities in November and for the rest of the winter were above 20 ppt. Bay and marsh salinities the latter half of the winter remained above 23 ppt forcing the cranes to seek out fresh water.

**2008-09** 23 lost out of 270 (8.5%).

63 juveniles and 7 adults/subadults died. Three carcasses found; bad knee on an emaciated subadult found still alive at the Boat Ramp; Infectious Bursal Disease isolated from an emaciated juvenile (thought to have been flightless due to its weakened condition) predated by Dunham Bay; scatted piles of white-plumaged feathers found at Upper Pump Canal.

The wolfberry crop was very limited. Blue crabs were present initially, but soon became scarce. The cranes occasionally found blue crabs all winter, but at greatly increased search effort. Low tides drained marshes for part of winter. Considerable open bay use was observed. There was remarkably high use of game feeders, including 21 whoopers on Lamar using feeders and 2 adjacent to Highway 35 north of Holiday Beach. Salinities were high throughout the winter with the cranes making daily use of fresh water to drink.

**Appendix 3. Tom Stehn's notes from talk 10-28-04 with Dennis Pridgen, TPWD fisheries biologist, Rockport.**

Subject: Timing of inflows to help blue crabs.

Blue crabs show a lot of variability and adapt to a wide range of conditions. Blue crabs eggs hatch, go rapidly through 7 zoeal stages and enter megalopal stages. These early stages are all carried by currents. The megalopae then change into what are commonly known as blue crab stages. The following are general rules for blue crab life cycles.

1. After the eggs hatch, zoeae and megalopal stages of blue crabs need high salinities above 21 ppt for high recruitment. Optimal salinities for egg hatching is 23-30 ppt; optimal salinity for zoeal matemorphisis is 21-28. Survival will be lower if salinities drop below optimal, say less than 15 ppt. Thus, most female crabs move into the Gulf of Mexico to spawn where salinities are conducive to survival and growth of early life stages of crabs. In drought years, spawning could occur in highly saline marshes or bays, with conditions okay for survival of early life stages, but growth of the first blue crab life stage would be low due to the high salinities.

2. After successful development of megalopae, survival of early crab stages is complicated, based on synergistic effects of salinity, temperature, pollutants, predation, disease, habitat and food availability. The first blue crab (2 ½ mm) stage and subsequent stages shows the best abundance and growth when salinities are intermediate (10-20 ppt).

3. During warm temperatures, it takes about 4 months for crabs to grow to reach 5 cm size, an approx. minimum size that cranes can easily consume. Growth rates of blue crabs are greatly reduced during periods of colder temperatures during winter. Crab eggs that hatch during August – October will not have time to allow for enough development and growth to be available for cranes until the following spring (Feb. – April) before the cranes leave for Canada by mid-April.

4. Blue crabs available for whooping cranes in the fall are ones that were generally hatched between April and July, plus older crabs surviving from the previous year. Total crab numbers with individuals ranging in size from the first crab stage (2 1/2 mm) to large adults (7 inches) are generally highest in the fall. The crabs present in the fall provide the food base for the whooping cranes during their entire winter stay, (mid-October through mid-April), although crabs that hatch in late summer would be available in the spring. Crab numbers in the salt marsh vary throughout the winter, depending on tide levels, temperatures, and predation by whooping cranes and other critters. Crabs generally move out into the bays seeking deeper water during the colder temperature and low tide periods from December into February. They will then re-populate the marshes, starting in February or March as tides rise and temperatures increase. The crabs eaten by whooping cranes in March and April generally are survivors from the spawn during the previous April-July period when survival was high due to moderate salinities and high inflows. Note that some of the crabs growing up to breeding size during the summer were carryovers from spawning the previous fall.

5. Inflows between April to July will influence crab survival positively. If inflows are high during this period, the blue crab population will do well. Thus, April to July inflows are very important to the whooping crane food base.

6. Fall rains, including tropical systems in August through October, will generally not add to the whooping crane food supply in the coming winter. However, such fall inflows are important because they lower salinities and

create an intermediate salinity regime in the fall and the following spring, which greatly helps survival of early crab stages (as in # 2 above). If spring salinities are too high, than growth of the first blue crab stages would be low, thus reducing energy available to the cranes.

7. Crabs breed between 6-8 months of the year, with spawning determined by water temperature. In Texas there may be a peak in March and April. As crabs grow larger and reach breeding size, some crabs will be spawning all the way from spring to fall. Females that breed in the fall (late October) can hold their eggs until the next spring. Increased spawning activity is not connected with inflow pulses. A peak of spawning occurs as temperatures warm up in the spring. The length of the spawning season is determined by water temperatures remaining being warm enough, with limited spawning occurring in winter in mild winters.

8. Other bay species such as white shrimp have different life cycles. Thus, this discussion about inflows and crab populations, although in general holds true for other species, varies somewhat depending on the species. For example, August rains would tend to still help white shrimp.

## Appendix 4. The relationship between inflows, crabs, salinities, and whooping cranes.

**by: Tom Stehn, Whooping Crane Coordinator, U. S. Fish and Wildlife Service, March, 2008**

The productivity and quality of coastal waters in winter whooping crane critical habitat at Aransas is directly dependent on freshwater inflows that start hundreds of kilometers inland from the San Antonio / Guadalupe River and flow into coastal waters (TPWD 1998). Flows from springs coming from the Edwards Aquifer are also crucial, especially in times of drought when they can make up 70% of Guadalupe River water. Thus, the ongoing reduction of freshwater inflows due to human population growth is a huge threat to the whooping crane that could lead to its extinction. The survival of one endangered species, the whooping crane, and one candidate species, the Cagle's map turtle, are directly tied to maintenance of sufficient inflows (Mendoza, 2001a).

### Whooping Crane Food Needs

Sufficient inflows are required to produce the necessary food for whooping cranes to survive. Inflows that carry nutrients and sediments and maintain proper salinity gradients in the estuary are needed to produce blue crabs that are the primary food for whooping cranes. Chavez-Ramirez (1996) found that when available, blue crabs can make up 80-90% of the diet of whooping cranes. An individual crane can consume up to 80 crabs per day. Studies by Nelson (1995) of whooping crane food items (crabs, clams, wolfberry, acorns) showed that blue crabs were the highest in protein and nutrition for the whoopers. When crabs are not available, whooping cranes will switch to other foods, but because of the poor nutritive value of these alternate foods, the whoopers may actually burn up fat reserves and have a net loss of energy for periods of the winter (Chavez-Ramirez 1996).

Data collected at Aransas National Wildlife refuge indicates a relationship between freshwater inflows on the Guadalupe River, blue crab populations, and whooping crane survival. When inflows are high, blue crab populations increase due to enhanced reproduction and survival, and whooping crane mortality is low. With reduced inflows, crabs do poorly and whooping crane mortality rises dramatically. This makes sense since blue crabs make up 80-90% of the whooping crane diet. For an eight-year period starting in 1993, intensive surveys were done to roughly estimate the number of blue crabs available to whooping cranes. The winters of 1993-94 and 2000-01 were poor crab years; the remaining six winters all had adequate numbers of blue crabs present. During the two winters with poor crab numbers, seven and six whooping cranes died respectively. In all six other winters, either zero or one whooper died. There is a strong inverse correlation between blue crab abundance and adult whooping crane mortality (Pugesek et al. 2008). In addition, following the poor blue crab winter of 1993-94, 37% of the known adult pairs (17 out of 46) failed to nest following their return to Canada. This was unusual since normally just about all pairs attempt to nest annually. In addition, production was reduced from the pairs that did nest (B. Johns, CWS, personal communication). This was all believed to have resulted from their reduced fat reserves that had not built up sufficiently during the previous winter. Therefore, the very survival of the species is dependent on water management strategies that provide sufficient inflows for the bays to remain productive (Mendoza 2001b).

**Whooping Crane Needs for Fresh Water**

Inflows which mix with Gulf waters help keep salinity levels moderate. When marsh and bay salinities exceed 23 parts per thousand (ppt), whooping cranes are forced to make daily flights to freshwater to drink (Allen 1952, Hunt 1987). These flights use up energy, reduce time available for foraging or resting, and could make the cranes more vulnerable to predation on the uplands (Tom Stehn, USFWS, Austwell, Texas, pers. comm.). Thus, inflows are crucial in keeping salinity levels below the threshold of 23 ppt in coastal marshes used by whooping cranes.

**Status of Guadalupe River flows**:

Human consumption of river water in Texas is a growing resource issue as the State's population continues to expand. This is a very worrisome trend since Texas water law reserves water for people but has fewer provisions for wildlife. Leaving sufficient water in the rivers to provide bay inflows is not explicitly designated as a beneficial use of water in Texas water law. National media attention was received in spring 2001 when the Rio Grande River dried up and flows no longer reached the Gulf. This is not the only river in Texas in trouble. So many people are using water from the aquifer and the rivers in central Texas, that the downstream folks and creatures are already seeing what most Texans do not want to acknowledge; that the rivers are already over-appropriated, and absolutely no one is minding the store, when it comes to making sure any fresh water ever makes it to the bays and estuaries (Diane Wassenich, San Marcos River Authority, San Marcos, Texas, pers. comm.).

Inflows on the Guadalupe River are already insufficient and reduced over historic levels leading to increases in mean salinity and decreases in blue crabs. As water development pressures mount, freshwater inflows to the Texas bay systems are being reduced, and blue crab populations are being adversely affected. This could have an alarming impact on whooping cranes. The death of 6 whooping cranes during the 2000-01 winter emphasizes how serious an issue this is.

The Texas Water Development Board (TWDB) data indicate natural droughts already threaten the ecosystem of the Guadalupe Estuary and predict that in less than 50 years withdrawals of surface and ground waters for municipal and industrial growth will leave insufficient inflows to sustain the ecosystem (CWS AND USFWS 2007). Long before ecosystem collapse due to lack of inflows, significant adverse impacts to blue crab populations would occur (Kretzschmar 1990). By 2040, due to anticipated diversions, a predicted decrease of 555,000 acre-feet of gaged inflows (Kretzschamer 1990) in an average year into the crane's winter range is projected to cause an 8% decline in blue crab populations (Texas Department of Water Resources 1980), but could have a much larger impact in drought years (Norman Johns, National Wildlife Federation, Austin, Texas, pers. comm.). Modeling indicates that if all existing water rights were exercised during a repeat of the 1950-1956 drought, estuary inflows would be reduced by 17% to 43% below current levels and by 36% to 72% below historic levels, depending on the year (Norman Johns, National Wildlife Federation, Austin, TX, pers. comm., in Fitzhugh and Richter, 2004). Additionally, there are pending water right applications for much of the remaining unappropriated water in the Guadalupe.

Upstream reservoir construction and water diversions for agriculture and human use reduce freshwater inflows. Many existing water rights are currently only partially utilized, but greater utilization is expected over time. Water rights continue to be granted on the Guadalupe, and some sections of the river are already over-appropriated. Withdrawals of surface and groundwater for municipal and industrial growth are predicted to leave insufficient inflows to sustain the ecosystem in less than 50 years. Projections indicate the river will be significantly threatened during periods of low flow and could cease to flow into the bay if all currently authorized water-use permits are utilized (National Wildlife Federation 2004).

The San Antonio and Guadalupe Rivers that empty into whooping crane critical habitat are calculated to need 1.24 million acre-feet per year to maintain ecosystem subsistence (TPWD 1998). Yet between 1941-1976, inflows were less than that amount in 14 out of 36 years, making its status already precarious (TDWR1980). In 2002, American Rivers named the Guadalupe on their annual list of the 10 most endangered rivers in the U.S. because of the inflow issue. In a report entitled *Bays in Peril,* a “Danger” ranking was given to San Antonio Bay because drought periods were predicted to increase by 250%, and years with low freshwater pulses in the spring were calculated to increase 26% from naturalized levels (National Wildlife Federation 2004).

Texas Water Development Board data indicate natural droughts already threaten the Guadalupe ecosystem. Without sufficient inflows, wildlife resources, including fish, crabs, and shrimp, all decline. The 1.15 million acre-feet figure is often quoted as an amount needed to maximize harvest of 9 marine species of commercial interest in the bays and estuaries. In the case of blue crabs, more than 1.15 million acre-feet is needed to produce high blue crab populations. TPWD data clearly show that increased water inflows result in higher blue crab numbers (Mendoza 2001b). Crab survival of all life stages increases when salinities are generally below 20 ppt, and the very young stages in the blue crab life cycle show much better survival when salinities are moderate. Blue crabs were found to be more abundant in the Guadalupe Estuary in salinities averaging between 10-25 ppt. A simple inverse relationship exists between blue crabs catch rates and mean salinity within an estuary (Longely 1994). Peak crab counts in the bays occur following periods of flooding. In San Antonio Bay, the 3 highest blue crab harvest years were all having inflows greater than 3 million acre-feet annually. Thus, to maximize blue crabs for whooping cranes to eat, managers should maximize freshwater inflows on the Guadalupe River. Providing for guaranteed minimum inflows to the bay is essential.

**Management Actions and Needs**:

The San Marcos River Foundation (SMRF) in 2000 applied for a 1.15 million acre-feet water right that would remain in the rivers to provide inflows to the bay. The application was denied in 2003 but an appeal was granted, sending the application back to the Texas Council on Environmental Quality for a re-hearing. This matter remains involved in litigation with the outcome pending. The 1.15 million acre-feet is the recommended target inflow level needed to maintain the unique biological communities of the Guadalupe Estuary (TPWD 1998) and keep the bays productive (TPWD 1998, Mendoza 2001b). Unfortunately, mechanisms to guarantee these flows are not provided by Texas water law, and critics have challenged the size of the target inflows. Water developers are saying that human needs for water are too great, that there isn't enough water available to provide the water identified by the Texas Parks and Wildlife Department study needed to sustain the bays and estuaries, and this amount of water is higher than that actually needed to keep the bays productive. This issue has received much attention, and support is needed if conservation flows are ever going to be granted. The U.S. Fish and Wildlife Service (USFWS) wrote a letter of support for the San Marcos River Foundation's application for 1.15 million acre-feet of water that would remain in the river for wildlife. USFWS believes that providing a water right to the bays, as proposed by the San Marcos River Foundation, would be a crucial first step in guaranteeing that the bays would continue to function ecologically for all users to enjoy (Mendoza 2001b). It would be precedent setting in Texas for a water right to be designated as an inflow.

With the population of Texas predicted to double in the next 50 years, the Texas legislature has initiated a state-wide water planning effort. However, there is no direct mechanism in Texas water law to secure freshwater inflows to the bays and estuaries. Basically, the bays get whatever is left over, and portions of Texas rivers, including the Guadalupe, are already over-appropriated. In May 2007, the Texas Legislature adopted a sweeping plan intended to help ensure the state's future water supply. The legislation would require basins to develop recommendations to meet instream needs for specified bays and estuaries. The Texas Commission on Environmental Quality (TCEQ) will be required to adopt these recommendations as environmental flow standards and give consideration to water permit applicants based on conservation considerations like water levels, the environment and public need. The measure would establish the Environmental Flows Advisory Group, made up of appointed members, to oversee the process. This action was hailed by some Texas environmental groups. However, the amount of needed freshwater inflows will be determined through a stakeholder process and there is no guarantee how this will all turn out, or how identified instream needs will be met.

USFWS is very concerned about the impacts that planned diversions from the Guadalupe River would have on environmental water needs for adequate inflow to San Antonio Bay. A proposal included in the state water plan proposes a diversion at the mouth of the Guadalupe River, pumping at least 94,500 acre-feet annually back to San Antonio for municipal use. Additionally, as the San Antonio region grows, with population expected to double in the next 50 years (SAWS 2003), pumping from the Edwards Aquifer in times of drought threatens spring flows. To prevent impacts and avoid take of the whooping crane under the Endangered Species Act (ESA), USFWS has urged planners to quantify the freshwater inflow needs to maintain bay productivity and the critical habitat of the whooping crane and to account for those needs in future versions of the State Water Plan (Mendoza 2001a). Formal consultations on flow reductions must ensure that downstream water needs are met (Stehn 1998). The USFWS must take a strong stand on the inflow / whooping crane issue. On the Platte River in Nebraska, a section of designated critical habitat used by whooping cranes in migration, USFWS has determined that any new water withdrawals greater than 25 acre-feet constitutes a jeopardy call to the species under the ESA. Thus, a precedent has been set for USFWS action. All conservation groups need to do all in their power to ensure that adequate inflows from the Guadalupe River reach the bays.

Inflow level targets have not been identified to adequately support whooping cranes. Any withdrawal of water from the San Antonio / Gaudalupe River system is harmful to whooping cranes (T. Stehn, USFWS, Austwell, Texas, pers. comm.) except perhaps in times of flood. Inflow modeling is needed specifically for impacts to blue crab populations. Until this is done, water planners cannot judge how much harm river withdrawals will do to blue crabs and thus whooping cranes.

Measures to protect instream flow, fish and wildlife habitat, and freshwater inflows to bays and estuaries should be part of each regional water management plan (Sansom 2000). It is essential that the Region L water plan provide a mechanism for providing adequate inflows to San Antonio bay for the health and survival of the whooping crane population.

Any environmental analysis for groundwater use should include a detailed assessment of potential impacts to fish and wildlife found in springs, streams, rivers, and even inflows to bays and estuaries. An example of an area of concern is the Edwards Aquifer and the impacts reduced flows would have on the whooping crane found in the San Antonio and Aransas bays (Mendoza 2001a). Especially in times of drought, groundwater-fed springs can provide 70% of the inflow from the Guadalupe River. Comal and San Marcos Springs combined can make up over 30% of the base flow of the Guadalupe River and nearly 70% during periods of drought (Sansom 2000).

Management actions needed are to

a) model inflows and blue crab populations for the Guadalupe Estuary and relate to ecological needs of whooping cranes.

b) devise strategies to conserve blue crabs populations by maintaining required inflows.

c) maintain inflows to keep marsh salinities below 23 ppt. (Stehn pers. comm.)

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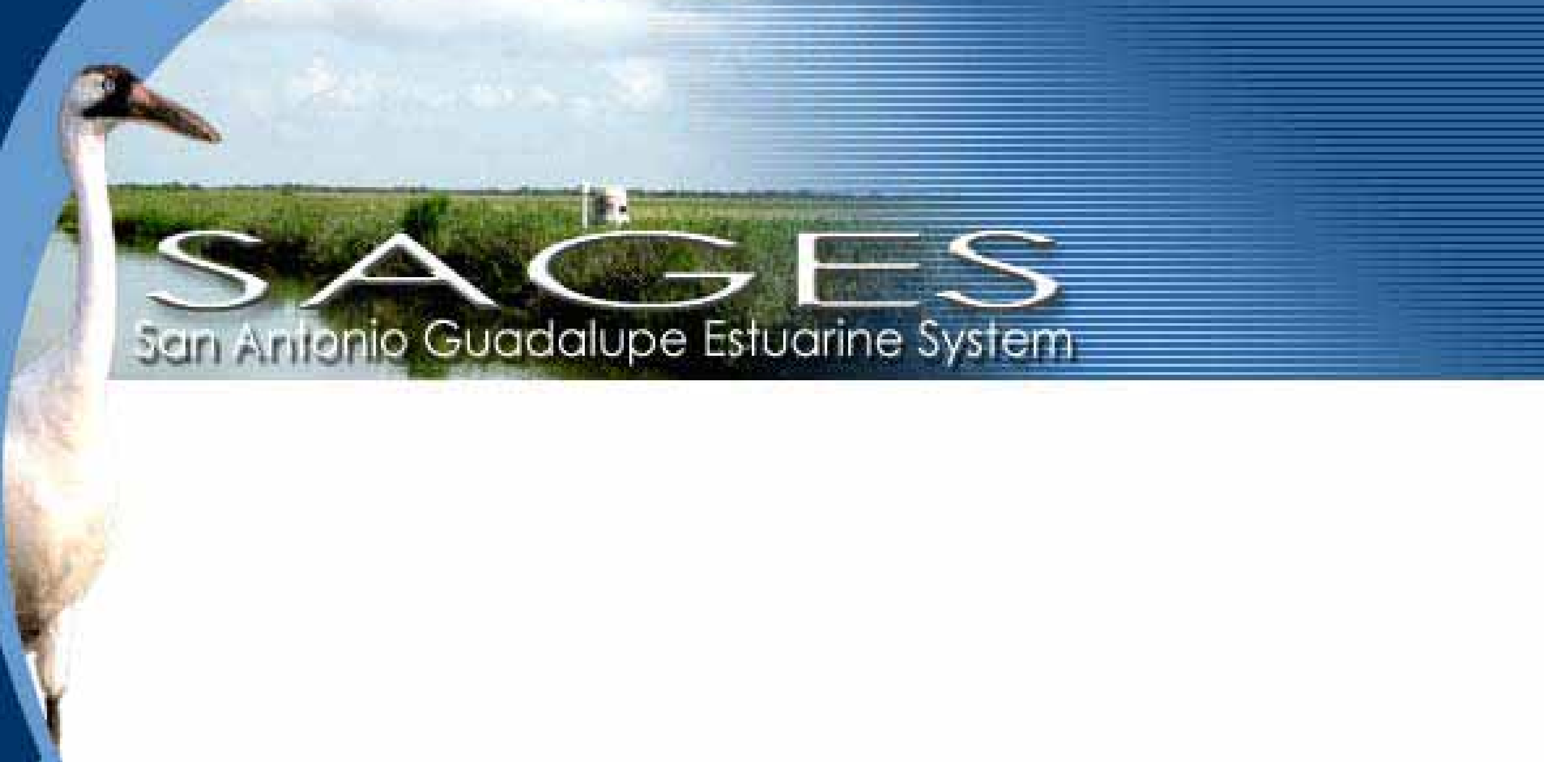


# Comments on SAGES Final Report

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June 8, 2009

***Via E-Mail: sraabe@sara-tx.org***
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Re: Draft SAGES Report San Antonio Guadalupe Estuarine System Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes

Dear Mr. Raabe:

In the following paragraphs, we have presented our comments on the Draft SAGES Whooping Crane Study. As will be noted, we have serious concerns with the method and conclusion of the SAGES Study. We have also included as Attachment 1 some comments and concerns regarding the SAGES report prepared by Dr. Ronald Sass, Harry C. and Olga Keith Wiess, Professor of Natural Sciences, Emeritus, Rice University.

In our opinion, the major problem with the SAGES study is the statistical relationships between salinity and blue crab abundance. The conclusion reached in the SAGES study is contradicted by most of the literature on Blue Crabs and by an analysis of long term data collected in San Antonio Bay. The faulty conclusions likely arise from an inadequate understanding of life history requirements of the crabs and poor study design. The direct result of these flawed relationships is that the greater the freshwater inflow, the worse off the Blue Crabs and thus the less food for Whooping Cranes and the opposite that increased freshwater inflow is detrimental to Whooping Cranes. This finding is strongly contradicted by a review of recent and longer term responses of the Whooping Crane population to low flows.

Longley (1994) cites over a dozen studies (p. 187-188) and concluded that higher catch rates are observed from lower salinity areas. (p. 137) Specifically for San Antonio Bay he found that “juvenile blue crabs are generally most abundant in vegetated habitats in the lower and middle bay where salinities range from 6 to 25 ppt” Trawl samples show significantly higher catches both in areas with mean salinities of less than 20 ppt and in areas influenced by the Guadalupe River flow.” (p. 151 -152) While the Longley report recognized that Blue Crabs utilize different salinity zones throughout their different life stages (an issue for which the SAGES study is silent) they also found that “adult males are found in low salinity waters, where salinities are less than 10 ppt, while females move to these lower salinity areas to mate and return to higher salinity areas afterward." (p 174)

The most recent freshwater inflow study conducted in San Antonio Bay (Pulich et al 1998) analyzed TPWD fisheries independent monitoring data and found the preferred salinity zone for Blue Crab to be between 5-20 ppt. This range is consistent with the more recent Matagorda Bay Health Evaluation (BioWest 2008) which reported similar ranges as optimal for Blue Crab. This finding is further supported in the Gulf State Regional Management Plan for the Blue Crab Fishery (Guillory et al 2003) which reported summaries for other studies that report similar preferences for lower and mid range salinities (p. 3-5)

The SAGES study cites a single laboratory study evaluating the effect of salinity on juvenile blue crab growth (Cadmen and Weinstein 1988). According to the authors of the SAGES report, one of the findings in Cadmen and Weinstein is that for "salinities below 27 ppt, blue crabs incur increasing high metabolic demands and osmoregulatory stress with decreasing salinity." Notably the abstract for that paper states that optimal growth occurs at 23 ppt though this finding is not presented in the SAGES report. This study also finds that crabs do most poorly at low salinity and high temperature though the authors of SAGES do not cite any other quantitative findings from Cadmen and Weinstein to specify at what low salinity levels these deleterious effects are manifested nor whether similar harmful effects occur at higher salinities.. While most studies on Blue Crabs and salinity acknowledge that very low salinities (< 1.0PPT in Holland et al 1971 cited in Longley, 1994) are detrimental to Blue Crab none that we've reviewed suggest that Blue Crabs only benefit from saltier conditions as is presented in the SAGES report.

So where did the SAGES report go wrong? It would be difficult to say without carefully reviewing their data, however here are a few ideas. First they do not acknowledge and therefore do not refute the long list of studies which result in relationships that contradict the one present in the SAGES report. While they include Guillory 2003 in their references, they don't mention any of the studies that he cites that suggest lower optimal salinity ranges. This leads us to suggest that they did not do a very thorough review of the literature. To completely ignore such an obviously controversial issue is perplexing.

It appears to us that life stage is an important factor in understanding the effect of salinity. One theme that seems common is the younger and smaller crabs may have a greater affinity to higher salinities. This is obviously true of the larval stages since they spawn off shore as high salinities are required for early life stages. The SAGES report acknowledges that the samples used to develop the regressions were smaller sub-adults as opposed to the sizes that Whooping Cranes eat, but they suggest that these sub-adults provide a good estimate of recruitment into the size classes consumed by cranes. An alternative hypothesis might be that these higher salinities might lead to lower recruitment into the larger class than would be achieved by salinities reflective of more accepted description of adult blue crab salinity preferences.

The main problem with this study has to do with design. Although samples were taken monthly, only about two and one half years worth of data where collected. In the second year, inflows were very low and salinities much higher than normal. The highest densities were observed in the fall of 2006 during the period of highest salinities, which leads to the conclusion that higher salinities lead to more blue crabs. This two years worth of data really represents only two data points corresponding to two seasons during which crabs migrated into the bay. This is insufficient to develop the regressions presented in this study and overturn without even acknowledging the overwhelming contradictory finding of most other studiues. Data for the periods when most crabs are off shore spawning and drifting in as juveniles are not particularly relevant to this analysis.

Other issues

The inflow salinity regressions would probably be improved by the inclusion of an antecedent flow term. After conducting the first inflow study on San Antonio Bay (Pulich 1998) the state agencies recognized this and included a term to account for inflows in the days 30-60 prior to the current day for the inflow studies on all of the other major bays in Texas. An antecedent salinity term would be even better. The “noise” about the regression equation covers about 10 ppt and thus simulated salinities do not do as good a job of predicting salinity as they could. Use of the existing salinity model for San Antonio Bay perhaps recalibrated and validated using some of the data collected in the present study would be even better.

The salinity regressions fall apart at flows less than about 600 cfs. At low flows they predict salinities that were deemed by the project team as unreasonably high and thus salinities are always cut off at 30 ppt if they predict higher than that. Sustained flows less than 600 cfs are rare in San Antonio Bay however the regressions are not useful predictors for droughts or potential future low flow scenarios predicted to result from increased diversions.

The study acknowledges that they were unable to develop a complete understanding or connectivity between the bay and the marsh and instead simply note that there is a correlation between salinities in the two areas. This is unfortunate and it would seem that a more carefully designed study could have made more progress on this critical issue.

It is unclear why the analysis focused on smaller sub-adult crabs in the marsh. It is possible that the larger adults had selected more desirable (lower) salinity conditions for mating especially in 2006 and thus insufficient numbers were collected to develop relationships for this age class.

Although not a prominent discussion in the written report, much was made of the ability of Whooping Cranes to switch from Blue Crabs to Clams or other sources when crabs are scarce. While this may happen it is not clear that these alternatives will provide satisfactory nutrition.

As a final note we mention that we have not had time to give the energy budget analysis the attention it needs but at the very least it is woefully simplistic and begs for a careful evaluation.

Thank you for the opportunity to present these comments on this very important issue.

Sincerely,

BLACKBURN CARTER, P.C.

by ______________________
James B. Blackburn, Jr.

Attachment

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**To: Whom it may concern**

**From: Ronald Sass, Harry C. and Olga Keith Wiess Professor of Natural Sciences, Emeritus, Rice University**

**Date: 7 June 2009.**

**Re: Some comments and concerns regarding the SAGES Final Report "Linking Freshwater Inflows and Marsh Community Dynamics on San Antonio Bay to Whooping Cranes"**

The SAGES or San Antonio Guadalupe Estuarine System project was conducted from 2002 to 2009, although actual field data did not begin for most studies until 2004 and was ended in 2006. The studies thus spanned two winters of whooping crane residence.

The study was composed of 12 core studies, 2 complementary SAGES studies and 3 non-SAGES studies. Both empirical field studies and model calculations were performed.

Some results from the empirical studies:

1. A clear effect of river inflows on the greater bay ecosystem. Freshwater inflows to the bay tended to flow in a southwest direction along Blackjack Peninsula and along the estuarine marshes at ANWR.
2. Freshwater inflow was inversely correlated with bay salinity.
3. Patterns of salinity in San Antonio Bay strongly correlated with salinities in the tidal creeks of Blackjack Peninsula and therefore bay salinity can be used as an indicator of marsh salinity.
4. Salinity leading up to the late summer leafing period was inversely correlated with peak wolfberry abundance.
5. At the ecosystem level, blue crab abundance was significantly correlated with bay water level, wind speed as measured in the bay, and bay salinity.
6. In addition to blue crabs and wolfberries, the whooping crane diet including snails, insects, snakes, fish and clams.

7. The whooping cranes spend approximately 65% of daylight hours foraging.

Conclusions derived from model considerations predicted:

1. The available food supply appears to be more than adequate to meet the energy needs of the whooping crane. None of the results of the study show that conditions at Blackjack Peninsula are marginal for whooping crane well-being.
2. Bay salinity is higher when freshwater inflows are low.
3. Wolfberry abundance is lower when bay salinity is high.
4. Consistent with prior studies, blue crab abundance increases with bay salinity.

**Comments:**

Many of the report's empirical findings and model predictions are consistent with results reported in extant journal papers and organizational documents as well as with prevailing opinion. Others are in serious disagreement with well-established previous findings. Rather than review all of the SAGES report, I will concentrate on what I consider to be the most important in terms of whooping crane survival and well-being.

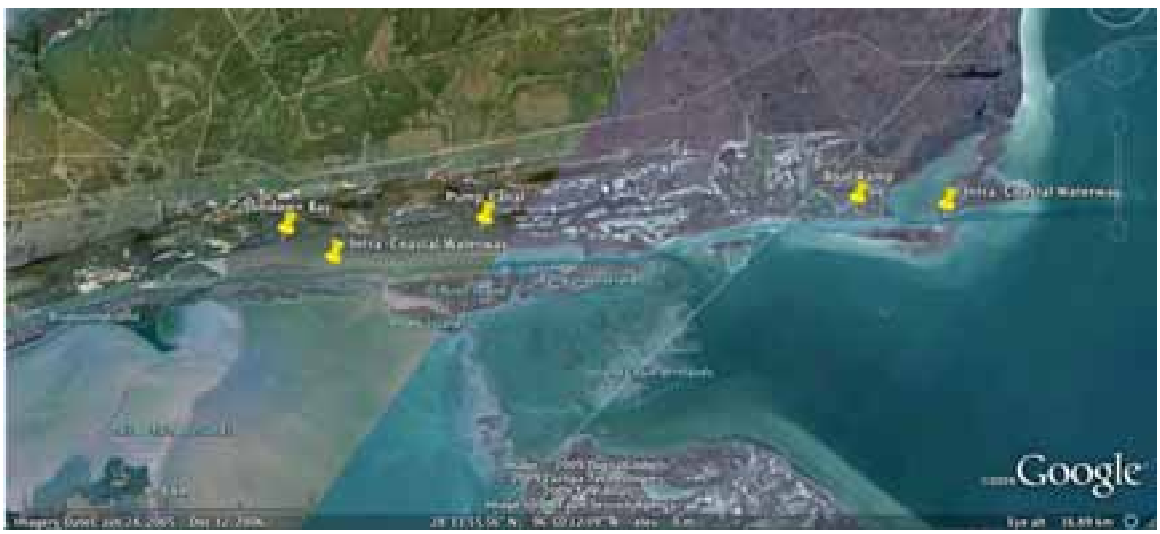
The relationship between river inflow and bay salinity is of key importance in defining the link between freshwater inflows and the well being of the whooping crane. Therefore it should be very carefully measured and modeled. The experimental relationship between salinity at GBRA 1 and the 28-day cumulative discharge ($m^3$/day) is shown in Figure 3.4. Although the authors indicate that salinity at this site is influenced by other variables such as wind, tide, direct precipitation, local runoff, etc., the model relationship used depended only on an empirical model based on the data in Figure 3.4. One striking feature of this figure is the observed widely varying salinity for the lowest measured discharges. The very lowest flow values show a measured salinity of 10 – 18 ppt. This range of salinities is not optimal (3 – 15 ppt) for the juvenile or adult blue crab, but is not particularly harmful to either blue crab or whooping crane and may be referred to as being in the moderate range. Documented events when the measured salinity in the marshes and bay are much higher (Tom Stehn, 2009) have resulted in high mortality within the whooping crane population.

The outer tale of the data (> $10^9$) is due primarily to heavy rains in late November 2004 and in July and August of 2007. These periods of high inflow are periods of high flushing of the bay system and should result in salinities near zero as shown. However, this fact truncates the majority of the data to the first third of the graph where the distribution of measured salinities is very broad for a particular inflow value, resulting in an uncertainty in salinity of at least ± 5 ppt. It is obvious from the data that there is either a low dispersion of the river water at low flow or there is a large effect of wind, tides, precipitation, etc. on the measured salinity. Thus, the use of GBRA 1 as a measure of the overall bay system salinity at any particular time is highly suspect. In my opinion, this condition invalidates a major equation in the model as well as any experimental observations relying on these data as a source of salinity values. Thus, equation 1 of the model is overly simplistic and does not take into consideration all of the important variables (*e.g.*, wind velocity and direction, tides) in calculating salinity. The authors recognize this problem by reporting a very large calculated individual prediction interval (dotted red line on Figure 3.4).

Figures 3.5 and 3.6 show the relationship between salinities at GBRA 1 and the tidal creeks associated with the three major experimental whooping crane territory sites. Figure 3.5 is based on data collected during the period from 24 Feb 2004 to Feb 25 2005. The monthly average freshwater inflow during this period ranged from 2,192 cu ft/sec (March 2004) to a high of 23,414 cu ft/sec during November 2004. All salinities shown in both figures fall below 25 ppt with a prediction interval of ±7 ppt.

A more revealing correlation between the three experimental sites and GBRA 1 is shown in figure 3.6. The correlation is qualitatively reasonable but differs in many important aspects of timing. In May 2004 the GBRA 1 salinity drops from ~15 ppt to ~5 - 10 ppt a good month before the salinity in each of the three sites drops from ~15 ppt to a lower value approaching 0 ppt salinity. Several other time lags are obvious indicating that there is a time lag as well as a current difference between GBRA 1 and the experimental sites. .

Figure 3.6 shows a great deal of similarity in the magnitude and time change of salinity among the three experimental sites. This is probably to be expected because of the positions of the sites (Figure 1, this report). All three sites are along the intra coastal water way and are protected from the main body of water in the bay by a narrow island chain. This would suggest that changes in the water (salinity, turbidity, flow) might be slower than in the main flow stream moving from the freshwater input down the bay to the gulf.




At no time did the salinity rise above 25 ppt and was below 5ppt approximately half of the time. River inflow value did not fall below 1.58-million ac ft/yr during this measurement period. Legislative mandated studies to determine freshwater inflows necessary to conserve healthy productivity of San Antonio Bay recommends 1.15 million ac ft/yr or roughly half of the average annual freshwater inflow from the Guadalupe and San Antonio Rivers. Texas Parks and Wildlife Department data suggests that a water inflow greater than 1.3 million acre-feet annually results in low enough salinities in the estuary to produce a healthy number of blue crabs. A level of flow this abundant produces a bay salinity of from 10 to 25 ppt.

Quoting from SAGES: "*3.3.1.2 Evaluation of equations predicting peak wolfberry density and blue crab density*

We first evaluated our [ ] daily blue crab density (Eq. 3) equations by assessing the reasonableness of predictions of these equations calculated from time-series data on freshwater inflow to San Antonio Bay from the Guadalupe and the San Antonio Rivers (used to predict salinities via Eq. 1) and water level and wind…"

Equation 3 is

$$BC_{i,j,t} = e\ (0.3751 + b1i + b2j + 1.844(wlt) + 0.1010(Salt) - 0.2597(wst))$$

where b is a habitat and site parameter, wlt is water level, salt is salinity and wst is wind speed. The report does not evaluate the relative sensitivity of the crab density with respect to the several variables used. The model is evaluated by comparison of the observed blue crab density with that calculated. The crab density calculated is for juveniles of carapace size 11 to 30 mm. This size choice is a bit troubling because the preferred dietary size for the whooping crane is that of larger crabs. Be that as it may, the study by Danielle Greer on "Patterns in blue crab abundance in shallow salt-marsh and bay habitats of the Texas Gulf Coast is concerned not so much on salinity, but rather habitat type.

Her main objectives were as follows:

1. Document spatio-temporal patterns in blue crab abundance and size-class structure within and adjacent to salt marsh at both fine and large spatial scales.

2. Investigate the effects of environmental (e.g., freshwater discharge, water temperature, vegetative cover) and random effects on blue crab abundance and size-class structure.

Her data show clear differences in the crab density that is habitat dependent and it seem evident that the work is well done and valid. Her density results by the month are interesting in that they cover the period from October 2004 to March 2006, all months for which the freshwater inflow was higher than recommended by Texas Parks and Wildlife as stated above. Thus, it may be postulated that salinity is not a major factor in the data but rather habitat type is the dominant variable. Whether this statement is true or false was not shown by any part of the SAGES report and needs to be clarified before any statement can be made about the effects of salinity on either blue crab density or whooping crane dietary viability. What the data do show is a peak crab density in all habitats in September and October of 2005 or immediately prior to the arrival of the whooping crane followed by a steady decline until February and March 2006 (the last data points) before the spring migration of the whooping crane. In other words much of the detail may be due to the whooping crane, a variable that is not included in the model!

**Summary:**

As in the case of all semi-empirical model, relationships are forced by the data even though the full impact of the underlying parameters is not completely understood. Preconceptions of which parameters are the most important and which may be ignored have lead to some erroneous conclusions. The most serious of these is the dependence of the vitality of the whooping crane on river inflow caused changes in salinity. Several studies have, in the past, strongly supported the negative dependence of blue crab population density with salinity. In addition, it is strongly suggested by other data that the years of high winter mortality are all years of low river flow during July to October before the arrival of the whooping crane. This would indicate that low river flow is affecting the growth of the necessary dietary components of the crane. Spanning the observational period of the SAGES study, river inflow was high during the critical time of 2004-05 while winter mortality of the whooping crane was low (0.9%) but during the same time period in 2005-06 river inflow was low but the whooping crane mortality was high (2.7%). This same pattern has been noted between the years 1988 to 2009 resulting in the following conclusions:

1. A high mortality rate is always accompanied by a low river flow and the resulting high salinity.

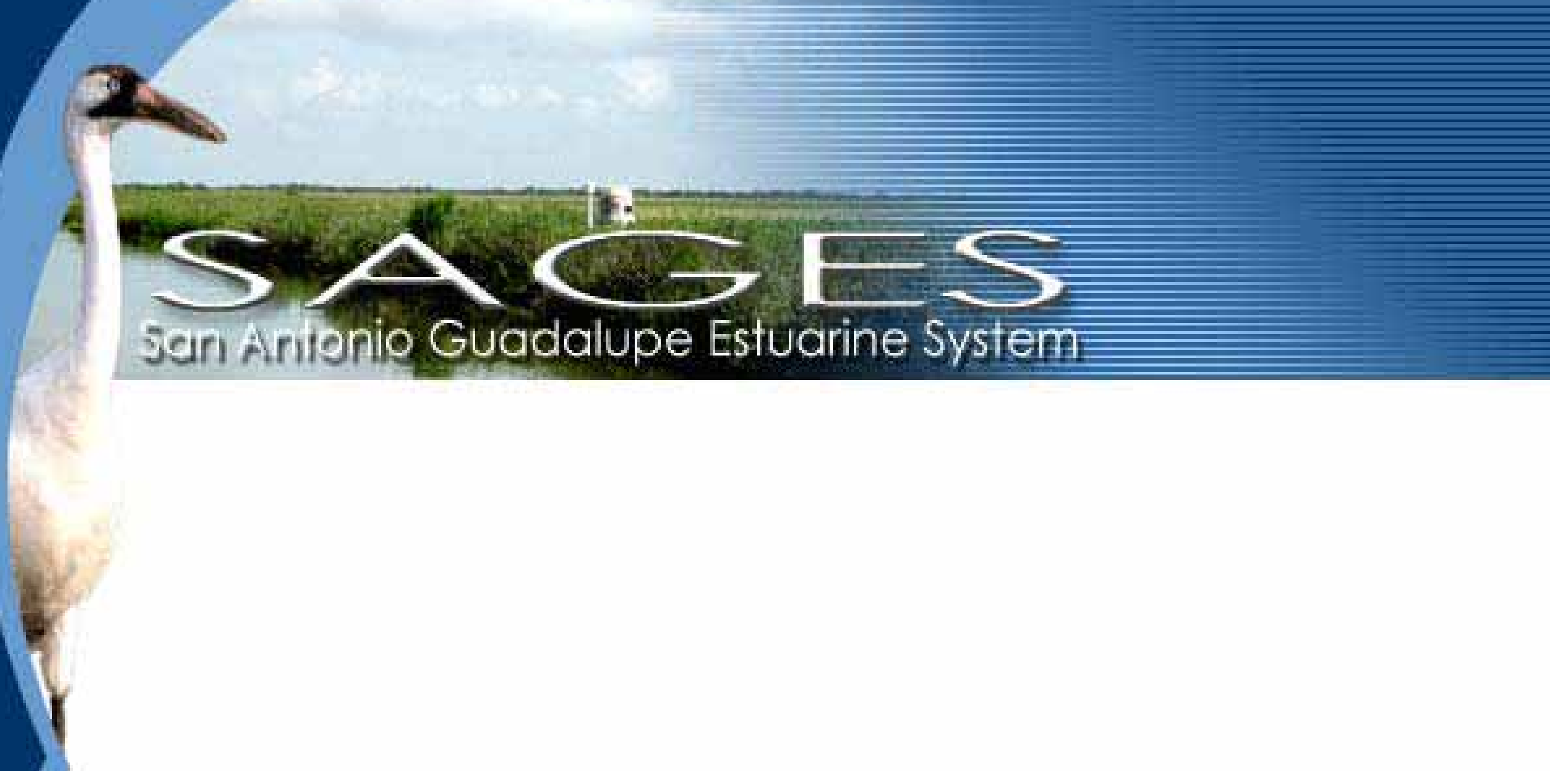
2. A whooping crane response to low river flow (high salinity) is one of excess stress. This condition does not necessarily lead to death but may be manifested as lack of sufficient bodily fat and protein that will be exhibited during the spring migration and subsequent poor reproductive behavior. For example, following the poor blue crab winter of 1993-94, 37% of the known adult pairs (17 out of 46) failed to nest following their return to Canada. This was unusual since normally just about all pairs attempt to nest annually.

3. Complete and accurate data on environmental stress that is manifested by poor migratory and reproductive behavior is hard to generate but may well be a major part of the story on salinity-diet relationships. Such behavior could include the need for frequent stops along the way for “refueling” and rest, inability to gain optimal flying altitude or flying speed, susceptibility to parasites and disease, high predatory mortality during migration and poor reproductive results after migration.

**Conclusions:**

**The SAGES report has many good qualities such as those studies relating the habitat dependence of blue crab density and the density of wolfberries on environmental parameters. I believe on the other hand, there are sufficient inconsistencies between the proposed model and the details of the various experimental observations, as pointed out above, to put the model into serious doubt. There are better models relating freshwater inflow to bay salinity. These may be adapted to give a greater degree of confidence to salinity predictions throughout the bay system and more meaningful correlations among the various data sets collected. In addition, although the work done at the three or four experimental sites are correctly done, it would be more useful in the overall picture of the bay system to expand to sites that are basically different from one another. We have no guarantee that the whole bay system responds to environmental forces in the same manner as**

**does those areas adjacent to the intra coastal water way and sheltered by the chain of adjacent islands.**




# Comments on SAGES Final Report

## From: Platte River Whooping Crane Trust

# Platte River Whooping Crane
MAINTENANCE TRUST, INC.

5 June 2009



To: Whom it May Concern:

From: Felipe Chavez-Ramirez and Platte River Whooping Crane Maintenance Staff

Following are some comments and concerns regarding the Sages Final Report "Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes" The comments are only based on the material that begins on page 1. The specific projects in the appendix were considered in relation to the report but will not be commented on here individually as most of them have been synthesized so much it is difficult to evaluate all the details of most of those studies.

P. 9-10
The model does not include any factors that could also affect the abundance and availability of food resources, such as competitors. The salt marshes in Aransas support many wading birds and other animals that eat crabs, for example. The second model does not include demographic aspects although there was a project designed to look at this aspect and incorporated into the overall model. Energetic budgets, had they been developed, could have been related to survival and potential reproduction of the species.
The conceptual model is not 100% consistent with mathematical models presented later on.

P. 11
Considering the title and objectives outlined in this report, it seems that Table 2.2 that present summaries of empirical studies, should have a column similar to "Findings in a nutshell" perhaps named "links or relevance to whooping cranes". Some of the findings in a nutshell (water quality, hydrological connectivity, nutrient levels etc), are never incorporated into the model or considered in any way in this report.

Regarding the summary table of projects it is not clear why complementary projects were included or what the importance of them is. Some do not appear to be related to the overall model or specific objectives of the report.

P. 22.
Stated Objectives of the report are:

1. Quantify patterns of habitat use by whooping cranes in relation to changes in human-induced disturbances at ANWR,
2. Evaluate relationships among water temperature, water salinity, water depth, other physical factors, and blue crab abundance in salt-marsh habitats of ANWR,
3. Determine changes in whooping crane foraging behavior and capture rates in

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relation to abundance of blue crab and wolfberry fruit,
4. Quantify macrophytic responses in saltwater marshes to intra- and inter-annual variability in freshwater inflows, salinity, and inundation,
5. Develop a simulation model relating freshwater inflows feeding San Antonio Bay to wolfberry fruit abundance and the availability of blue crabs to whooping cranes in saltwater marshes of ANWR.



Objective 1. There is no presentation of habitat use patterns anywhere in the report. While it may have been done as part of one of the studies it does not seem to be treated anywhere in the document. The information presented in regards to habitat use deals more with behavior changes than changes in habitat use patterns.

Objective 2 appears to be missing wolfberries in addition to crabs, as an item of study.

Objective 3 is not actually accomplished as written. Whooping crane foraging is not explicitly related to abundance of blue crabs or wolf berry per se in this report. It appears that differences in crab abundances between years, is what is considered to fulfill this objective.

It is not clear how objective 4 is included in the simulation model.

Objective 5 would be more accurate if it said "abundance" rather than "availability" of blue crabs. Availability was never actually measured or presented anywhere in this report.

P. 26.
Figure 3.1 is not identical to figure 2.1 as stated in the legend of figure 3.1.

P. 28.
From report: "Based on ecologically-interpretable empirical relationships among the regional environmental factors and the salt marsh components, we parameterized a simulation model that predicts whooping crane energy balance as a function of the interaction of freshwater inflows, bay water level and wind (Figure 3.3)."

Comment:
The model as presented does not really estimate energy balance, as energy expenditure versus input is not considered explicitly, rather an estimate of the abundance and energy content of food resource items in the theoretical territories is what is really estimated by the model presented.

P. 29
Figure 3.3 suggests that wind influences wolfberry, but wind is not considered in the model for wolfberries, only the one for blue crabs.

P. 30 and 31
Despite discussions regarding factors that influence salinities, the equation presented only includes freshwater inflows. On the marsh itself, some factors that may be very important for affecting salinity

levels at that scale are not considered at all, such as precipitation and evaporation. These factors, it is likely, would have less influence on salinity levels at the bay wide scale which is where the salinity values used in the model are obtained from. It is not clear why bay salinity is the variable used in this model instead of salinities within the actual whooping crane territories? We know through empirical observations that salinities can be very different in crane marshes versus those in bays during the same time period.



P. 33
In Equation 3a for blue crabs, temperature is ignored. Apparently this is because temperature data could not be fitted to the large crabs (according to appendix data). In addition these equations are based on small crabs which are reported elsewhere (in appendix) as not being whooping crane food items. The best model on page 117 includes water temperature.
If small crabs are going to be the basis of the model on the assumption that they will grow to a size suitable for cranes at a rate of 14 mm per month, then this variable should be included in the equation to account for growth. It is not, however, even though that is the assumption explained in the text. It would be more realistic to include estimates of crab abundance and availability based on size actually taken by whooping cranes.
The equations also do not appear to account for monthly differences in density or energy of crabs even though the empirical data presented elsewhere in the report shows that it fluctuates up and down over the winter period. Perhaps it was considered, but the report does not represent any of this in an explicit way.

P. 37
The wolfberry equation does not include factors (e.g., precipitation, temperature, wind, inundation regime, soil porewater salinity), that later on are mentioned as important variables for wolfberry. For example, on p. 38, a series of factors are considered to affect wolfberry however, none of these variables are included in the equation regarding wolfberry production.

P. 40
The legend of Figure 3.7 explains that increases in wolfberry densities were due to increases in number of wolfberry plants present (not sure where this data is as the empirical study in appendix does not report density of plants). If this is true, then there must be an upper limit of how many wolfberries you can have per meter square which should be based on the number of plants present in that meter square. It is not clear that plant density was considered in the model as only berries per meter square are presented. It is also not clear whether berries per meter square is all berries or only red ripe berries. Whooping cranes do not regularly consume the green berries.

The above information, in addition to that information on pages 48 onward, shows that in two of the territories wolfberry is not really abundant. Table 3.3A shows that in some years the peak wolfberry abundance is 0.87 berries/m square. I cannot imagine how a crane can get enough to eat in a territory that has 0.87 berries per meter square if they are consuming 100% wolfberries during those peaks as suggested by one of the empirical studies. Some of the material in the appendices reports that whooping crane feed almost exclusively on wolfberries 100% of one month of one year (after peak). If we use the approx 5 berries captured per minute reported in the appendix, and 65% of time spent foraging (39 minutes/hr), as reported in another section of the report, that comes to 195 berries per hour. The crane will need to forage 9.2 hours to fulfill its 465 kcal (which is based on 5 kg captive bird and should actually be more like 7 kg

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based on wild bird weights) required by the model. However, if the peak density is 0.87 berries per meter square there is no more than one wolfberry every 10 m (0.87 berries/m square). Which means the cranes will have to travel at least 1,950 meters every hour for the 9 hours which totals 17,550 mts. It is unreasonable to assume that a crane travels 17,550 m in a day. This is not what has been observed in the field. So with minimum peak densities ranging from 0.01-0.87 (Tables 3.5A and B) it is inconceivable and unrealistic that the crane can act in a way the model expects it to do so to acquire enough energy in those years when peak wolfberry densities are so low. There are even lower values for wolfberry density (0.01, 0.06, 0.23, etc.) presented in tables. Obviously, regardless of potential disagreements as to how much a crane can move in one day while foraging, the only way to know if a real whooping crane is spending 100% of its foraging time on wolfberries during a day is to use the habitat use patterns data which is one of the stated objectives of this project. However, there is no habitat use pattern information presented anywhere despite being and objective of this study. Field observations that were conducted could also provide information on how much distance is covered by a real whooping crane in the field which would help check how realistic or unrealistic the model assumptions are.



Considering that salinities were not allowed to go above 30ppt and the model still estimated very low wolfberry densities at some points, it is possible there would be even less wolfberries if the salinities were allowed to have been estimated above 30ppt in marsh territories.

P. 39
I am not sure how the salinity levels at GBRA1 can be considered as similar or reflective of crane marsh areas (territories). It is a good measure of what is happening in the bay itself but we do not remember ever having seen salinities higher than 35ppt in the bays relative to the marsh where salinities can exceed 35ppt on a regular basis. In addition, salinities vary in different ponds in the marsh, so it's unreasonable to assume that salinity in the bay is equal and homogeneous in the marsh itself.

P.42.
section 3.2.3
From report: "We selected a model (Eq. 3) that predicted crab density relatively well at the ecosystem level (Pearson product-moment correlation factor, rave, = 0.792) for small crabs (11 to30mm carapace width). Although this size class is slightly smaller than what whooping cranes eat, given the rapid growth of crabs (14 mm/month [Adkins, 1972]), we assumed that it provided a good estimate of recruitment into the size classes consumed by cranes."

Comments
The above statement makes some significant and unrealistic assumptions and ignores some important points:

- Abundance (or density) of prey is not equal to availability for most species in complex environments. Abundance is what is present, while availability is what the animal has access to which is rarely 100%.
- A large proportion of small blue crabs can be removed before they grow by many other species (wading birds, fish, raccoons, hogs, etc.) present in the salt marsh, so it is unrealistic to assume that all small crabs become crabs of the size cranes would eat.

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- Blue crabs could be buried due to low temperatures, maki ng them less available which is ignored in the model equation.
- There is no measure of variability in the information presented, abundance is reported per year versus by day, week, or month, (although some tables refer to days of energy deficit)



- Crabs less than 30mm were not observed to be eaten by whooping cranes in the empirical studies presented in this report (and many other observations), yet that size class is the basis to assume cranes have more than enough to eat. If recruitment was as high as assumed in the statement above, then all the crabs that were trapped would not be less than 30 mm in size all winter long.
-
- The equation does not include temperature even though it is widely recognized that temperature is highly influential on crab growth. If the assumption is that the small crabs will grow to the size eaten by cranes, then temperature effects on growth should be considered rather than assuming equal growth all winter regardless of temperature. You would also have to consider what proportion of the estimated crabs that are 11-30 mm reach the size classes suitable for cranes.

From the report: "Crabs may be influenced by water level for several reasons, which led us to assume that more crabs would usually be found in deep water rather than in shallow water. Crabs may select deeper water to avoid predation from foraging wading birds or other terrestrial or aerial predators…"

Comment
It is not clear what "deep water rather than shallow water" means here. The statement is likely to be true for crab abundance. However, beyond a certain depth blue crabs will no longer be available because cranes can either not see them or reach them. So even if we assume that deeper water has more crabs it does not mean they are available for cranes. Cranes may avoid depths greater than 80 cm to 1 m. While it is recognized that higher water level may limit predation by birds and other non-aquatic organisms, the issue that is ignored is that higher water levels may increase predation by aquatic organisms (fish, larger crabs, etc.). There is also a discussion regarding the effects of higher water buffering the effects of high or low temperatures, despite the fact that temperature is not even a variable in the equation. If the statements in the report are true, then what is the actual effect on temperature of higher water levels, what are those temperature differences, and what is the effect of temperature on variables estimated or assumed here such as crab density, crab growth and crane foraging activity.

P. 43.
From the report: "We assumed that wind speed was a proxy for water turbidity. Our original assumption was that increasing mechanisms for turbulence (e.g., wind) would increase water turbidity and subsequently increase concealment (or survival) of blue crabs in the water column (see Minello et al. 1987). In Eq. 3, crab density decreased with increasing turbidity. This indicates that crabs may be more dependent on other variables regulating

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concealment or predation risk. For instance, they may be more tied to pond edges, soft bottom substrate, high structural complexity in the water column, and/or shallow water depths than we originally assumed."



Comment
Concealment of blue crabs because of turbidity may change visual detection by cranes or other birds, as noted, and therefore availability. Water turbidity alone should not change actual crab density (which is what is reported in model results). However, it could change availability, but availability is not a factor actually estimated in this model despite references to potential crab concealment under variable conditions of wind, etc. The assumption, that crab density changes with turbidity is unrealistic, rather what changes with decreased visibility is the possibility of being eaten by a visual predator such as the whooping crane. However, changes in availability or predation risk are not included in the model.

P. 45.
From the report "We calculated an index of whooping crane energy balance within each territory (i) at time t (EBi,t) based on our estimates of numbers of wolfberries and blue crabs (TWBi,t and TBCi,t). We calculated the metabolizable energy (kcal) contained in TWBi,t (METWBi,t) and TBCi,t (METBCi,t) as: METWBi,t = TWBi,t * wtWB * GEWB * MECWB (4) METBCi,t = TBCi,t * wtBC * GEBC * MECBC (5) where wtWB and wtBC represent the weight of wolfberries (0.44 g each, Chavez-Ramirez 1996) and blue crabs (between 11 and 30 mm carapace width, 0.939 g each, Greer, in progress), and GEWB and GEBC represent the gross energy content of wolfberries (1.214 kcal / g) and blue crabs (0.785 kcal / g), and MECWB and MECBC represent the metabolizable energy coefficient of wolfberries (0.438) and blue crabs (0.355), all as reported by Nelson et al. (1996). We then calculated EBi,t as: EBi,t = (METWBi,t + METBCi,t) / (DER * NCi,t) (6) where DER represents the daily energy requirement of a free-living 5 kg whooping crane (465 kcal, Nelson et al., 1996) and NCi, t represents the number of cranes occupying territory i at time t. Thus, EBi, t > 1.0 indicates a positive energy balance and EBi, t < 1.0 a negative energy balance for the cranes in territory i at time t."

Comment
There are several flawed assumptions in the above statement as described below.
This energetic model is based on daily energy requirement of cranes, it is not considering actual energy intake. Therefore, what is estimated in this model cannot be called energy balance. This model assumes that cranes automatically consume all they need every day. Assuming equal energy requirements everyday is a flawed assumption. Also basing the static daily energy requirements is likely underestimated as it is based on the weight of birds in captivity and wild birds have been recorded up to 2 kg heavier than the 5 kg used for the estimates here.
As mentioned above, food abundance is not equal to availability, therefore it should not be assumed that all cranes get their fill every day automatically just because it was estimated that there was enough food in the environment. Food consumption was estimated in a part of this project but that information is not used to determine actual food intake rates. It would have been much more realistic to have used actual food intake and energy intake rather than just assume that energy requirements are met 100% of the time if the abundance is present somewhere in the territory. When you consider that cranes in general do not visit every square meter of their territory every single day it is illogical to assume that because there is enough energy in the territory for a crane to fulfill its daily needs it actually does. Most cranes only use a portion

of their territory during any particular day. Since some of the empirical studies were supposed to have looked at movements throughout their territories, why was this data not used to look at the proportion of territory used by the cranes per day? The food in the portion of territory used during a day would then be the potential energy available to the crane not the food in the entire territory as the model assumes. It appears that no crane activi ty patterns were considered despite havi ng observed cranes. Determining how much a crane moved in one day (the distance travelled in different habitats would dictate how much area of marsh and open water it was exposed to) would give us a better idea of how much actual food they could potentially access in their foraging activities during a day. It is unrealistic to assume that 100% of food in a territory is available to the cranes every single day, especially when there appears to be no depletion rates considered at any point in time in the model.



The weight of whooping cranes used here of 5kg is based on the one used by Nelson which is for captive whooping cranes. The weight for wild birds is known to be better represented at 7kg. Wild adult whooping cranes (unknown sex) have been weighed at 7.14 – 7.85 kg during the fall in Minnesota (Roberts 1932). Estimates of energy requirements would be greater using a bird that was 2 kg heavier than that used in the model here.

P. 45

From the report: "Our primary concern was that we neither overestimate abundance of crane food resources (specifically, wolfberries and blue crabs) nor underestimate crane energy requirements at the territory level."

Comment

It is very likely, based on the different comments in this write-up, that food was overestimated and energy requirements of cranes underestimated.

Based on the use of small crabs size classes, and not having included variations by month, there is very likely a considerable overestimation of abundance for blue crabs. But even considering that estimates are realistic for the territory it does not mean that the crane has access to every single resource in its territory every day, as discussed above.

P. 46.

From the report "Salinities predicted at high and moderate inflow rates were similar to salinities observed at the GBRA1 gauge (Figure 3.9), but salinities predicted at low inflow rates (28-day cumulative discharges < 2* 107m3 /day), were unrealistically high (>40 ppt). Thus, we put an upper bound on the predictions of Eq. 1 such that predicted salinities did not exceed 30 ppt, which is 1 ppt higher than the maximum salinity observed at GBRA1 from 2003 to 2007."

Comment

Salinities on the Aransas marshes can at many times exceed 30 ppt. This is not rare, so it is not clear why salinities in the model were truncated at 30 ppt, especially when the effects of salinities are supposed to influence crab and wolfberry factors in the marsh. By limiting the model to 30 ppt some potential negative impacts of high salinities are therefore not included in the model. For example, high salinities were shown by one of the studies in this report (appendix) to affect wolfberry growth (p.37-38 and 98-99 of report). During winter of 2008-2009, many wolfberry plants were observed dead in some areas which was likely due to the fact that they were inundated for extended periods of time with high salinities. In addition, high

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salinities have other energetically demanding actions on whooping cranes. At salinities above 23 parts per thousand, the cranes must leave the marsh to drink freshwater at upland water sources. This means cranes must fly there, which is an energetically expensive activity. Since the model is assuming the same energy needs every day and limits the higher end of salinities, it ignores energy demands at higher salinity levels present in the marsh. A crane that needs to fly everyday to drink freshwater will have greater energy expenditure than one that does not fly at all during a day.



P. 49
It is not clear what peak number of berries/meter square per year is. By peak, one would assume number of berries in October, however, the legend of Figure 3.10 says peak number of berries/meter square per year and there is a single bar for each year. Does this mean that during the time cranes are there, there will be X number of wolfberries every day, or is it during the peak date in October and therefore less wolfberries before and after that peak, or is it total wolfberries regardless of phenology during the fruiting season. It is difficult to understand how the phenology of wolfberries would graph over the time period the whooping cranes are present based on a single peak value.

P. 50
It is not clear what time steps are here, as in wolfberry above. For example, predicted and observed crab densities are compared in a graph, however, the observed data as reported in the appendix is based on monthly sampling and the model, it appears, deals with daily variations ("days of energy shortage"). Figure 3.11 says crab abundance as total number of crabs/year. This does not make sense as the cranes are only there during the winter. Are the months when the cranes were not present also part of the total number of crabs/year? It is not clear by reading just the legend, and it is not graphed or presented in any other format than crabs/year. As it is presented, it is not clear how this relates to crab abundance over a daily (model expectations) or monthly (as empirical data is presented) time steps during the winter period.

P.68
Many of the relationships and connections described in this section (Conclusions of study), which I assume are based on the empirical studies, are not included in the model itself. For example, it says "The second major area of study was on the behavioral ecology of cranes. The main objectives here were to document food habits and time-activity budgets of cranes, while investigating the effects of environmental conditions, food abundance, and human disturbance on the crane's energy balance." Many of the results regarding this information, some of which is presented in the Appendix, are not incorporated in the model. For example, time activity budget information, food habits, and foraging information, do not appear anywhere in the model. Some of this information could help to better inform and define some of the assumptions currently in the model that do not appear to relate to reality very well.

I am not sure what responses they are talking about as no behavior data is presented.

Conclusions regarding efficiency are misleading as empirical data show food items were included that were not included in the model. So while the conclusion may be referring to empirical studies, up to this point in the report the empirical studies do not show up. They are presented as appendices.

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Summary of inconsistencies and unreasonable assumptions made in the model that make the overall results of the model unrealistic:

- Salinities measured in the bay are assumed to be equal to those in the crane territories.
- Salinity levels measured in the bay are assumed and used in the model to influence crab abundances in crane territories.
- Salinity levels measured in the bay are assumed and used in the model to influence wolfberry abundance in crane territories.
- Salinity levels are truncated at 30 ppt. Empirical data shows salinity levels in the marsh exceed 30 ppt regularly. Higher salinities also have implications for whooping crane energetics and wolfberry production.
-
- Crab equations use small crab size class (11-30mm) in the model despite data presented in the appendix that mentions that the likelihood of cranes eating that size class of crabs is near zero.
- Growth of small crabs is assumed and therefore is the reason for using the small size class, yet there is no variable in any equation to account for crab growth.
- While growth of crabs is assumed, equation for crab abundance ignores temperature as a variable despite the well known fact that temperature, in combination with salinity, are import factors influencing crab growth.
-
- Biomass and energy estimated in a whooping crane territory in a particular day is assumed to be 100% available to cranes instantaneously.
- There is no consideration of actual whooping crane energy expenditure, rather energy requirement is assumed to be equal every day.
- Not clear what time steps are. For example predicted and observed crab densities are compared in a graph, however the observed data is based on monthly sampling and the model is supposed to deal with daily variations ("days of energy shortage"). The figures say crab abundance as total crabs/year. This does not make sense as the cranes are only there during the winter. Are the months when the cranes where not present also part of the total number of crabs/year? It is not clear.

Considering the large number of potentially flawed assumptions, and inconsistencies of the model assumptions to reality, it would be unwise to assume that the results and conclusions presented in this report represent reality in the field with any degree of certainty. Models of this nature should be used to explore relationships among variables, not present the results of the simulations as if they indeed represent reality at any point in time. This is particularly true of this model when so many issues regarding whooping foraging, energy expenditure, and habitat use patterns are ignored in the model. For example,



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modeling the density of blue crabs and getting similar results to empirical data is one thing, but even that information has to be qualified. The model may simulate or estimate small blue crab density very well, however, if we know and the report acknowledges this, whooping cranes do not eat this size class the conclusions that there is enough food in the territories is suspect. How food abundance is extrapolated and then assumed that whooping cranes somehow magically absorbed the energy in the environment without habitat use and foraging activity patterns being considered is quite a different story. Using similar logic we could estimate fish biomass in whooping crane territories and conclude that whooping cranes have more than enough energy in their territory to fulfill their needs. However whooping cranes eat fish only rarely (just as small crabs), so my conclusions would have to be suspect and extremely unrealistic.



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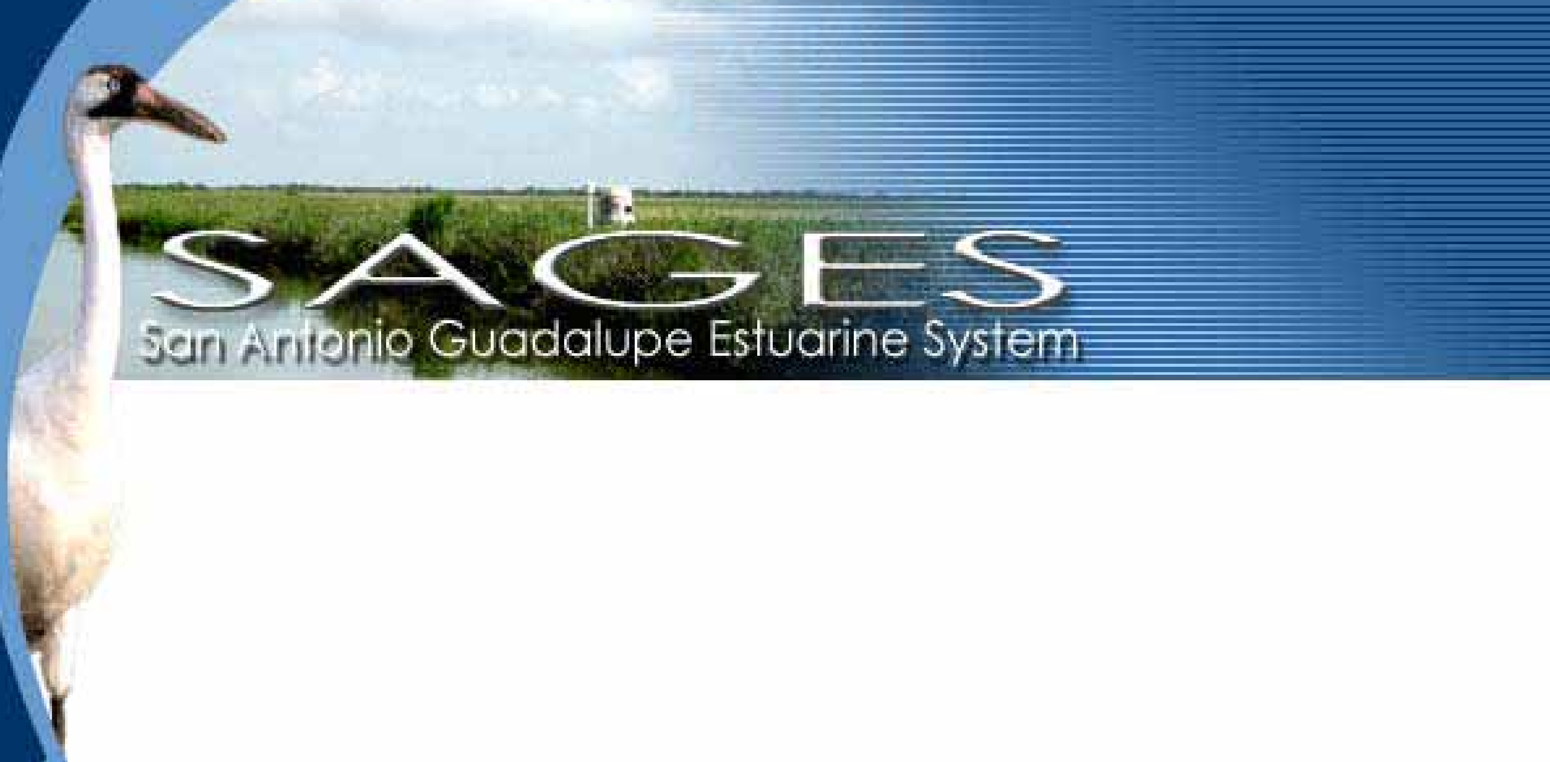



# Comments on SAGES Final Report

# From: Texas Parks and Wildlife Department

June 8, 2009



Dr. Todd Votteler, Executive Manager of Intergovernmental Relations and Policy
Guadalupe-Blanco River Authority
922 East Court Street
Seguin, Texas 78155

Dear Dr. ~~Votteler:~~ Todd

Staff of the Texas Parks and Wildlife Department (TPWD) have reviewed the San Antonio Guadalupe Estuarine System (SAGES) Final Report: Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes. TPWD staff agrees with the report's conclusion that the relationships between inflows, blue crabs, and whooping crane energetics are complex and not well understood and request the authors of the SAGES study better identify the limitations and inconsistencies in its findings in the final report.

The initial interpretations and publicity regarding the SAGES study have surprised, and perhaps even alarmed, many in the scientific, regulatory, and conservation communities. Specifically, statements such as "In summarizing the study, researchers commented that in nearly all conditions simulated, the food supply for whooping cranes appears to be more than adequate to meet their energy needs. (GBRA press release, 04-29-09)" seem inconsistent with earlier studies regarding whooping cranes, their food, and their habitats and imply that reductions in freshwater inflows will not affect the health of whooping cranes on the Texas coast. TPWD urges the project sponsors to carefully address these concerns, especially in light of contrary findings from previous studies.

In summary, the SAGES report clearly expresses the limitations associated with any model, including the SAGES model, and acknowledges that "the relationship between salinity and crane energetics is still uncertain"; however, the way in which the findings of this study have been presented have unfortunately led to implications that changes in freshwater inflows are unlikely to affect whooping crane food availability (and, by extension, their survival). TPWD strongly encourages the authors to qualify statements regarding predictions of food availability under the model with caveats regarding the limitations of the model. TPWD staff have highlighted some of more significant limitations in the attached document.

Please see attached specific comments. Do not hesitate to contact me at 512/389-8715 or cindy.loeffler@tpwd.state.tx.us if you have further questions or concerns.

Sincerely,

Cindy Loeffler

Cindy Loeffler, Chief
Water Resources Branch

Attachment

Cc: Tom Stehn, U.S. Fish and Wildlife Service
Joe Trungale, Trungale and Associates
Ruben Solis, Texas Water Development Board

**TPWD Comments: San Antonio Guadalupe Estuarine System (SAGES) Final Report: Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes**

**Blue crab abundance as a function of bay salinity** - Despite the wealth of research and literature regarding the relationship of blue crabs and salinity, the authors only listed a single reference (Cadman and Weinstein 1988) in their discussion of this source of variation (pp. 104-105). This reference focuses on a lab study which concluded that growth was generally higher at higher salinities. This is counter to previous work on blue crabs, which suggests that salinities in the range of 5-15 ppt are optimal (In fact, the online project description by the SAGES authors states, "Although blue crabs occur over a broad range of salinities in Gulf of Mexico estuarine waters, they are most abundant in low to intermediate salinities (Guillory et al. 2001)."). Although some studies do corroborate the negative effect of low salinity on blue crab growth, many others show that abundance is often higher at low to moderate salinities. Numerous studies of blue crab growth/abundance vs. salinity should have been included for comparison, not the least of which is Longley (ed.) 1994 "Freshwater Inflow to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs". A list of other pertinent references is included in the attachment. Also, TPWD Coastal Fisheries monitoring data (unpublished but available to the authors) indicate higher catch rates at salinities less than what Cadman and Weinstein reported as optimum for growth. It is not unusual for different environmental factors to act synergistically and result in animals residing in conditions where no specific parameter is at the optimum level. Without establishing a relationship between larger crab density and salinity it is not possible to predict densities under different conditions. In addition, the authors were unable to develop an adequate model for predicting density of blue crabs over 30 mm. This is important because study number 9 in the appendix (*Whooping crane foraging ecology: Gains, costs and efficiency of foraging during winter*) indicated that the cranes consume crabs >30 mm; the authors did not show empirically that the small crabs would reach the larger size during the winter months on the Aransas National Wildlife Refuge. Cadman and Weinstein concluded that crab growth rates were lowest at low salinities and low temperatures. Without being able to model the density of crabs less than 30 mm is it not possible to accurately forecast the availability of this food item to the cranes under changing inflow conditions.

Furthermore, the model is built on two offsetting premises—that higher salinities increase blue crabs as a food source and that lower salinities increase wolfberries as a food source. The equations in the model regarding these relationships appear to be linear, with a suggestion that 30 ppt is the optimal salinity for blue crab abundance. This decision was critical in the performance of the model in predicting food abundance. If the model assumptions are wrong and blue crab abundance peaks at salinities lower than 30 ppt, then it would be highly unlikely that reductions in inflows of 90% would produce adequate food resources. Even a slight modification of this assumption might not allow the SAGES team to conclude that a 100,000 acre-feet/year reduction had no noticeable effect on food abundance ("no days in which net energy balance of cranes was negative") (Final report, page 59). Statements such as this are likely to be widely-referenced as decisions are made regarding water use and allocation in the future.

**Marsh salinity as a function of bay salinity** - Statements are made that "more crabs were found in bay than any other habitat (p. 107)" and "density was positively related to salinity (p. 108), yet nowhere in the chapter are there any data correlating density or abundance with salinity. This is a glaring omission considering that one of the four major relationships and a primary objective of the entire study concerns salinity. The authors seem to imply that bay habitat has higher salinity (and thus greater crab density) than the other four habitats (Figure A8, p. 114); if so this should be stated and supported with tables or figures. The chapter's Conclusions section consists of three paragraphs relating crab abundance vs. habitat, yet nothing about salinity. If the crab abundance/salinity relationship is important enough to merit one of four bullets in Executive Summary, there should be some accompanying text and literature references in the Conclusions section as well. The applicability of the model for predicting food availability for whooping cranes in their marsh territories is uncertain, as it acknowledges that "the team does not know the extent to which marsh salinity is dependent on bay salinity" (Final report, page vi). Since the model's predictions are based on measures of bay salinity, this shortcoming is significant. It is regrettable that the model did not better quantify the relationships between bay salinity and marsh salinity. This is a significant data gap as the relationship of marsh salinity to freshwater inflows is the fundamental building block for the overall model. Without an accurate marsh salinity to inflow relationship it will not be possible to accurately predict the responses of wolfberries or crabs to changing inflow conditions. In addition, an upper bound of 30 ppt was set on model predictions to constrain model results from producing "unrealistically high (>40 ppt)" marsh salinity values. The TPWD Coastal Fisheries monitoring database contains numerous instances of salinities between 30 ppt and 40 ppt in this estuary. Limiting the model to 30ppt is not realistic for this estuary, especially given the extreme low inflows at which the model is being tested.

Overall, the inability to successfully develop models linking freshwater inflows to marsh salinity, or to predict the density of crabs >30 mm would seem to render the modeling efforts unsuccessful.

**Alternate Food Sources** - The report suggests that alternate food sources are mathematically equivalent in their exchange in the diet of whooping cranes and even suggests that blue crab are energetically expensive for whooping cranes to consume; however, previous research has shown that whooping cranes apparently select for blue crabs when blue crabs are present (Hunt and Slack 1989; Chavez-Ramirez 1996). The SAGES authors also note in their online project description that "Chavez-Ramirez (1996) has reported that breeding success of Whooping Cranes at Wood Buffalo National Park is closely tied to the availability of their primary food (blue crabs) while they are on coastal wetlands during the winter." Much previous research has shown that whooping cranes take a variety of food items (although press releases associated with the SAGES study imply that this study is unique in documenting such findings); however, alternative food sources may not be nutritionally equivalent to blue crabs. Data collected by Greer as part of the SAGES study illustrate this, showing that in the winter of 2004-05, when blue crabs were a significant component of whooping crane diet in November and December, energy intake, protein intake, and lipid intake were much higher than in 2005-06 when blue crabs were not a significant component of the diet. Field data collected by Tom Stehn of the U.S. Fish and Wildlife Service in those same years showed that in 2005-06 blue crabs were rare in transects conducted in whooping crane territories and that whooping cranes suffered above-average winter mortalities. Finally, research by Pugesek et al. (2008) conducted from 1997 through 2005 showed that mortality of adult whooping cranes in the wintering grounds was inversely correlated with blue crab abundance as measured by transects conducted in whooping crane habitat. The SAGES authors should address the inconsistency of their findings in relationship to existing research.

**Energetics as a function of salinity** - The SAGES model does not consider ancillary energetic costs of high salinities. When marsh salinities are high whooping cranes are forced to fly to inland sources of fresh water, which uses energy and exposes them to additional predation risks. In their project description online, the SAGES authors note that "movements of cranes from salt marsh territories to adjacent uplands and wetlands (which may increase predation risks) increase during periods of crab shortages in the marsh (Chavez-Ramirez and Slack 1999)." Although the SAGES authors acknowledge that their model is not comprehensive, secondary effects of freshwater inflow on whooping crane fitness and survival should be acknowledged.

**Competition for food resources** - The SAGES model does not consider inter-specific competition for food resources. The model substitutes an increase in whooping crane group size (four birds in the territory instead of the usual 2-3); however, it is unknown whether this is an adequate representation of competition for food resources, especially in stress years, such as drought. The limitations of the model should be acknowledged when statements regarding adequacy of food resources are made.

**Limited study period** - The SAGES empirical study (Feb. 2003 – Dec. 2007) period did not include a year of extreme drought and low inflows, such as 1990 or 2008, and it included only one of the winters in which the U.S. Fish and Wildlife Service has documented significantly above-average mortalities (2.7% in 2005-06). Winter mortality for whooping cranes is usually less than 1%; however, in seven years since 1988 Aransas National Wildlife Refuge staff has documented significantly higher mortality (2.7% - 8.5%) which has been either anecdotally or empirically associated with high salinities and low blue crab numbers. Similarly, the simulated SAGES model runs (1997-2007) only included two years in which higher mortalities on the wintering grounds were noted, and these were two of the less severe mortality winters (2005-06 with 2.7% and 2000-01 with 3.3%). The study results also showed that diet varied greatly from winter 1 to winter 2. Although the study duration did not practically allow for wider sampling across a broader range of years, it should be noted that the study may not have sampled during environmental extremes which may occur in the whooping crane habitat.

**Whooping crane foraging ecology: gains, costs, and efficiency of foraging during winter** – SAGES Study Results showed that whooping crane diet varied greatly between winter 1 (2004-2005) and winter 2 (2005-2006):

> "Percent of the diet containing blue crab (all sizes combined) declined by over 80% from winter 1 to winter 2"
> "Dry mass intake of blue crabs (all sizes combined) declined 70% from winter 1 to winter 2"
> "Intake of wolfberry fruit increased 3.7-fold from winter 1 to winter 2"
> "Foraging gains were over twice as much in winter 2 as winter 1"
> "Whooping cranes foraged 3-7 times more efficiently during winter 2 than winter 1".

The authors did not explain why cranes seemingly abandoned blue crabs in winter 2 when crab density was highest during September-October of this time period in several habitat types. This would seem important if the cranes actually preferred crabs over other food items. Figure A20 should be repeated for each crab size-class. If the cranes prefer larger crabs then that size should be broken out into a separate figure. TPWD staff recommends that the relationship between food items consumed and what was actually available should be examined as well as composition of the cranes diets each winter compared to the corresponding freshwater inflow. The declining amount of inflow and thus water level from winter of 2004-05 to 2005-06 would explain the decreased availability of crabs to the cranes during winter 2. The Executive Summary (Whooping Crane Behavior, p. v) does state "Whooping cranes foraged most efficiently during the winter of 2005-2006 when water levels were lowest". Relationships such as this would be useful in each of the chapters, comparing the data collected to the amount of inflow during the respective study period.

**Other information** - The SAGES team did not take advantage of several existing sources of information regarding whooping crane mortality to expand their analyses. Long-term data on whooping crane winter mortality is available. It is rare that one has the luxury of such close monitoring of the entire population of a species. TPWD recommends the SAGES team correlate the long-term mortality data with other existing historical environmental parameters, such as median inflow during different seasons, peak salinities, and blue crab abundance.

**Whooping crane territories** - A map depicting all known whooping crane territories on the ANWR should be included and the 4 crab/crane territories sampled noted. If the results from the 4 sampled sites are to be extrapolated to all crane territories the reader needs to be able to visualize all territories. The various crane territories are widely scattered with some adjacent to the ICWW and some on the island shoreline. These two areas are very different and are differentially affected by freshwater inflows, wind, and local runoff.

**Attachment - Literature Citations**

**Blue crab/salinity relationships**

Longley, W.L., ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.

This report presents in detail the relationship between blue crab abundance and salinity, and specifically models freshwater inflow and salinity effects on San Antonio Bay and its fishery resources.

Guillory, V., H. Perry, and S. VanderKooy, eds. 2001. The blue crab fishery of the Gulf of Mexico, United States: a regional fishery management plan. Gulf States Marine Fisheries Commission, Ocean Springs, Mississippi.

Chapter 3 of this plan devotes 8 pages (3-11 to 3-18) to factors affecting distribution, abundance, and survival of the different life stages of blue crab (zoeae, megalopae, juveniles and adults). Table 3.1 (p. 3-15) compares blue crab distribution by salinity from four different studies; these studies are listed below. It also contains three pages on megalopal settlement and recruitment, none of which was cited in Chapter 8 of the SAGES report.

Christmas, J.Y., Jr. and W. Langley. 1973. Estuarine invertebrate, Mississippi. Pages 255-317 *In* J.Y. Christmas, Jr. (ed.), Gulf of Mexico Estuarine Inventory and Study, Mississippi. Gulf Coast Research Laboratory.

Details 818 samples from Mississippi where blue crabs are most abundant at salinities of 10-24.9 ppt, and decline at salinities from 0-9.9 ppt and >25 ppt.

Perret, W.S., W.R. Latapie, J.F. Pollard, W.R. Mock, G.B. Adkins, W.J. Gaidry, and J.C. white. 1971. Fishes and invertebrates collected in trawl and seine samples in Louisiana estuaries. Section I. Pages 39-105 *In* Cooperative Gulf of Mexico Estuarine Inventory and Study. Phase IV. Biology. Louisiana Wildlife and Fisheries Commission.

Details 1,179 samples from Louisiana where blue crabs are most abundant at salinities of <4.9 ppt, and are nearly equally abundant at salinities from 5->30 ppt.

Perry, H.M. and K.C. Stuck. 1982. The life history of the blue crab in Mississippi with notes on larval distribution. Pages 17-22 *In* H.M. Perry and W.A. VanEngel (eds.), Proceedings of the Blue Crab Colloquium. Gulf States Marine Fisheries Commission Publication 7.

Details 3,249 samples from Mississippi where blue crabs are most abundant at salinities of 0-19.9 ppt, and decline at salinities from >25 ppt.

Swingle, H.A. 1971. Biology of Alabama estuarine areas – cooperative Gulf of Mexico estuarine inventory. Alabama Marine Research Bulletin 5:1-123.

Details 179 samples from Alabama where blue crabs are most abundant at salinities of <9.9 ppt, and less abundant at salinities from 10-29.9 ppt.

Hammerschmidt, P.C. 1982. Population trends and commercial harvest of the blue crab *Callinectes sapidus* Rathbun, in Texas bays September 1978-August 1979. Texas Parks and Wildlife, Coastal Fisheries Branch, Management Data Series 38, 69 pp.

Based on one year of bag seine data in Texas, there was no direct relationship found between catches of juvenile crabs and salinity.

Ogburn, M.B., J.L. Jackson, and R.B. Forward, Jr. 2007. Comparison of low salinity tolerance in *Callinectes sapidus* Rathbun and *Callinectes similis* Williams postlarvae upon entry into an estuary. Journal of Experimental Marine Biology and Ecology 352 (2):343-350.

Blue crab megalopae from an estuarine site were more likely to survive exposure to low salinities than those from a higher salinity coastal site. Megalopae from the coastal site exhibited increased survival after acclimation to salinities of 27 and 23 ppt for 12 hours.

Texas Department of Water Resources. 1980. Guadalupe Estuary: A study of the influence of freshwater inflows. Texas Department of Water Resources Report LP-107.

Blue crab commercial fisheries harvest showed no significant relationship to salinity, but life history and migration information indicate that adequate freshwater inflow during the summer through fall is important to good growth and survival of the stocks.

**Negative Effect on blue crab growth at lower salinities:**

King, E.N. 1965. The oxygen consumption of intact crabs and excised gills as a function of decreased salinity. Comparative Biochemistry and Physiology 15:93-102.

Findley, A.M., B.W. Belisle, and W.B. Stickle. 1978. Effects of salinity fluctuations on the respiration rate of the southern oyster drill *Thais haemostoma* and the blue crab *Callinectes sapidus*. Marine Biology 49:59-67.

These two studies show that consumption of oxygen increased markedly at salinities below 15-20 ppt.

Tagatz, M.E. 1968. Growth of juvenile blue crabs, Rathbun, in the St. Johns's River, Florida. Fishery Bulletin 67:281-288.

This study, with a sample size of >2,000 observations and experimental design controlled for temperature and animal size, found a small yet significant decrease in molt increment in crabs held in freshwater (<1 ppt) compared to those held at higher salinities. There was no effect on intermolt period.

Rome, M.S., A.C. young-Williams, G.R. Davis, and A.H. Hines. 2005. Linking temperature and salinity tolerance to winter mortality of Chesapeake Bay blue crabs (*Callinectes sapidus*). Journal of Experimental Marine Biology and Ecology 319 (1):129-145.

In Chesapeake Bay laboratory studies, mortality was highest in the lowest temperature (1 °C) and salinity (8 ppt) treatments.

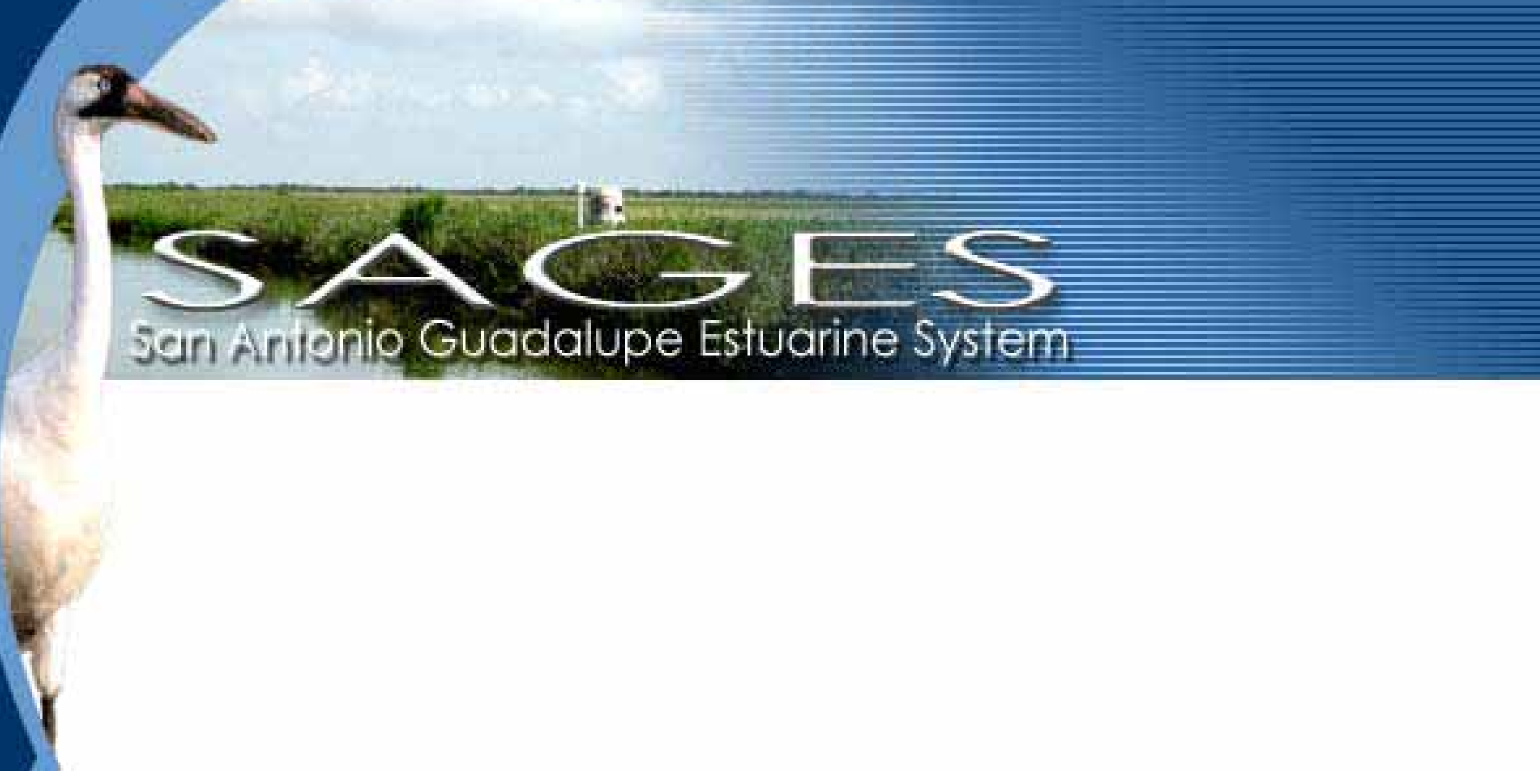
**Blue crab settlement and recruitment:**

Perry, H.M., D. Johnson, C. Trigg, C. Eleuterius, and J. Warren. 1998. Application of remote sensing to settlement of *Callinectes sapidus* megalopae in the Mississippi Bight. J. Shellfish Res. 17(5):1439-1442.

Johnson, D.R. and H.M. Perry. 1999. Blue crab larval dispersion and retention in the Mississippi Bight. Bull. Mar. Sci. 65(1):129-149.

Perry, H.M., D.R. Johnson, K. M. Larsen, C.B. Trigg, and F. Vukovich. 2003. Blue crab larval dispersion and retention in the Mississippi Bight: testing the hypothesis. Bull. Mar. Sci. 72(2):331-346.

Rakocinski, C.F., H.M. Perry, M.A. Abney, and K.M. Larsen. 2003. Soft-sediment recruitment dynamics of early blue crab stages in Mississippi Sound. Bull. Mar. Sci. 72(2):393-408.




# Comments on SAGES Final Report

From: Dr. P. Montagna, Texas A&M Corpus Christi

Dear Mr. Votteler,

I have had an opportunity to read the final report of the SAGES study that was posted on line and have the following comments.

1) The report only provides an abstract of each individual study in Appendix A, and one would have to download and read the complete studies individually. I just don't have time to read all the supporting documents, which I feel is necessary before I could make any comments of a substantial nature regarding the science supporting the conclusions.

I must admit to surprise at some of the findings regarding blue crab (Callinectes sapidus) biology and have some general comments about that.

2) The focus of the experimental design is to look at ponds and connectedness of ponds. I am was not aware that blue crab spawn in these ponds as suggested by the study. My understanding is that blue crab is an estuarine dependent species, which means that it spawns offshore, larvae go through several planktonic stages in the water column before settling to the bottom as juveniles. This means that the crab actually use a range of habitats at different points in its life cycle. The conventional understanding is that the salinity gradient is very important for the planktonic stages to find nursery habitat. Thus, the complete range of habitats from the inlet to the Gulf of Mexico to the mouth of the river is the entire habitat range. It appears only a small part of that range was studied.

3) There are two species of blue crab in Texas. The second one is C. similis, yet there is little mention of this in the report. In my own sampling, I have found similis to be much more abundant that sapidus. There are also at least 50 other species of crabs in Texas bays, many of which do not have an estuarine dependent life cycles. It is not clear how the study of crab larvae identified the organisms captured in the samples as sapidus.

4) Blue crab abundances have been declining along the entire Texas coast since about 2000. In general, this indicates some large scale, coast-wide phenomenon is occurring. Also, similar declines started in the early 1990's along the east coast of the US. The best guess right now is climate change, in particular the effects of temperature and dissolved oxygen are key drivers. There is not much mention of the larger scale population issues, which is critical for an estuarine dependent species.

5) The main body of the report is about the whooping crane metabolic model (Chapter 3). In general, the conceptual model on how inflow affects salinity, and how salinity affects biology is correct. However, the model depends on linking several empirical relationships. For example, there is a great deal of variability between empirical relationships between flow and salinity (Fig. 3.4), which is found everywhere. The same is true for wolfberry-salinity relationship (Fig. 3.7). A problem arises when these noisy relationships are multiplied by one another because the errors are magnified. It would have been nice is some statistics of model fit to data were calculated or if the model was validated with independent data.

6) In the model section, the empirical formula given is that blue crab increase exponentially with salinity (and some other variables). This is not likely realistic, and it would have been nice to see this plotted to determine how the multiple variables are interacting with one another. What really happens is that estuarine dependent organisms have a preferred salinity range for each part of their life cycle, and it never increases without limit. I know from TPWD reports that there is more shellfish in northeastern Texas bays, and the number drop off as you move to saltier bays to the southwest, which make me wonder if the trend within a bay system with regards to salinity is ever significant.

Hope these comments prove useful to the authors of the study.

Paul Montagna

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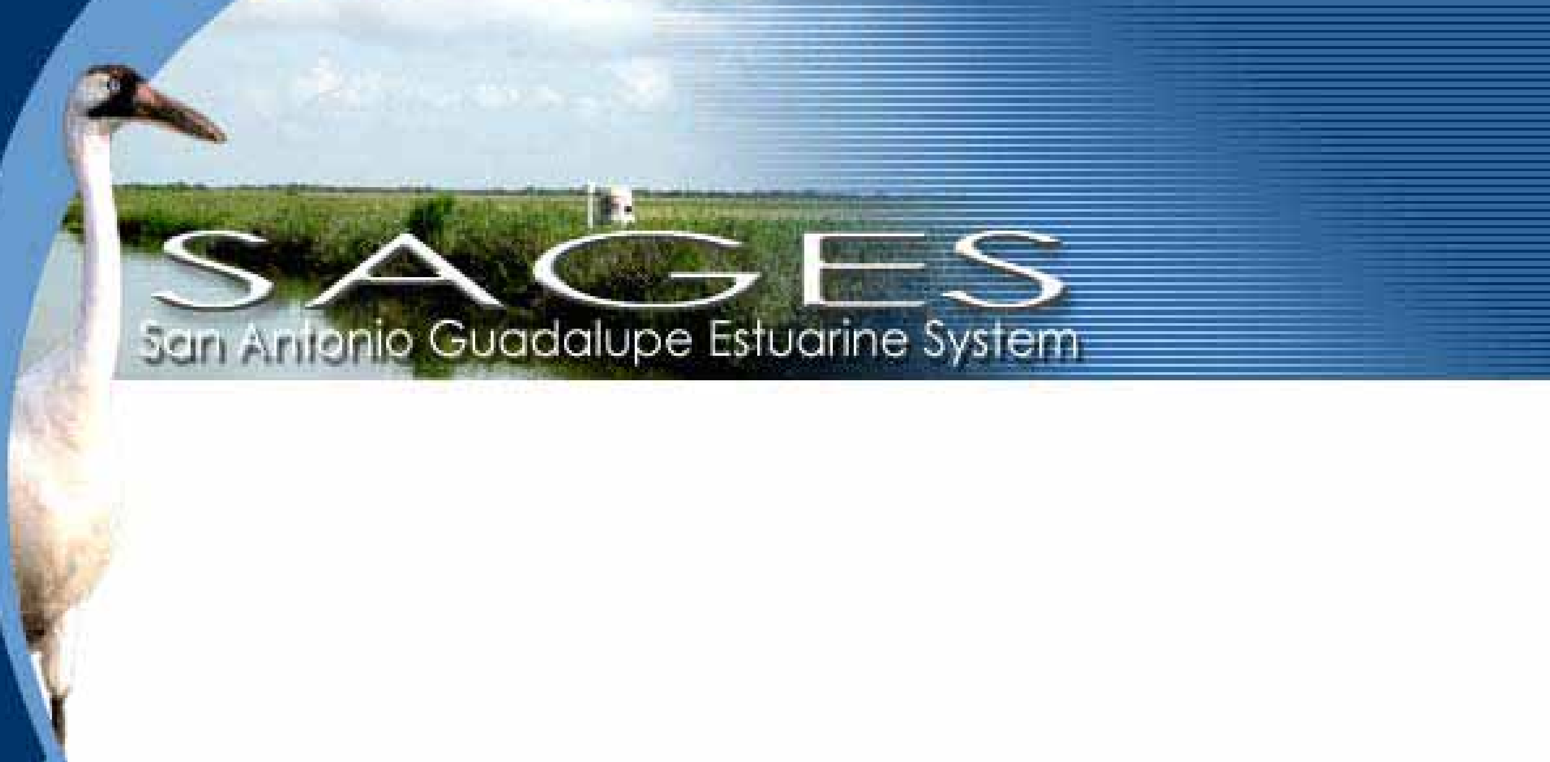


# Comments on SAGES Final Report

## From: Texas Water Development Board

# Texas Water Development Board

## Memorandum

June 18, 2009

From: Carla G. Guthrie, Ph.D., Natural Resource Specialist, Surface Water Resources Division
Ruben S. Solis, Ph.D., P.E., Team Lead for Bays and Estuaries

To: Matt Nelson, Team Lead, Regional Water Planning
Barney Austin, Ph.D., P.E., Director, Surface Water Resources Division

Re: Comments on Final Draft Report of the San Antonio Guadalupe Estuarine System Study, *Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes*, TWDB contract no. 0704830697.

Contracted Work

The goal of the San Antonio Guadalupe Estuarine System (SAGES) Study was to evaluate the relationship between freshwater inflows and Whooping Crane (*Grus americana*) population dynamics. Specifically, TWDB (contract no. 0704830697) funded the development of an ecological model to predict marsh ecosystem responses to variation in freshwater inflows. The project scope of work identified *one deliverable*, an ecological simulation model driven by six submodels: (1) water, (2) salt, (3) macrophytes, (4) blue crab, (5) crane abundance, and (6) crane weight. While the final draft report includes description of and results from an ecological model predicting changes in Whooping Crane food supply as a result of changes in freshwater inflows, the final simulation model differs from the one outlined in the scope of work. The original model was to have related freshwater inflows to *several aspects* of marsh ecosystem dynamics. The end result, however, still achieves the overall intent of the modeling effort by relating important variables (freshwater inflow, salinity, etc.) to Whooping Crane biology. A comparison of the proposed versus final ecological model is describe in the table below.

Overall Application of Model and Study Conclusions

While the individual submodels developed in this study for salinity, wolfberry, and blue crab appear reasonable, the range of conditions over which they were applied in the report (Section 3.4) likely far exceeds the range to which they can be applied with confidence given the limited range of data available for developing the models. Model predictions are presented for scenarios in which inflows are reduced by up to 90%. At such an extreme level of inflow reduction, particularly if prolonged over time, many other significant factors such as the shifting of salinity zones, changes in bay and wetland habitat type and location, changes in nutrient loads, effects on predator/prey species, and many other effects might overwhelm and indeed invalidate the model results as presented in this report. *A more reasonable approach might be to present results for a much narrower range of conditions to avoid this issue or to more adequately qualify the conclusions given the large uncertainties in ecosystem response to the extreme inflow conditions considered.*

| **Proposed Model** | **Finalized Model** |
|---|---|
| *Water submodel* - includes overland sheet flow, ebb/flow of water into marsh, evaporation and temperature represented, possibly the intent was to use a hydrodynamic model | Inundation model was developed, but was ultimately not used in development of the ecological model. |
| *Salt submodel* – similar to water submodel, based on a hydrodynamic and salinity transport model to represent salinity in marsh and bay | *Salinity as a function of freshwater inflow* – based on a regression analysis |
| *Macrophytes submodel* – represents net primary production and decomposition of (all) rooted plants | *Peak Wolfberry density equation* – based on regression analysis to mean summer salinity |
| *Blue Crab submodel* – represents recruitment as a function of day of year and adult female abundance; Mortality as a function of macrophyte biomass, crane abundance and other predator abundances; and, Movement among marshes and bay as a function of temperature, salinity, and day of year. | *Blue Crab density equations* – developed for 11-30mm size class using a regression analysis to habitat type, salinity, water level, and wind velocity. The model does not represent recruitment into or out of this size class nor does it represent mortality. Although the study assumes that the 11-30mm size class serves as a good proxy for the size class consumed by cranes, the size class modeled is *smaller* than those eaten by cranes. The study provides no indication as to what percent of the 11-30mm size class recruits into a size eaten by cranes |
| *Crane abundance submodel* – represents reproduction and mortality of cranes on northern breeding grounds; migration to marsh; movements within marsh; natality as a function of body weight index and day of year; mortality as a function of body weight | Not included. Companion studies may have addressed this, but crane abundance is not explicitly in the ecosystem model. Rather, an energetics model was applied (see next comment) |
| *Crane weight index submodel* – represent changes in body weight index as a function of availability of blue crabs and other food and energy expenditures | *Whooping Crane energy balance equations* – energy balance equations were developed for wolfberries, blue crabs of the small size class (11-30mm), and for each territory. While the nutritional equivalents between wolfberries and blue crabs were determined, the study does not seem to account for potential changes in territory sizes or foraging efforts. |

*Specific comments*:

Authors need to review and correct mis-numbered tables, figures, and or studies. Several items referenced in the tables and text do not match each other.

Supporting statements, arising from the empirical work, frequently are given, but not backed-up with either direct reference to the companion study or by statistical significance. Additionally, some of the supporting statements based on observations or literature citations are not reflected in model decisions or conclusions. For example, the report states that blue crabs will be more abundant in deeper water (p. 42), but the scenario developed to push crabs towards minimum abundance (p. 58) increased water levels 50%.

P.42: The report cites studies that demonstrate a positive response of blue crabs to increasing salinity. It is not clear whether this applies to both sexes and all size classes. If the response is not universal, discussion of the implications of this on the conclusions would be helpful.

P.46: Although the salinity model is cut off at 30 ppt, observed bay salinities on occasion exceed 30ppt. This is shown in TWDB Datasonde data for San Antonio Bay and Mesquite Bay, particularly during periods of low freshwater inflow. Salinities of this level may be rare, but would be reflective of bay conditions during low flow periods. It may be important to recognize the limited scope of the analysis when drawing conclusions about the effect of low flow conditions.

P.46: Precipitous drops in salinity as recorded at GBRA1 may be explained by shifts in freshwater a plume moving through the bay. Freshwater currents will hug the western edge of San Antonio Bay; if these currents shift towards the bay center, then they would influence sonde readings. The precipitous drops in salinity are very possibly measurements of a real phenomenon that the model isn't capturing.


# Comments on SAGES Final Report

From: Mr. Kirkwood, concerned citizen

# Comments on the SAGES Conclusions

I have been an interested and frequent observer of whooping crane activities at Aransas National Wildlife Refuge (ANWR) since 2001. For most of that period (2002 through 2008), I have led tours 6 days per week from November through March to the refuge on board the tour boat Wharf Cat to observe the birds. The winter of 2009, I led tours 3 days per week. During this entire period I have closely observed activities of the birds, conducted extensive readings of the available literature, and had personal exchanges with such crane experts as Tom Stehn, USFW Whooping Crane Coordinator and George Archibald, PHD, co-founder of the International Crane Foundation and known globally as the world's leading scientific authority on cranes.

I find that the conclusions of the SAGES report are inconsistent with the body of knowledge existing about the whooping cranes and inconsistent with my own personal observations.

During the period of the SAGES study, historical drought extremes did not occur. During this last winter (2008-2009), there was little or no rainfall on either ANWR or in the watershed of the Guadelupe/San Antonio River complex. This lack of fresh water resulted in much higher salinities than were considered in the report. As a result, almost no Carolina wolfberries were available to the cranes upon their arrival. This lack of wolfberry fruit correlates with the wolfberry model of the study. What the study did not do is extend the impact of a wolfberry crop failure to the survivability of the whooping crane. The wolfberry is extremely important in order to replace the fat loss whooping cranes experience on their 2500-mile migration from Canada to the Gulf of Mexico. If that boost in nourishment is not available to them, then the impact of any subsequent reduction in food availability is magnified.

The study conclusion that blue crab availability should increase with higher level salinities is also inconsistent with the literature and my observations. The <30mm crab sizes that were the focus of the study are much smaller than those I observe the whooping cranes eating. I estimate that the crabs I see the cranes eating are 60mm or larger. It is this size crab that the cranes depend on to build up their energy reserves for the journey back to Canada and for the summer nesting season. During the winter of 2008-2009, crabs of this size were almost nonexistent. I seldom saw cranes finding and eating crabs of this size all winter long. My observations are consistent with the observation of others who have witnessed the cranes foraging through this and previous drought years.

Furthermore, the SAGES study did not account for the additional energy the cranes require to forage during seasons of low blue crab availability. If the crabs are not available in the shallow water ponds of the marshes, then they are not available to the cranes even if they are abundant in the deeper water. Whooping cranes are bottom foragers. When they are in the deeper waters of the bay, they are not searching for crabs, which are not on the bottom in that habitat, but for clams and other bottom dwellers. These resources may supply biomass, but they do not supply much energy to the cranes. Consequently, the cranes resort to foraging the uplands for reptiles, small mammals, nuts, acorns, and other vegetative matter. The travel to the uplands from the wetland territories and back uses energy that is barely replenished by the forage provided by the upland terrain.

As important, the SAGES study did not address the cranes requirement for drinking water. The cranes can drink water with salinities usually present in their home territories. They cannot drink water at the much higher salinities seen this last winter. This last winter, the cranes had to travel to fresh water ponds and tanks inland for water. This additional travel not only used energy they could ill afford, but it also exposed them to predation by the larger predators that live on ANWR around the fresh water ponds.

The winter of 2008-2009 was the worst winter for the whooping cranes since records have been kept. I observed many cranes visibly emaciated and lethargic. Some were crippled or sick. Twenty-three died. This is the largest number and the highest percentage of the flock to die since USFW has been keeping records.

In conclusion, the SAGES study is seriously flawed because it does not consider abnormal climate conditions, focuses on the wrong segment of the crab population, does not consider the importance of the wolfberry crop to the cranes on their arrival at ANWR, does not account for the additional energy required by the cranes to find and consume alternative forage, and disregards the impact of the availability of drinkable water on the cranes. The conclusions drawn by the study are neither consistent with prior studies nor with observations made by competent observers in the field.