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.

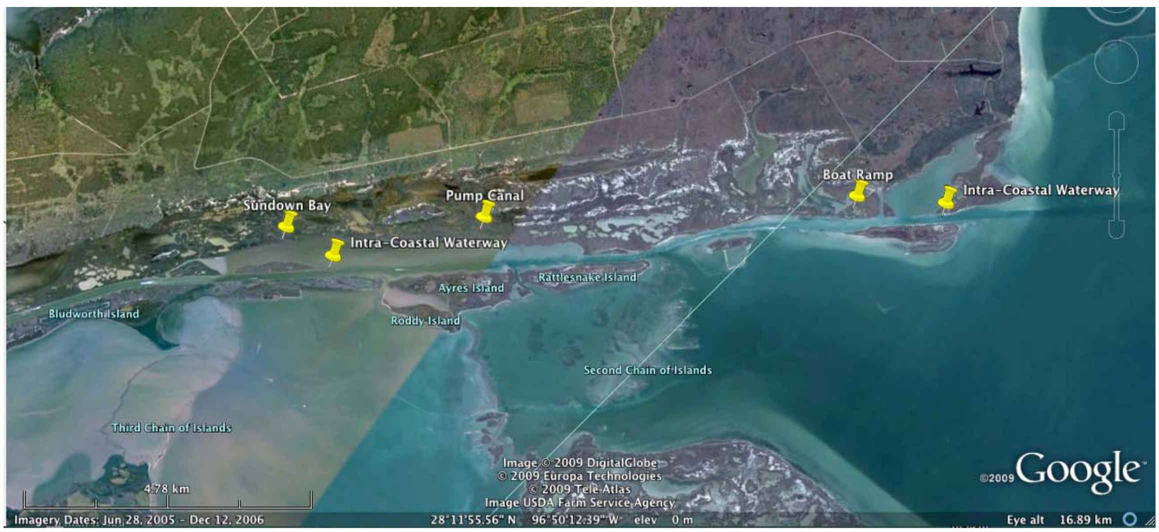
The relationship between river inflow and bay salinity is of key importance in defining the link between freshwater inflows and the well being of the whooping crane. Therefore it should be very carefully measured and modeled. The experimental relationship between salinity at GBRA 1 and the 28-day cumulative 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.