



June 8, 2009

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Mr. Steve Raabe, Director of Technical Services
San Antonio River Authority
100 East Guenther Street
San Antonio, Texas 78204

Dear Mr. Raabe: *Steve*

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.

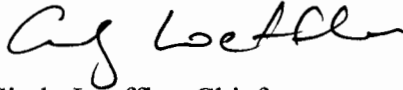
The initial interpretations and publicity regarding the SAGES study have surprised, and perhaps even alarmed, many in the scientific, regulatory, and conservation communities. Specifically, statements such as "In summarizing the study, researchers commented that in nearly all conditions simulated, the 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.

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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,

A handwritten signature in black ink, appearing to read "Cindy Loeffler". The signature is fluid and cursive, with the first name "Cindy" written in a larger, more prominent script than the last name "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 Pugsek 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.