10 August 2009

We received numerous comments on the SAGES report during the public comment period. The comments were very detailed and we would to thank those individuals that provided us with feedback for taking the time to provide such a thorough review of our study.

The majority of the comments of the SAGES report focused on two themes: (1) our results are contrary to what has been observed historically (we received numerous comments focusing on our analyses of the relationship between blue crabs and the environment) and (2) our simulation model fails to address the conditions observed in 2008. Below we provide a general summary as well as a detailed response to the criticisms we received from the United States Fish and Wildlife Service.

General statements

As guided by the peer review team in its study design, the SAGES team chose to focus on (1) the ecology of key crane foods (blue crabs and wolfberries) and how environmental factors influenced the abundance and distribution of these foods, and (2) the behavioral and foraging ecology of cranes. The study design was guided and focused by a team of experienced scientists from the throughout the U.S. whose expertise included most aspects of crane and estuarine ecology. Indeed, the SAGES research group was charged by the external reviewers with conducting intensive field-based studies to provide the fundamental foundation for the development of a simulation model. Our overall objective was to gather new data regarding marsh dynamics at ANWR and to analyze those data using current statistical methodologies and state-of-the-art computer modeling.

We would like to clear up the confusion regarding the relationship between the empirical studies (Appendix A) and the simulation model (chapter 3). The overall objective of the empirical studies was to collect and analyze new field data collected at ANWR and within San Antonio Bay during the 4 year field study. The results from the empirical studies have added considerably to the knowledge of the greater San Antonio Bay ecosystem. The team identified several key relationships among environmental variables and marsh components. The team's results showed a clear effect of river inflows on water quality patterns across 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. Freshwater inflow was strongly, inversely correlated with bay salinity: as freshwater inflow decreased, bay salinity increased. Patterns of salinity in San Antonio Bay were also strongly correlated with salinities in the tidal creeks of Blackjack Peninsula and therefore bay salinity can be used as an indicator of marsh salinity. Results from both field and laboratory experiments indicated salinity was an important factor in wolfberry fruit production. More specifically, salinity immediately prior and leading up to the late summer leafing period was inversely correlated with peak wolfberry abundance. At the ecosystem level, the team found that blue crab abundance was significantly correlated with three abiotic factors: bay water level, wind speed as measured in the bay, and bay salinity. In addition to blue crabs and wolfberries, the team documented the frequencies that whooping cranes consumed food items, including wolfberries, blue crabs, snails, insects, snakes, fish and clams, and that whooping cranes spend approximately 65% of daylight hours foraging. Human disturbance did not appear to detrimentally affect foraging behavior.

The objective of the simulation modeling project was to develop a simulation model based on the results of our empirical studies that related freshwater inflows into San Antonio Bay to wolfberry and blue crab abundances to whooping cranes in salt marshes of ANWR. The relationships established through the empirical studies were used to develop a quantitative, systems-level simulation model that was used to determine the impacts of freshwater inflows on whooping crane energetics. Obviously, we do not view our quantitative model as all-inclusive, but rather, as a useful simplification of a complex system, which focuses attention on evaluating the most likely links between inflow and cranes that could be explored with the resources at our disposal.

The simulation model presented in this report is based on statistical correlations between our field data and environmental factors of the greater San Antonio Bay ecosystem. We focused our analyses on correlating the patterns observed in wolfberry and blue crab densities during our study to environmental factors that occurred during the same time period (that is, 2003-2006). As with any quantitative modeling approach, our equations can best predict the dynamics of food abundance during time periods when environmental conditions are similar to those that occurred during our study. This is not to say that the model cannot be used to extrapolate marsh dynamics for environmental conditions not observed during our study. However, it is important to understand that our confidence in model predictions is highest when simulating environmental conditions similar to those under which model equation were derived, and, as with any model, decreases when simulating environmental conditions very different from those observed during our field study.

The San Antonio Bay-Guadalupe estuary is a complex ecosystem. This study elucidated several of the previously poorly-quantified relationships among marsh components and the greater ecosystem. As we stated in chapter three, we do not view our model as all inclusive, but rather as a useful simplification of a complex system which focused on evaluating the most likely links between inflow and cranes that could be explored with the resources at our disposal. Further, we believe the first step in approaching any complex issue, is to understand the system. This study has significantly increased the state of knowledge of the San Antonio Bay ecosystem, the links between the estuary and bay, and the dynamics of two important food items of whooping cranes.

General Response to Blue Crab data collection and analyses

The main objective of our blue crab studies was to understand the year-round dynamics of blue crabs within the marshes of ANWR. We chose to sample crabs at 3 territories and considered each territory to be composed of 3 different habitat types: (1) bay-marsh interface (referred to as *bay* in our report), (2) connected ponds and (3) unconnected ponds. For each habitat type within each territory, four trapping locations were randomly chosen during each sampling period (refer to Figure 1 in this document for a map of our sampling locations). During each sampling period, we recorded a suite of local environmental factors, which are described in detail in empirical study # 7 in the SAGES report. We also retrieved data on regional environmental variables from several gauges (refer to section 3.1 in the SAGES report for the links to the websites). Our methods involved sampling within the waters of the marsh using custom-designed boom rigs as well as stainless steel drop traps (Figure A7 in SAGES report). Crab sampling occurred monthly during 2004, 2005 and 2006 and we collected 915 samples during this time period. Our sample size was more than adequate to develop predictive models for blue crabs. Crabs that were captured were placed in formalin and transported back to the laboratory where the analyses were completed. In the lab we took standard measurements for each crab (including carapace width). We divided the crabs into 10 mm size classes and determined the abundance of each size class per sampling period (month) as well as year.

In order to determine quantitatively the relationships between blue crab abundance and environmental factors, we used an information-theoretic approach (for detailed description of the method, please refer to Burnham and Anderson, 2002) to formulate ecologically-interpretable hypotheses (i.e., statistical models). We did not assume a directional relationship between environmental factors and crab abundance – neither the value nor direction (positive or negative) of the coefficients in our equations was chosen by any member of the team. We chose a set of factors we felt were causally-related to variation in crab numbers. Salinity, among many others, was considered a factor (empirical study # 7 in the SAGES report). Using established statistical methodologies, specifically generalized linear mixed models, we tested numerous hypotheses that related environmental/habitat conditions to blue crab abundance. Coefficients for these models were estimated using maximum likelihood techniques within the statistical software used (in this case, PROC GLIMMIX in SAS).

Our results indicated that blue crabs have a complex, non-linear relationship with spatial location, habitat type, salinity, wind speed and water level. Simpler models failed to explain the variation in crab numbers. Within our multivariate model, salinity was a statistically significant factor, and was positively correlated with blue crab abundance, however, it is important to note that our model is not a single-factor model and contains four other variables that act synergistically with salinity to explain the abundance and distribution of blue crabs. Coefficients for a single variable cannot be interpreted alone, rather the entire predictive equation must be interpreted as an undividable entity.

Our sensitivity analysis of model parameters (Table 3.3 in the SAGES report) indicated that, compared to all of the other variables in the equation, salinity was the least important. In fact, doubling salinity (that is, a 100% increase in salinity), holding other parameters constant, resulted in an increase of less than 1 crab / m^2 (Table 1, this document). Water level was the most important continuous variable in our equation. Simulating a 100% increase in water level, holding other parameters constant, resulted in a 300% increase in simulated blue crab abundance.

The relationship between the distribution and abundance of blue crabs and the environment is complex (Guillory et al., 2001). Blue crab distribution and survival have been reported to be affected by several factors including salinity (which is the relationship most often explored), water temperature, water circulation, tides, bottom substrate, predation, habitat loss, food availability, inter- and intra-specific competition, among others (Livingston et al., 1976; Daud, 1979; Laughlin, 1979; Van Engel, 1982; Heck and Cohen, 1995; Guillory et al., 2001). The diversity of possible factors, as well as possible synergistic effects among factors, makes precise identification of the influence of specific variables difficult (Guillory et al., 2001).

Several previous studies have focused on the relationship between blue crabs and salinity, but a consensus regarding the exact effects of salinity on the distribution of blue crabs has not been reached. Daud (1979) found small blue crabs (5-10 mm CW) in shallow brackish waters and larger size classes in fresher waters. Perret et al. (1971) and Swingle (1971) noted that maximum blue crab abundance was at salinities less than 5 ‰, which contradicts the results of Christmas and Langely (1973) and Perry and Stuck (1982), who both found highest abundances at salinity above 14.9 ‰, with abundance decreasing when salinities were above 25 ‰. Hammerschmidt (1982) was unable to correlate blue crab catch data and salinity. Walther (1989) found a negative correlation between blue crab catch and salinity. The blue crab commercial harvest in the Guadalupe estuary did not have a significant relationship with salinity (Texas Department of Water Resources, 1980). Pugesek et al. (2008) estimated blue crab abundance at Aransas National Wildlife Refuge by walking transects and were unable to develop a significant relationship with salinity, water level, habitat type, or distance to open water. In laboratory studies, growth rates (Cadman and Weinstein 1988) and percent survival (Guerin and Stickle 1997) of juvenile blue crabs generally increased with salinity, but the effect of salinity on growth was minimal in comparison to that of temperature.

The mixed results and breadth of the aforementioned studies indicates that the relationship between blue crabs and the environment is complex and depends upon the interactions among many different variables. The results from our study agree with Guillory et al., (2001) in that blue crab abundance is best explained by a suite of environmental factors that cannot be simplified into single-factor predictive models.

Figure 1. Map of blue crab sampling locations for Boat Ramp, Pump Canal, and Sundown Bay (Pipeline).

Table 1. Influence of environmental parameters on changes in maximum and minimum simulated daily blue crab density for each habitat type (*HT*) within each of 3 whooping crane territories. *Base* represents simulated daily blue crab density at baseline levels (no adjustment to Eq. 3 from SAGES report). *Inc.* represents simulated values when (a) salinity, (b) water level and (c) wind velocity were independently increased by 100%, holding other parameters constant at baseline values. *Diff.* is the difference between *Baseline* and *Increase* and *% change* represents the percent change between the two. Refer to SAGES report pp. 48, 53-55 for more details.

(a) Salinity

		Maximum				*Minimum*			
Territory	HT	Base	Inc.	Diff.	% change	Base	Inc.	Diff.	%change
Boat Ramp	Bay	11.65	12.47	0.82	7.04%	2.38	2.71	0.33	13.87%
	CP	4	4.28	0.28	7.00%	0.82	0.93	0.11	13.41%
	ICP	3.36	3.6	0.24	7.14%	0.69	0.78	0.09	13.04%
Pump Canal	Bay	12.93	13.84	0.91	7.04%	2.64	3.01	0.37	14.02%
	CP	4.44	4.75	0.31	6.98%	0.91	1.03	0.12	13.19%
	ICP	3.73	3.99	0.26	6.97%	0.76	0.87	0.11	14.47%
Sundown Bay	Bay	9.99	10.7	0.71	7.11%	2.04	2.33	0.29	14.22%
	CP	3.43	3.68	0.25	7.29%	0.7	0.8	0.1	14.29%
	ICP	2.88	3.09	0.21	7.29%	0.59	0.67	0.08	13.56%

(b) Water Level

		Maximum				*Minimum*			
Territory	HT	Base	Inc.	Diff.	% change	Base	Inc.	Diff.	%change
Boat Ramp	Bay	11.65	49.08	37.43	321.29%	2.38	2.54	0.16	6.72%
	CP	4	16.86	12.86	321.50%	0.82	0.87	0.05	6.10%
	ICP	3.36	14.16	10.8	321.43%	0.69	0.73	0.04	5.80%
Pump Canal	Bay	12.93	54.45	41.52	321.11%	2.64	2.81	0.17	6.44%
	CP	4.44	18.7	14.26	321.17%	0.91	0.97	0.06	6.59%
	ICP	3.73	15.71	11.98	321.18%	0.76	0.81	0.05	6.58%
Sundown Bay	Bay	9.99	42.1	32.11	321.42%	2.04	2.18	0.14	6.86%
	CP	3.43	14.46	11.03	321.57%	0.7	0.75	0.05	7.14%
	ICP	2.88	12.14	9.26	321.53%	0.59	0.63	0.04	6.78%

(c) Wind Velocity

		Maximum				*Minimum*			
Territory	HT	Base	Inc.	Diff.	% change	Base	Inc.	Diff.	%change
Boat Ramp	Bay	11.65	5.6	-6.05	-51.93%	2.38	0.22	-2.16	-90.76%
	CP	4	1.92	-2.08	-52.00%	0.82	0.08	-0.74	-90.24%
	ICP	3.36	1.61	-1.75	-52.08%	0.69	0.06	-0.63	-91.30%
Pump Canal	Bay	12.93	6.21	-6.72	-51.97%	2.64	0.25	-2.39	-90.53%
	CP	4.44	2.13	-2.31	-52.03%	0.91	0.08	-0.83	-91.21%
	ICP	3.73	1.79	-1.94	-52.01%	0.76	0.07	-0.69	-90.79%
Sundown Bay	Bay	9.99	4.8	-5.19	-51.95%	2.04	0.19	-1.85	-90.69%
	CP	3.43	1.65	-1.78	-51.90%	0.7	0.07	-0.63	-90.00%
	ICP	2.88	1.38	-1.5	-52.08%	0.59	0.05	-0.54	-91.53%

HT = Habitat type, Base = baseline values, Inc. = increasing parameter by 100%, Diff. = difference between simulations, % change = % change between baseline and Inc. simulations

General response to energetics

We calculate the abundance of two food resources at ANWR: ripe wolfberry fruit and blue crabs. We predict the density of wolfberries and blue crabs from the predictive equations described in sections 3.1.2 and 3.1.3, respectively. We convert these densities into abundances values (# of food items per territory) and then convert the abundances into energy (kcal/territory) based on the calculations of Nelson (1996). A detailed description of our energetics calculations follows below. We compare the energy present on the marsh to an estimate of daily energy required for four adult whooping cranes to determine if there is enough energy present on the marsh to meet the daily requirement of these cranes.

At the onset of the SAGES study, the SAGES team, at the advice of the peer review advisory board, focused its resources on the two aforementioned food resources, and therefore our simulation model only includes wolfberries and blue crabs. During our final year of the study, we captured very few blue crabs, and our model simulates this trend well (Figure 3.11, SAGES report). Our model indicates that there was enough energy present in blue crabs to sustain the whooping cranes on each of our study territories, yet our foraging data indicate that whooping cranes consumed few blue crabs (Figure 2, this document). Our results may seem contradictory, but we feel they are grounded in ecological theory, specifically optimal foraging theory (Stephens and Krebs, 1986). Briefly stated, assume a predator (in this case, a whooping crane) maximizes the net rate of energy gain while foraging. If a particular food resource is rare, then the predator will have to expend more energy searching for that food resource, whereas it could be consuming food resources that are more readily available and ultimately have a net energy gain. Our foraging results (a separate data set than the blue crab sampling data, refer to empirical study # 9) showed that the dietary composition of whooping cranes varied between winters. During the first winter, blue crabs were 36.8% of the diet and only 5.9% of the diet during the second winter (Figure 2, this document). Our blue crab sampling data indicated that there were blue crabs on the marsh, but not in the numbers seen the year before. This indicates to us that whooping cranes would benefit by consuming other food items rather than spend time (and expend energy) searching for blue crabs. Blue crabs were present within the marsh of ANWR during the 2005-2006 winter, and according to our results, at levels that would sustain the cranes. However, we hypothesize that during the winter of 2005-2006, blue crabs were rare enough that whooping cranes would have had to spend more time, and thus energy, foraging for crabs, whereas other food items, albeit less energetically valuable, provided a larger net energy gain because they were more readily available in larger quantities.

Our estimate of daily whooping crane energy was 465 kcal per bird per day (Nelson, 1996). This estimate represents the cost of free existence and was calculated from Time Energy Budgets (TEB) of captive whooping cranes at Patuxent Environmental Science Center, Maryland, USA. This estimate provides a reasonable estimate for free living whooping cranes and has been validated by measurements of daily energy expenditure (DEE) for captive whooping cranes (Nelson, 1995).

Whooping crane wintering territories generally have either two adults or two adults plus a young-of-the-year. In order to take into account energy requirements of wild whooping cranes, we estimated that each territory contained 4 adults, thereby creating an energy requirement of 1860 kcal/day per territory (4 birds* 465 kcal/day). If there were only 2 birds on a territory, our daily energy estimate per bird would be 930 kcal/day (i.e., 1860 kcal/day / 2 whooping cranes = 930 kcal/day per bird). If there were 3 birds on each territory, our energy estimate per bird was 620 kcal / day (i.e., 1860 kcal/day / 3 whooping cranes= 620). During our study, the following number of whooping cranes occupied our territories:

2003-2004
- Boat Ramp: 2 adults
- Pump Canal: 2 adults
- Sundown Bay: 3 birds (2 adults and 1 juvenile)

2004-2005
- Boat Ramp: 3 birds (2 adults and 1 juvenile)
- Pump Canal: 3 birds (2 adults and 1 juvenile)
- Sundown Bay: 2 adults

2005-2006
- Boat Ramp: 3 birds (2 adults and 1 juvenile)
- Pump Canal: 2 adults
- Sundown Bay: 3 birds (2 adults and 1 juvenile)

According to field data collected by Chavez-Ramirez (1996), the average daily energy expenditure (DEE) for an 11-month period (October 1992 through April 1993, October and December 1993, January and March 1994) was 604.74 kcal/day[1]. It is important to note that Chavez-Ramirez's (1996) data were recorded during a non-high mortality year (1992-1993) and a high mortality year (1993-1994) (Nelson, 1996; T. Stehn, pers. comm.). The SAGES study had two non-high mortality years (2003-2004, 2004-2005) and one high mortality year (2005-2006). Note that we are specifically referring to high mortality as over-wintering mortality events when greater than 2.7% of the flock die.

When three birds are on a territory, our estimate is comparable to the daily energy expended as observed in the field (Chavez-Ramirez, 1996) (i.e., 620 kcal/day compared to 604 kcal/day). If two birds are on a territory, our estimate is 326 kcal/day more than the mean daily energy expended by whooping cranes as estimated by Chavez-Ramirez (1996).

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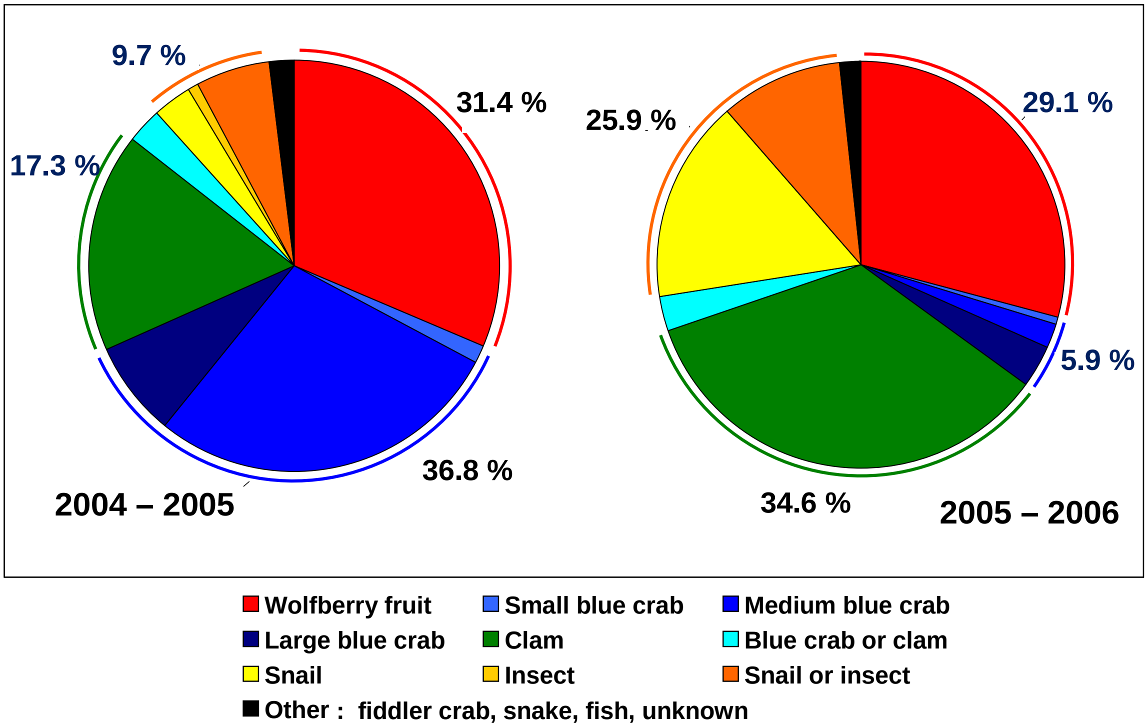
[1] Chavez-Ramirez reported values in kilojoules (kj). We converted kj into kilocalories (kcal) using the conversion: 1 kcal = 4.1868 kj

Figure 2. Whooping crane diet during two winters 2004-2005 and 2005-2006. Note the increased use of clams during the second winter.



Literature Cited:

Adkins, G. 1972. Study of the blue crab fishery in Louisiana. Louisiana Wildlife and Fisheries Commission, Technical Bulletin 3, 57 pp.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York.

Chavez-Ramirez, F., 1996. Food availability, foraging ecology, and energetics of whooping cranes wintering in Texas. Ph.D. Dissertation, Texas A & M University, College Station, Texas.

Christmas, J. Y., Jr. and W. Langley. 1973. Estuarine invertebrates, Mississippi. Pp. 255-317. in J.Y. Christmas, Jr. (ed.), Gulf of Mexico Estuarine Inventory and Study, Mississippi. Gulf Coast Research Laboratory.

Daud, N. M. B. 1979. Distribution and recruitment of juvenile blue crabs, *Callinectes sapidus*, in a Louisiana estuarine system. M.S. Thesis. Louisiana State University, Baton Rouge.

Grimm, V. G. 1999. Ten years of individual-based modelling in ecology: what have we learned and what could we learn in the future? Ecological Modelling 115:129-148.

Guerin, J. L. and W. B. Stickle. 1997. A comparative study of two sympatric species within the genus *Callinectes*: osmoregulation, long-term acclimation to salinity and the effects of salinity on growth and moulting. Journal of Experimental Marine Biology and Ecology 218:165-186.

Guillory, V., H. Perry, P. Steele, T. Wagner, W. Keithly, B. Pellegrin, J. Peterson, T. Floyd, B. Buckson, L. Hartman, E. Holder, and C. Moss. 2001. The blue crab fishery of the Gulf of Mexico, United States: A regional management plan. Gulf States Marine Fisheries Commission. Ocean Springs, MS.

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.

Heck, K. L. and L.D. Coen. 1995. Predation and the abundance of juvenile blue crabs: A comparison of selected east and Gulf Coast (USA) studies. Bulletin of Marine Science 57:877-883.

Hunt, H.E. and R.D. Slack. 1989. Winter diets of whooping and sandhill cranes in South Texas. Journal of Wildlife Management 53:1150-1154.

Laughlin, R. A. 1979. Trophic ecology and population distribution of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola estuary, (North Florida, U.S.A.). PhD Dissertation. Florida State University, Tallahassee.

Livingston, R. J., G. J. Kobylinski, F. G. Lewis, III, and P. F. Sheridan. 1976. Long-term fluctuations of epibenthic fish and invertebrate populations in Apalachicola Bay, Florida. Fishery Bulletin. 74:311-321.

Nelson, J. T. 1995. Nutritional quality and digestibility of foods eaten by whooping cranes on their Texas wintering grounds. M.S. Thesis. Texas A&M University, College Station, Texas.

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. pp. 39-105 in Cooperative Gulf of Mexico Estuarine Inventory and Study. Phase IV. Biology. Louisiana Wildlife and Fisheries Commission.

Perry, H. M. and K. C. Stuck. 1982. The life history of the blue crab in Mississippi with notes on larval distribution. pp. 17-22 92 in H.M. Perry and W.A. Van Engel (editors). Proceedings of the blue crab colloquium. Gulf States Marine Fisheries Commission Publication 7.

Pugesek, B.H., M. J. Baldwin and T. V. Stehn. 2008. A low intensity sampling method for assessing blue crab abundance at Aransas National Wildlife Refuge and preliminary results on the relationship of blue crab abundance to whooping crane winter mortality. Proceedings of the tenth North American Crane Workshop. Pp. 13-24.

Stephens, D.W. and J. R. Krebs. 1986. Foraging Theory. Princeton University Press. Princeton, NJ. 247 pp.

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

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

Van Engel, V.W. 1982. Blue crab mortalities associated with pesticides, herbicides, temperature, salinity, and dissolved oxygen. Pp. 89-92 in H.M. Perry and W.A. Van Engel (editors). Proceedings of the blue crab colloquium. Gulf States Marine Fisheries Commission Publication 7.

Walther, D. 1989. The influence of salinities in lower Barataria Bay upon year class strength of the blue crab, *Callinectes sapidus*. Louisiana Department of Wildlife and Fisheries, Unpublished Report, 25 pp.

<u>Response to Comments from Mr. Tom Stehn of U.S. Fish and Wildlife Service</u>

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

We collected field data at ANWR from 2003-2006. Our field studies and subsequent statistical analyses were designed using accepted methodologies. Our statistical analyses found significant correlations between inflow and bay salinity, summer salinity and peak wolfberry abundance, and crab abundance and 5 environmental factors. These correlations were calculated using the environmental conditions we observed during our study. Our study is not contrary to traditional viewpoint, rather, our analyses provided unique quantitative insights into the dynamics of the greater San Antonio bay ecosystem that occurred during the time period of our study. We do not view these studies as all inclusive, rather we view our work as a crucial step in understanding the complexity of the greater San Antonio Bay ecosystem.

A correlation has been noted between winters of high whooping crane mortality (1998, 1989, 1990, 1993, 2001, 2005, 2008) and low river inflows on the Guadalupe below the level of 1.3 million acre-feet recommended by TPWD require for a healthy bay/estuary system (R. Sass, Professor of Natural Sciences, Emeritus, Rice University, unpublished data)

It is important to understand that the SAGES study does not attempt to relate low inflows to whooping crane mortality. Specifically, the SAGES simulation model (chapter 3 in the SAGES report) simulates changes in peak wolfberry density and daily blue crab density, converts those food resources to energy (in kilocalories) and compares the amount of energy present on three whooping crane territories to the daily energy requirement of 4 adult whooping cranes. In the simulation model, food abundances were calculated from equations that statistically correlated food abundance to environmental factors (see chapter 3 for specific equations). The daily energy requirement was calculated by Nelson (1996). It also is important to note that while our study used bay salinity as a predictor variable, we did not have data to demonstrate whether bay salinity is a direct causal factor relating to wolfberry and blue crab abundance, or instead an indicator of drought conditions that directly impact the marsh habitat

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

Our field study ended in 2006 and we finished our statistical analyses and modeling efforts in 2008, and we did not collect data or simulate conditions past the 2007 winter. Inferences regarding our model predictions beyond this date remain conjecture. We focused our analyses on correlating the patterns observed in wolfberry and blue crab densities during our study to environmental factors that occurred during the same time period (2003–2006). As with any quantitative modeling approach, our equations can best predict the dynamics of food abundance during time periods when environmental conditions are similar to those that occurred during our study. This is not to say that the model cannot be used to extrapolate marsh dynamics for environmental conditions not observed during our study. However, it is important to understand that our confidence in model predictions is highest when simulating environmental conditions similar to those under which model equation were derived, and, as with any model, decreases when simulating environmental conditions very different from those observed during our field study. During the 2005-2006 winter, our model predicted low abundances of blue crabs and wolfberries, which were the conditions observed in the field.

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

The methods we used to collect blue crabs in the marshes of ANWR were quite different than Pugesek et al. 2008. Below we provide a comparison of our blue crab study to that of Pugesek et al. 2008. Please refer to our general response on our blue crab study for detailed description of our study design.

Pugesek et al. (2008) used transects and sighting methods to estimate blue crab abundance in the whooping crane territories at ANWR. They sampled three 1200-1400m transects, separated into 100 m sections, by walking the transects, tallying the blue crabs they saw in each 100 m section and estimating the carapace width of each crab. For any given section, the minimum visibility required to collect crab count data was that the substrate could be observed at 0.6m or more from the bank and data were only collected when water levels were within a range of 0.5m – 0.8m mean low tide.

From Pugesek et al. (2008):
Salinity was related to crab abundance in only a minor way in one year (p. 21)
Our finding of a weak relationship between crab abundance and salinity is likely due to restricted sampling conditions (p. 21)

Pugesek et al. (2008) hypothesized that the lack of a strong relationship was due to restricted sampling, but our data, which were gathered using a more robust design, indicate that the relationship between blue crabs and salinity may not be a result of limited sampling design. Our results further illustrate that salinity is (1) only part of a complex suite of environmental factors that affect blue crabs and (2) is not the most important factor, given the suite of other factors. Table 1 in the general response section quantitatively illustrates the effect of changing parameter values has on blue crab abundance. In our equation, water level has the strongest effect on blue crab abundance.

From Pugesek et al. (2008):
Little evidence was found linking water temperature to crab abundance (p. 21)

Likewise, our model selection procedure did not indicate that water temperature was a factor that best explained our data.

From Pugesek et al. (2008):
Habitat type and distance to open water were not found to affect crab abundance (p. 21)

Unlike Pugesek et al. (2008), we found that habitat type was an important factor in estimating blue crab abundance at ANWR. Given the other factors in the model, blue crabs the bay-interface habitat type had the most crabs, the connected ponds were next and unconnected ponds were the least important habitat type.

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(…)… Blue crabs appear to be the most important source of energy for wintering whooping cranes…

The comments associated with this bullet point focus on the relationship between blue crabs and whooping cranes. We agree with Mr. Stehn that blue crabs are an important food item, however, our study is not in direct conflict with previous studies. Our study represents a snapshot of what was occurring at ANWR during the time period of our study (2003-2006). Whooping crane behavior and food consumption was recorded during two winters (2004-2005 and 2005-2006). Over these two winters, we recorded over 700 hours of footage in both winters with a spy camera attached to a 2000 mm telephoto lens (refer to page 137 in the SAGES report). Our observations showed that during the first winter (2004-2005), blue crabs were 36.8% of the whooping cranes' diet (see Figure 2 in the general response section). During winter two, cranes did not eat as many crabs (5.9%), which indicates that blue crabs were not abundant in the marsh (as evidenced by both our study and Pugesek et al. (2008). As noted in previous studies, whooping cranes are omnivores and their diet consists of consume several other food items (Hunt and Slack, 1989; Chavez-Ramirez, 1996; Nelson 1996). Our study indicates that the winter of 2005-2006 was not a bountiful year for crabs and whooping cranes foraged for other food items.

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

…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.

These are excellent suggestions for future research. We would like to comment on developing these models: Our results indicate that that the issues facing whooping cranes are more complex than an inflow-salinity-crane model. As evidenced by the analyses of our blue crab data, the relationship between blue crabs, an important whooping crane resource, and the environment is non-linear and complex. Our results indicate that simple models cannot provide the best answers to the issues facing whooping cranes. The greater San Antonio Bay ecosystem is complex and we believe that our study provides a crucial step in understanding its dynamics, which is crucial if the greater San Antonio Bay ecosystem is going to be managed successfully. Moreover, one hypothesis is that it is drought impacts directly on the marsh that affects cranes more than salinity in the bay. If so, then correlating inflows with crane mortality would not represent a causal relationship

(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!

Please refer to the general response section for a detailed description of our approach to analyzing our blue crab data. Briefly, the relationship between salinity and crab abundance was positive because that was the quantitative relationship that best described the data. The specific quantitative relationships between environmental variables and blue crab abundances were not a priori assumptions.

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

Our analyses of microhabitat characteristics indicated that sea grass and algae affected blue crab abundance. We agree that future research should determine the impact of hydrology (and salinity) affect these vegetative types.

(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.***

We agree that this is a good suggestion for future research. We do feel that one of the biggest priorities for future research is developing a better understanding of the underlying hydrology of the marsh, including hydrological connectivity of unconnected ponds. By understanding the dynamics of water moving into and out of the marsh, scientists could then begin to develop relationships between connection periods and salinity of unconnected ponds and further understand how whooping crane food resources change over time (i.e., under different hydrological patterns).

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

We disagree with this statement. We estimated the abundance of blue crabs from 11-30 mm, which are smaller than whooping cranes eat, but given the rapid growth (14 mm / month, Adkins 1972), we assumed it provided a good estimate of recruitment into the size class that whooping cranes eat. We do not view this as a misuse of data because we provided ecologically sound reasoning and were quite transparent with our assumptions.

(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.***

As we have emphasized previously, we do not view the interactions in the model as all inclusive, but rather, as a useful simplification of a complex system. Thus, we expect the model is capable of representing general trends resulting from interactions among the simulated environmental variables over the ranges of these variables close to those we observed in the field. Of course, a primary use of the model is to simulate system dynamics over a broader range of conditions than we were able to observe in the field, as we do in section 3.4 of the report. But, it is extremely important to understand that our confidence in model predictions decreases when simulating conditions very different from those observed during our field study.

Based on our results, we are confident in out model's ability to reproduce general trends in marsh dynamics. Low wolfberry and low blue crab years that were observed in the field were also predicted by the model (Figures 3.10 and 3.11).

We agree that sediments, nutrients and organic matter brought by inflow to the Guadalupe estuary are important components of the system. This project was not designed to address sediment/nutrient loads of inflows into San Antonio Bay. This will be addressed by the Estuarine Response Project (ERP) by Dr. George Ward of the University of Texas.

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

Wolfberry plants fruit in mid-October and the fruits are gone by the end of the calendar year (Godfrey and Wooten, 1981). This temporal variability is captured in the model. Our predicted blue crab abundance does change daily, so temporal variability is captured there as well. Further our predicted values of blue crab abundance decrease seasonally (Figure A12 in the SAGES report), decreasing in early winter of each year.

(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***

Our conclusion regarding reducing the amount of potential wolfberry habitat in the whooping crane territories was that the reduction in wolfberry habitat did not reduce the daily energy present on the marsh below that of 4 adult whooping cranes. Our results indicated that energy present in blue crabs exceeded the daily energy requirements of 4 adult whooping cranes.

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

Mr. Stehn is correct. We did not analyze the energetic costs of cranes being forced to leave the salt marsh to drink. We think this is an excellent suggestion for future research.

Please refer to our general response section for a description of our energetics calculations.

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

We agree that this should be considered for future research.

(15) Peer review of the SAGES study was inadequate

The scope of peer review team was in study design, not review of the results, which are entirely empirical.

(16) *This 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.

This is an error on our part. We will correct the diagrams.

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.

It is important to consider the spatial scale of the SAGES model. We do not disagree that fish can make the water more turbid, but we feel at the spatial scale in which we are interested (i.e., ecosystem scale) that windspeed is a process that contributes significantly to turbidity at a large spatial scale.

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.

This is an error on our part – an artifact of an earlier draft that did not get removed. We simulated the Boat Ramp territory considering the large lake. This will be corrected in the final version.

p. 54 – The date selected by SAGES for whooping crane arrival (October 16) is actually the average date for the <u>first</u> 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.*

We agree that this is an inconsistency. We wanted to simulate conditions that captured time periods when cranes were present. We chose 16 October because that is when cranes are present at the marsh, that is, when cranes begin utilizing food resources at ANWR. We chose 7 April because that represented a date when the majority of the cranes have left. Future modeling efforts should include simulating conditions through April when all the cranes, rather than a majority, have left.

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).*

We agree that future research should include determining how to best understand the dynamics of larger-sized blue crabs.

Response to Blackburn Carter, P.C.

(1) ***In our opinion, the major problem with the SAGES study is the statistical relationships between salinity and blue crab abundance.***

Please refer to the general response section for a detailed description of our blue crab study design, analysis and conclusions.

From Blackburn Carter (p.3)
(2) ***The main problem with this study has to do with design. Although samples were taken monthly, only two and one-half years worth of data were 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 only represents two data points corresponding to two seasons during which crabs migrated into the bay. This is insufficient to develop the regressions presented in the study and overturn without even acknowledging the overwhelming contradictory finding of most other studies. Data for the periods when most crabs are off shore and spawning and drifting in as juveniles are not particular relevant to this analysis.***

We did not sample crabs in the fall of 2006. Our field-data collection for blue crabs ended in March of 2006. Our crab abundances were highest in the fall of 2005 (when inflows were not low and bay salinity (both predicted and observed) was between 15-20 ppt (SAGES report p. 47 [Fig. 3.9]).

Refer to our general response for a comparison of our work to preceding studies.

Other issues
(3) ***Inflow equation***
The inflow equation for SAGES correlates 28-day cumulative inflow from the Guadalupe and San Antonio Rivers with salinity at the GBRA1 gauge station. That is, our correlation includes inflows from the current day as well as the preceding 27 days. As stated in our report (SAGES report, p. 30) our equation does not suggest that a specific inflow causes an exact measure of salinity at GBRA1, only that our indicator of inflow (28-day cumulative inflow) is statistically correlated with salinity at GBRA1.

(4) ***Connectivity***
We agree with the reviewers that continued study of connectivity should be a priority for future research.

(5) ***Size class of crab***
We estimated the abundance of blue crabs from 11-30 mm, which are smaller than whooping cranes eat, but given the rapid growth (14 mm / month, Adkins 1972), we assumed it provided a good estimate of recruitment into the size class that whooping

cranes eat. Our report provided ecologically sound reasoning and we were quite transparent with our assumptions (SAGES report, p. 42)

(6) *Crane nutrition and energy budget*

Previous studies indicated that the major diet items of whooping cranes were wolfberries and blue crabs (Chavez-Ramirez, 1996; Nelson, 1996). At the onset of our study, we chose to focus our efforts on these two food items, recognizing that cranes did consume other foods. Unlike previous studies, which noted crane use of food items, our study provided unique insight into the frequency of other items in the whooping crane diet. Further, the SAGES study also showed that cranes consume other items in larger proportions than previously thought (based on over 700 hours of video footage shot with a spy camera and a 2000 mm lens). We agree with the reviewers that future research should involve more detailed analysis of the nutrition and energetic content of these other food items.

Please refer to our general response section for a description of our energetics calculations.

Response to Texas Parks and Wildlife

From TPWD Comments:
(1) Blue crab abundance as a function of bay salinity

Please refer to our general response for a detailed description of our blue crab study, analysis and conclusions.

(2) Marsh salinity as a function of bay salinity
From TPWD comments:
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.

In the SAGES model, we estimated wolfberry fruit based on a statistically significant correlation between mean summer salinity (calculated as the average of daily salinities from 1 June to 31 August) and peak wolfberry abundance. This relationship was non-linear (the relationship was an exponential decline).

We estimated blue crab abundance based on a non-linear correlation between blue crabs and 5 variables (territory, habitat type, 28-day mean salinity, 28-day mean water level, 28-day mean windspeed). We neither assumed nor suggested that 30 ppt was optimal salinity for blue crab abundance.

From TPWD comments:
Statements are made that "more crabs were found in bay than any other habitat" and "density was positively related to salinity", yet nowhere in the chapter are there any data correlating density or abundance with salinity.

Please refer to our general response section for a description of our blue crab study.

Our statistical correlation between blue crabs and the environment is composed of 5 explanatory variables: territory, habitat type, 28-day mean salinity, 28-day mean water level and 28-day mean windspeed (SAGES report, eq. 3). These parameters act synergistically and cannot be separated into single components. Given the other parameters in the model, salinity is positively related to crab abundance, however, of the parameters included in the model, salinity had the least amount of quantitative influence over the predicted abundance of blue crabs.

…The authors seem to imply that bay habitat has higher salinity…

We do not imply that the bay habitat has higher salinity. Given the other parameters in the equation, habitat type had the most quantitative influence over the predicted abundance of blue crabs. Figure A8 relates the number of blue crabs we captured during the field studies, divided by habitat type (the sampling unit). Equation 3 in the body of the SAGES report represents a statistical correlation between blue crabs and environmental factors.

(3) Alternate food sources
From TPWD comments:
The SAGES authors should address the inconsistency of their findings in relationship to existing research.

We have provided a detailed comparison of our study to previous research in the general responses.

We further agree that future research should focus on nutritional values of all potential whooping crane food items in the marsh.

(4) Energetics as a function of salinity
Competition for food resources

From TPWD comments:
The SAGES model does not consider ancillary energetic costs of high salinities
The SAGES study does not consider inter-specific competition for food resources

We agree that future research should include detailed empirical analyses of energetic requirements of free-living whooping cranes as well as study the impact of competitors on whooping crane food resources.

Please refer to our general response section for a description of our energetics calculations.

(5) Limited study period

From TPWD comments
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.

We recognize that our study did not occur during environmental extremes which can occur in the greater San Antonio Bay ecosystem. Our study represents a snapshot of what was occurring at ANWR during the time period of our study (2003-2006). We focused our analyses on correlating the patterns observed in wolfberry and blue crab densities during our study to environmental factors that occurred during the same time period. Our equations can best predict the dynamics of food abundance during time periods when environmental conditions are similar to those that occurred during our study. It is important to understand that our confidence in model predictions is highest when simulating environmental conditions similar to those under which model equation were derived, and, as with any model, decreases when simulating environmental conditions very different from those observed during our field study.

(6) Whooping crane foraging ecology: gains, costs, and efficiency of foraging during winter

From TPWD comments
TPWD staff recommends that the relationship between food items consumed and what was actually available should be examined as well as the composition of the cranes' diets each winter compared to the corresponding freshwater inflow

Our model predicts blue crab abundance in three whooping crane territories at ANWR. Currently, it is unknown what proportion of blue crabs is available to whooping cranes. We agree with TPWD staff that future research should include quantifying the availability of blue crabs to whooping cranes. Further, our analyses have indicated that the relationship between blue crabs and the environment is complex and we feel that a single factor relationship (blue crabs and inflow) may not capture the true dynamics of the ecosystem.

(7) Other information
The SAGES team did not take advantage of several existing sources of information regarding whooping crane mortality to expand their analyses.

We agree that future research should focus on analyzing the census data of the whooping crane flock, environmental factors, and availability of food resources.

(8) Whooping Crane Territories

We believe that our territories were representative of all whooping crane territories and have provided two maps (Figures 2.3 and 2.7) which depict our study sites.

Response to Platte River Whooping Crane Trust

(1) From Platte River Whooping Crane Trust (PRWCT) (p.1):

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...

As we stated in chapter three, we do not view our model as all inclusive, but rather as a useful simplification of a complex system which focused on evaluating the most likely links between inflow and two food resources at ANWR (wolfberry plants and blue crabs) that could be explored with the resources at our disposal. We recognize competitors are an important aspect of the system and feel that this is an excellent suggestion for future research.

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.

We are not sure what PRWCT is referring to by "the second model", but the simulation model presented in this report (SAGES report, Ch.3) was never intended to include whooping crane demographics.

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.

Table 2.2 was designed to provide an overview of all of the work that was done during the study period.

(2) From PRWCT pp. 1-2

1. Quantify patterns of habitat use by whooping cranes in relation to changes in human-induced disturbances at 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.***

Whooping crane habitat use was considered in empirical studies 9 & 10.

2. Evaluate relationships among water temperature, water salinity, water depth, other physical factors, and blue crab abundance in salt-marsh habitats of ANWR,

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

Wolfberries were considered in Objective 4.

3. Determine changes in whooping crane foraging behavior and capture rates in relation to abundance of blue crab and wolfberry fruit,

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

Our simulations simulate daily abundances of blue crabs and wolfberries. Whooping crane foraging behavior is presented in empirical study #9. Foraging behavior is not included in the simulation model.

4. Quantify macrophytic responses in saltwater marshes to intra- and inter-annual variability in freshwater inflows, salinity, and inundation,

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

Wolfberries are macrophytes and are included in the simulation model.

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 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.***

We agree with PRWCT.

(3) From PRWCT p. 2

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

We agree with PRWCT. This will be changed in the final report.

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.***

We agree with PRWCT that we consider the amount of energy present on the three territories. The territories we modeled, however, were not theoretical. They were digitized versions of actual whooping crane territories at ANWR.

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.

We disagree with PRWCT. This figure depicts wind influencing food resources. We did quantitatively test the influence of wind on blue crab abundance, which is a food resource.

(4) From PRWCT pp. 2-3

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.

We recognize salinity in the estuary can be affected by sources other than inflow. Figure 3.5 (SAGES report) indicates that salinity in San Antonio Bay was a good index of salinity conditions within the marsh (that is, there is a strong correlation between bay and marsh salinity).

From SAGES report (p. 31)
Certainly wind, direct precipitation, and local runoff accounted for deviations from the ANWR tidal creek/bay salinity relationships we observed in this study (Figure 3.5). In fact, data from our three sites suggest a coupling between cumulative monthly precipitation, mean river discharge, and tidal creek salinity (see Figure 2 in Butzler and Davis 2006). However, the overall set of relationships between 28-day lagged inflows versus bay salinity (Figure 3.4) and bay salinity versus salinity at each tidal creek (Figure 3.5) accounted for much of the variability without inclusion of these other variables. Trends in tidal creek salinity followed salinity patterns observed in the bay, but tidal creek salinity was generally higher than bay salinity (Figure 3.6).

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.

PRWCT has misinterpreted our model selection procedures (from empirical study #7) and how we applied those results to the simulation model. Briefly, crab capture data were divided into 3 size classes (1-10mm, 11-30mm, >30mm). For each size class, we tested a series of hypotheses relating environmental and habitat variables to the abundance of that particular size class. Temperature was considered for each size class, among many other factors (refer to pp. 102-105 in the SAGES report). For the simulation model, we used the 11-30mm size class, a size class for which temperature was not significant statistically in explaining abundance.

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.

In the simulation model equation 3 simulates daily abundance of blue crabs, which fluctuates based on the quantitative values of the environmental parameters for each specific day during the time period simulated.

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.
From the SAGES Report (p. 38)

Our correlation indicates that peak wolfberry production is strongly correlated with mean summer salinity at GBRA1. As we mentioned in the report (SAGES report, p. 38). As we stated in the report, we recognize other factors can affect wolfberry production, but our correlation indicates that mean summer salinity in the bay is a good indicator of peak wolfberry production in the marsh.

(5) From PRWCT pp. 3-4

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.

We assumed the number of plants per plot was representative of the number of plants per territory. We only modeled red, ripe berries.

P. 40. 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^2 square…

Tables 3.3A-C are the results of the sensitivity analysis we performed on model parameters. It should be interpreted as follows (using the Boat Ramp territory as an example): At baseline levels (no changes to parameter values), the maximum peak berry abundance for any year during the 11 year simulation was 15.33 berries/m^2. The minimum number estimated for peak berry abundance for any year during an 11-year simulation was 0.23 berries/m^2. These numbers reflect differences in wolfberry production based on variable summer inflows. As has been observed at ANWR, wolfberries have "good" and "bad" years and our model captures this dynamic.

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^2). 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.

We do not simulate whooping crane movement or foraging behavior. Nor do we assume that the energy present in wolfberries is the only resource available to whooping cranes when the birds first arrive. Our model simulates the daily amount of energy present in wolfberries and blue crabs at each of three territories. We then compare this number to the daily energetic requirement of 4 adult whooping cranes. Given the foraging data, it is logical to assume that whooping cranes would utilize other food resources if wolfberries production is lower than average.

(6) From PRWCT p. 4

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.

Figure 3.5 provides the quantitative relationship between bay salinity and marsh salinity. The strength of the correlations indicates that the salinity in GBRA1 is a good indicator of salinity in the marsh.

(7) From PRWCT pp. 4-6

[SAGES TEAM PARAPHRASING]: comments at the end of page 4 through the first part of page 6 focus on the equation we used to estimate crab abundance. We have provided a detailed description of our method below:

Please refer to our general response section for a detailed description of our blue crab study and our energetics calculations.

We agree that future research should include detailed empirical analyses of energetic requirements of free-living whooping cranes as well as study the impact of competitors on whooping crane food resources.

(8) From PRWCT pp. 7-8

p. 46. 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 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.

The model truncates bay salinity at 30, not marsh salinity. Figure 3.9 shows the relationship between inflow, predicted and observed salinity. During the time period of the study, bay salinity was never recorded above 30. The correlation equations developed from Fig. 3.5 provide estimates of salinity in the tidal creeks of each territory. We agree with PRWCT that future research should include exploring the effects of salinity on wolfberry plants.

Regarding crane energy, please see our general response section.

(9) From PRWCT p. 8

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.

Peak number of wolfberries represents the time period (day) when wolfberry density is highest. Density then declines exponentially from the peak number (SAGES report, p. 37)

P. 50. It is not clear what time steps are here, as in wolfberry above...Figure 3.11 says crab abundance as total number crabs/year.

The model simulates daily abundances of blue crabs (and wolfberries). Figure 3.11 compares sampled data (crabs captured at ANWR during field studies) to predicted crab abundance. It is important to note that the objective of the blue crab portion of this study was to understand the year-around dynamics of blue crabs in the marsh at ANWR. Model evaluation (Fig. 3.11) compares the blue crabs sampled throughout each year to blue crabs simulated during the same years. When we calculate energy present on the marsh, we only consider the time period that whooping cranes are present.

Response to Dr. P. Montagna, Texas A&M, Corpus Christi.

Dr. Montagna provided us with comments focusing on our blue crab portion of the study. As a result of his comments, among others, we added a more detailed description of our crab study in section 3.2.3 of the SAGES report. The general response section of this document includes maps of our sampling location (Figure 1) as well as an explanation of our findings regarding blue crabs and their relationship with environmental factors. Further, we agree with Dr. Montagna that "…blue crabs are 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." The objective of our blue crab larval study was to document patterns of settlement and recruitment of larval crabs in the marsh habitat. We recognize that blue crabs settle in other habitats, however, due the limited time period available for our study, we focused our resources in the habitats within the marsh.

Regarding Dr. Montagna's comment regarding the particular species of blue crab captured:

In our marsh studies of blue crabs, both *Callinectes sapidus* and *C. similis* were encountered. Although, *Callinectes sapidus* dominated collections in the marsh, both species were lumped for statistical analyses.

Response to Texas Water Development Board

Comments regarding simulations:

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.

Please refer to the general statement in this document for the conditions in which we feel comfortable applying our model. The simulations of inflow reductions were never intended to be viewed as management decisions, rather, we ran these scenarios in order to document the full range of model behavior. As a result of TWDB's comments, among others, we significantly revised section 3.4 of the SAGES in order to provide a more detailed description of how to best apply the simulation model.

Specific comments:

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%.

This was an error on our part. We have changed the text to reflect that we decreased water levels by 50%, rather than increased.

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.

Equation 3 predicts crabs in the 11-30 mm size class, as mentioned in section 3.2.3. Please refer to our general response section on our blue crab study for a detailed description of our methods. Further, we revised section 3.2.3 in the SAGES report to include a more detailed description of our blue crab study, comparisons to previous work, and interpretation of our results.

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.

During the time period of our study, however, salinities did not exceed 30 ppt. Our statistical analyses only included environmental conditions exhibited during our study, so if salinities exceed 30 ppt, then we completely agree with TWDB that future efforts should consider higher salinities in the bay.

Response to Mr. Kirkwood, concerned citizen

Mr. Kirkwood provided us with an excellent commentary based on his experience observing whooping cranes along the Texas coast, including the marshes of ANWR. Please refer to our general statements on our research methods, blue crab study, and energetic model for a more detailed description of our methods, analyses, and interpretation.