Hurricane Katrina Impacts to White-tailed Deer on John C. Stennis Space Center

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Abstract: Limited information is available regarding wildlife responses to hurricane-related disturbances. We monitored white-tailed deer (*Odocoileus virginianus*) by spotlight counts on NASA's John C. Stennis Space Center (SSC) during fall-winter periods from 2002–2004 before Hurricane Katrina's landfall and from 2006–2008 post-hurricane to index changes in relative population size. Comparisons of survey results during pre- and post-hurricane periods indicated that deer numbers were stable in years following hurricane landfall. Average number of deer recorded during spotlight counts was 26.7 deer/night pre-hurricane (31 survey nights) and 47.2 deer/night post-hurricane (20 survey nights), and average number of young-of-year/night (YOY) increased from 2.8 pre-hurricane to 14.7 post-hurricane. Herd health evaluations by Mississippi Department of Wildlife, Fisheries, and Parks on SSC revealed increased body weights and kidney fat levels for adult females following Hurricane Katrina. We suggest that more forage was available for deer after Hurricane Katrina because downed trees and salvage timber removal opened overstory and stimulated growth of mid-story and ground-cover vegetation which resulted in improved body condition and a possible increase in herd productivity. Although our study did not investigate direct mortality of deer from Hurricane Katrina, deer spotlight counts on SSC pre- and post-hurricane suggest that the deer population responded favorably to hurricane-induced habitat alterations.

Key words: Hurricane Katrina, white-tailed deer, Mississippi, population size, reproduction

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Hurricanes can severely alter ecological interactions and ecosystem processes within coastal regions (Chapman et al. 2008). Storm impacts may include changes to forest structure and composition, habitat availability, scouring and flooding of river channels, saltwater inundation and a decrease in freshwater availability that may affect biotic communities (Dunn and Miller 1964, Simpson and Riehl 1981, Folk 1991, Diaz and Pulwarty 1997). Recent hurricane seasons have been the most active on record and current trends indicate that greater hurricane activity may persist for another 10–40 years (Goldenberg et al. 2001, Emanuel et al. 2006). Therefore, the potential effects of extreme weather on wildlife populations have gained interest among biologists and natural resource managers. However, information regarding wildlife responses to hurricanes remains limited due to lack of sufficient pre-hurricane data to make comparisons (Langtimm and Beck 2003). Wildlife responses to hurricane damage vary from minimal effects to substantial impacts such as displacement by the storm, delayed health effects and changes in reproduction, population fluctuations following disturbance, and direct mortality (Langtimm and Beck 2003). Studies have reported impacts of hurricanes on wildlife including soricids (*Sorex longigrostris* and *Blarina carolinensis*; Cromer et al. 2007), migratory birds (*Chaetura pelagic*; Dionne et al. 2008), wild turkeys (*Meleagris gallapavo*; Baumann et al. 1996), northern bobwhite *(Colinus virginianus*; Hernández et al. 2002), Everglades white-tailed deer (*O. v. seminolus*; Labisky et al. 1999), Florida Key deer (*O. v. clavium*; Lopez et al. 2003), and the Florida manatee (*Trichechus manatus latirostris*; Langtimm and Beck 2003).

On 29 August 2005, Hurricane Katrina made landfall in southeastern Louisiana and southwestern Mississippi as a Category 3 hurricane with sustained windspeeds of 180–220 km/h. Hurricane Katrina was one of the strongest hurricanes to make landfall on the U.S. coast in the last century (Graumann et al. 2005). Extensive wind, rain, and tornado-related damage impacted areas of Louisiana, Mississippi, western Tennessee, and western Kentucky (Graumann et al. 2005). Because the impacts of catastrophic storms to wildlife populations were undocumented in Mississippi, responses of deer populations during the post-hurricane period were unknown.

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NASA's John C. Stennis Space Center (SSC) was located within the epicenter of the storm's landfall in Hancock County, Mississippi, and presented an opportunity to observe the effects of an intense hurricane on a wildlife species for which pre-hurricane data existed. We monitored deer on SSC from 2002–2004 as part of a long-term monitoring program toward development of an Integrated Natural Resource Management Plan for the landbase. Our goal was to determine deer population trends and the relationship between deer numbers and deer-vehicle collisions, which had been a growing occurrence on SSC (NASA 2008). To investigate population response to disturbance, monitoring efforts were resumed at SSC in November 2006, 14 months after landfall. The overall objective of this study was to determine the impacts of Hurricane Katrina on white-tailed deer at SSC by comparing abundance, productivity, and metrics of herd health pre- and post-hurricane. Herein, we present a comparison of white-tailed deer demographic parameters pre- and post-hurricane disturbance in the Coastal Flatwoods region of Mississippi.

Study Area

Stennis Space Center (SSC) is located in Hancock County in southwestern Mississippi, east of the Pearl River and just north of Interstate 10. SSC is a space shuttle booster rocket testing and research base covering 3,823 ha. About half of the base is forested with the remaining area used for rocket test facilities, laboratories, offices, and other operational facilities (NASA 2008).

Currently, no hunting is allowed on the base, so there has been concern about size of the deer population and associated habitat damage. Deer hunting on SSC has been very restricted since the land was acquired in 1963. The only hunting occurred on a small area of the base for about 10 years from 1980–1990 during which limited bow hunting was allowed, and 13–16 deer were taken annually. All hunting was banned after 1990 due to safety issues and a negative public perception of hunting expressed by employees of companies on the base (D. Golden, Biologist, SSC Natural Resource Management Team, personal communication). Consequently, the deer population was dense on SSC, and deer-vehicle collisions were common. From January 2000–August 2006, 150 collisions were reported (NASA 2008; H.Carr, NASA Environmental Office, personal communication). After Hurricane Katrina, SSC was enclosed on its northern and eastern boundaries and about three-quarters of its western boundary by a 2.5-m high-fence topped with a 0.5-m span of barbed-wire which may have restricted deer movement to an unknown extent. Mike's River formed the lower quarter of the western boundary, and a man-made transportation canal formed the southern boundary (Figure 1). Movement of deer to and from SSC was possible via these water bodies.

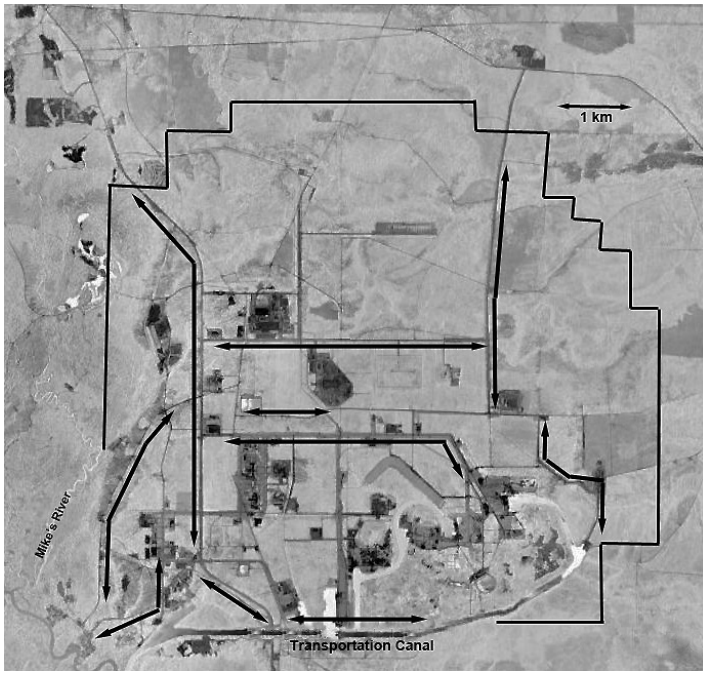

Figure 1. Deer spotlight count survey routes (black arrows) on Stennis Space Center, Picayune, Mississippi, 2002–2008. Portions of the facility boundary secured by a 2.5-m high fence are indicated with black border.

Methods

We monitored the deer population on SSC for three years before Hurricane Katrina (Year 1: winter 2002, Year 2: fall 2002 and winter 2003, Year 3: winter 2004) and two years after impact (Year 4: fall 2006 and winter 2007, Year 5: fall 2007 and winter 2008). Fall months were November and December and winter months were January, February, and March.

We surveyed deer by spotlight counts along 10 road routes distributed across SSC; all routes were monitored each survey night (Mitchell 1986, Collier et al. 2007). Survey routes were established by selecting roads where deer-vehicle collisions were greatest and ranged from 1.2–3.7 km in length and totaled 27.4 km (Figure 1). Two Q-beam 2-million candlepower spotlights were used with a person illuminating each side of the road. Deer were identified as adult doe, young-of-year (YOY), or adult male, and number of antler points was recorded for adult males. We recorded only deer that were clearly visible in open, mowed areas along roadsides and in mowed areas surrounding buildings near roads, so although there was significant change to forest structure between pre- and post-hurricane surveys, visibility and detectability of deer did not change. Deer that were near the wood line and partially obscured by vegetation were not counted.

We summarized data by number of total deer/night, YOY/

night, adult does/night, adult males/night, and ratio of YOY/adult doe and adult male/adult doe by night. Data were not normally distributed, so we used a non-parametric Kruskal-Wallis test to determine significant differences ($P \leq 0.05$) in pre- and post-Hurricane Katrina counts and ratios (Conover 1980).

As deer density increases in an area, health of the herd may decline if available nutrition is not sufficient. We wanted to investigate whether or not deer herd health had changed on SSC as a result of an apparent increase in population size. To assess health of deer on SSC, deer herd health evaluations were conducted by biologists from the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) (Demarais and Jacobson 1982). Data from herd health evaluations were provided by MDWFP from past evaluations in the Coastal Flatwoods soil region (1995, 1997, 1998, 2000), from pre-hurricane evaluations on SSC (1997, 2001, and 2003), and from an evaluation on SSC in 2008 (McDonald 2008, MDWFP 2008). We used a one-way ANOVA (Freund and Wilson 2003) to determine if there were differences in mean dressed weight, mean kidney fat index (KFI), mean number of fetuses, and mean number of corpora lutea among adult females (≥2.5 years of age) on SSC in 2008, on SSC pre-hurricane, and in the Coastal Flatwoods soil region pre-hurricane. A Fisher's LSD test was used to compare means in pair-wise comparisons if there were significant differences as determined by ANOVA analysis (Freund and Wilson 2003).

To estimate deer density on SSC, we estimated area surveyed along roads using the area measurement tool in program Google Earth. This method allowed us to measure area of mowed landscape visible from roadways using satellite images from 2006. We used this method to estimate survey area rather than geographic information system (GIS) software, because there was no GIS coverage available which quantified this feature of the landscape on SSC due to security restrictions. We divided number of hectares by average number of deer counted each night to determine an estimated density of deer which may be of interest and useful to biologists in the future.

Results

Spotlight count surveys conducted prior to Hurricane Katrina's land fall ranged from 2–6 nights/month depending on accessibility due to NASA rocket booster-testing and weather conditions ($n = 31$ nights). Post-hurricane surveys were conducted two nights/month from November–March 2006–2008 ($n = 20$ nights). All demographic parameters differed between pre- and post-hurricane survey periods (Table 1). Figures 2–4 reveal trends in estimates by survey period. We detected differences in total number of deer ($\chi^2 = 14.57$, $df = 1$, $P < 0.001$), YOY ($\chi^2 = 27.87$, $df = 1$, $P < 0.001$),

Table 1. Average demographic metrics by survey night for pre- and post-Hurricane Katrina counts and population demographic ratios for white-tailed deer on Stennis Space Center, Mississippi, 2002–2008.

Parameter	Pre-Katrina (n=31) 2002–2004 $\bar{x} \pm$ SE	Post-Katrina (n=20) 2006–2008 $\bar{x} \pm$ SE	P-value
Total deer	26.2 ± 3.6	47.2 ± 4.4	<0.001
Adult does	22.0 ± 3.2	26.05 ± 6.5	0.028
YOY	2.8 ± 0.7	14.7 ± 5.5	<0.001
Adult male	2.0 ± 0.2	6.1 ± 7.5	<0.001
Adult male/adult doe ratio	0.135 ± 0.02	0.272 ± 0.02	0.002
YOY/adult doe ratio	0.147 ± 0.03	0.536 ± 0.03	<0.001

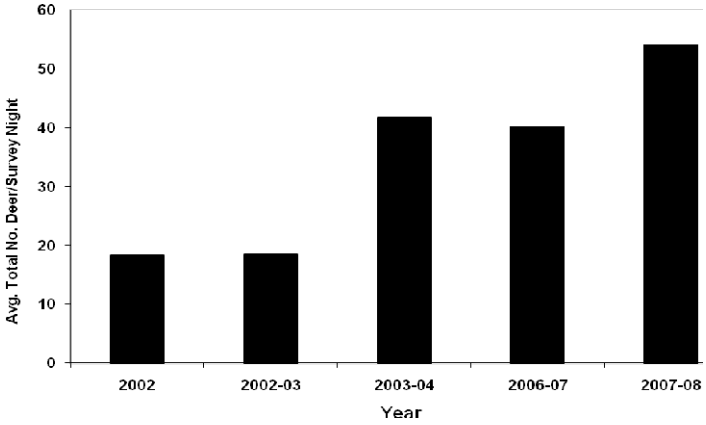

Figure 2. White-tailed deer population trends for total counts from spotlight surveys by year on Stennis Space Center, Mississippi, pre-Hurricane Katrina (2002–2004) and post-Hurricane Katrina (2006–2008).

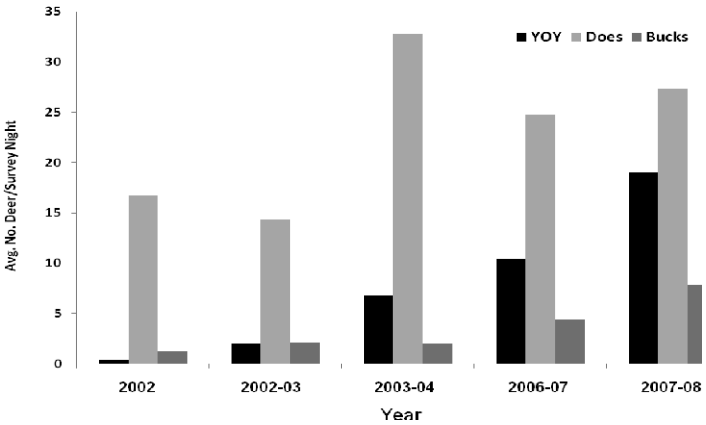

Figure 3. White-tailed deer population trends for demographic groups from spotlight surveys by year on Stennis Space Center, Mississippi, pre-Hurricane Katrina (2002–2004) and post-Hurricane Katrina (2006–2008).

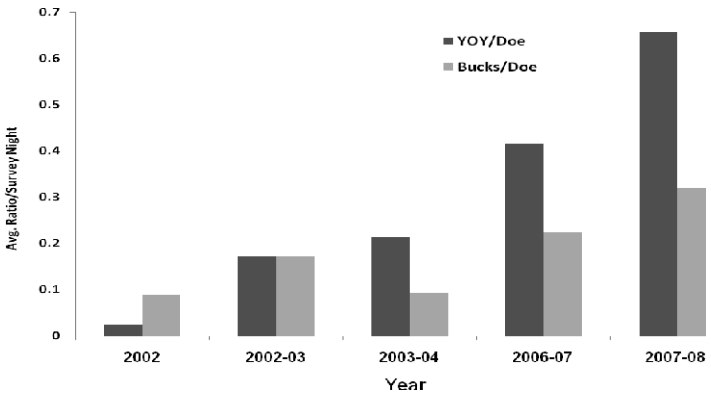

Figure 4. White-tailed deer population trends for demographic ratios from spotlight surveys by year on Stennis Space Center, Mississippi, pre-Hurricane Katrina (2002–2004) and post-Hurricane Katrina (2006–2008).

Table 2. A comparison of average body condition and reproductive measures of 2.5+ year-old adult does for white-tailed deer in the coastal flatwoods soil region of Mississippi, Stennis Space Center in past years, and Stennis Space Center in 2008.

		Dressed wt. (lbs)	Fetuses per doe	CLs per doe	Kidney fat index (%)	Conception date
Site	***n***	$\bar{x} \pm$ **SE**	$\bar{x} \pm$ **SE**	$\bar{x} \pm$ **SE**	$\bar{x} \pm$ **SE**	
Coastal Flatwood historical[a]	22	66.50 ± 2.00	1.50 ± 0.14	1.76 ± 0.06	28.46 ± 5.78	23 Jan
SSC historical[b]	28	70.86 ± 2.12	1.64 ± 0.09	1.78 ± 0.08	22.35 ± 2.17	7 Jan
SSC 2008	8	76.76 ± 3.88	1.75 ± 0.16	1.88 ± 0.13	40.54 ± 5.72	4 Jan

a. Coastal Flatwoods historical: 1995, 1997, 1998, 2000
b. SSC historical: 1997, 2001, 2003

adult does ($\chi^2 = 4.86$, $df = 1$, $P = 0.028$), adult males ($\chi^2 = 21.96$, $df = 1$, $P < 0.001$), YOY/adult doe ($\chi^2 = 25.41$, $df = 1$, $P < 0.001$ $\chi^2 =$), and adult males/adult doe ($\chi^2 = 9.96$, $df = 1$, $P = 0.002$). Average total counts were 26.2 deer/night pre-hurricane and 47.2 deer/night post-hurricane (Table 1). Spotlight surveys covered approximately 166 ha, so density of white-tailed deer was estimated to be 0.16 deer/ha pre-hurricane and 0.28 deer/ha post-hurricane.

Mean number of fetuses/doe ($F_{2,55} = 0.71$, $P = 0.500$) and mean number of corpora lutea/doe ($F_{2,55} = 0.69$, $P = 0.508$) was not different among groups. Mean dressed weight ($F_{2,55} = 3.39$, $P = 0.041$) and mean KFI ($F_{2,55} = 3.20$, $P = 0.048$) of adult females was significantly different among groups (Table 2). Pair-wise comparisons revealed that mean weight was greater on SSC in 2008 compared to the historical value of the Coastal Flatwoods soil region but not different than the historical value for SSC, and mean KFI was greater on SSC in 2008 compared to the historical value on SSC but not different than the historical value for the Coastal Flatwoods soil region.

Discussion

The deer population did not decline and appeared to remain stationary on SSC after Hurricane Katrina's landfall in August 2005. Although average count of total deer post-hurricane was significantly greater than the pre-hurricane average, counts from the 2003–2004 survey period indicate that population size the year before the hurricane was about the same as the two survey periods afterward, but in the two preceding survey periods (2002–2003) population size was considerably lower. Some metrics of adult doe body condition were similar during pre- and post-hurricane periods, but mean KFI and body weight indicated that fat reserves may have increased post-hurricane. Average kidney fat index was 181% greater for does on SSC in 2008 compared to the SSC historical average and 142% greater compared to the Coastal Flatwoods soil region historical average. Based on this parameter, adult does appeared to be in better condition 2.5 years after disturbance. Additionally, we found a significant increase in numbers of YOY. These results concur with previous studies of hurricane impacts on deer populations along the southeastern U.S. coast. Labisky et al. (1999) found a decrease in fawn production of deer in the Everglades in the year following Hurricane Andrew. However, fawn production increased from 10 fawns in July–August 1993 to 103 fawns in July–August 1994, one year after the hurricane. Following Hurricane George in 1998 and Hurricane Irene in 1999, Florida Key deer mortality rates were low (<2%) and there was a significant increase in YOY/adult doe estimates in 1999–2000 with a mean YOY/adult doe ratio greater than two times the observed ratio pre-hurricane (Lopez et al. 2003).

The stability and possible increase in productivity of the deer population on SSC is probably related to habitat disturbance caused by Hurricane Katrina. Although we did not measure change in overstory tree canopy coverage after disturbance, Forest Management Plans conducted prior to and after Hurricane Katrina's landfall indicated an average loss of 60% of the tree cover in most habitats of SSC many areas (NASA 2008). At nearby Pearl River Wildlife Management Area, Faulkner et al. (2007) found that between 19%–65% of trees had been snapped or blown over in study sites during Hurricane Katrina. Chapman et al. (2008) found that hurricane-related tree mortality in the first year following Hurricane Katrina was four times greater than mortality rates occurring in prior years within the Pearl River basin of Louisiana. Canopy gaps resulted from numerous snapped and fallen trees which allowed sunlight to reach the forest floor and stimulate growth of ground-level and mid-story vegetation, which is a typical response to increased light levels on the forest floor after such disturbance (Loope et al. 1994, Nielsen 2006). Reduction in overstory canopy yielded greater availability of forage for all herbivores. Lopez et al.

(2003) partially attributed an increase in deer herd productivity following hurricane disturbance to changes in forest structure. They speculated that a reduction of overstory canopy closure due to wind damage may produce short-term increases in forage from windthrown trees and broken branches and possibly long-term effects due to re-growth and sprouting of forage plants.

Use of spotlight count surveys has been associated with biases in population estimation. Collier et al. (2007) reported that spotlight counts are known to underestimate deer numbers and population density estimates. However, because we surveyed areas with no restrictions on visibility (i.e., an open, mowed landscape), we considered our estimates to be a reliable index of population size. At the least, our surveys did provide a measure of relative abundance among years which allowed examination of population trends and impacts of the hurricane to deer numbers along roadside right-of-ways on SSC.

Greatest densities in a deer population can be expected about five years after a major forest disturbance such as Hurricane Katrina (B. Strickland, Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, personal communication). Consequently, we could observe an increase in the deer population at SSC through 2010 and potentially 2011. Because increases in deer numbers could be associated with increased deer-vehicle collisions and potential increases in contagious diseases, we suggest continued monitoring of deer population trends at SSC and adaptive management strategies based on the results of surveys. Nevertheless, our survey results suggest that deer populations are not always devastated by catastrophic hurricanes, but rather hurricane-induced habitat alterations may impact deer populations positively during years following hurricane landfall.

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Literature Cited

Baumann, D. P., Jr., W. E. Mahan, and W. E. Rhodes. 1996. Effects of Hurricane Hugo on the Francis Marion National Forest wild turkey population. Proceedings of the National Wild Turkey Symposium 7:55–60.

Chapman, E. L., J. Q. Chambers, K. F. Ribbeck, D. B. Baker, M. A. Tobler, H. Zeng, and D. A. White. 2008. Hurricane Katrina impacts on forest trees of Louisiana's Pearl River basin. Forest Ecology and Management 256: 883–889.

Collier, B. A., S. S. Ditchkoff, J. B. Raglin, and J. M. Smith. 2007. Detection probability and sources of variation in white-tailed deer spotlight surveys. Journal of Wildlife Management 71(1): 277–281.

Conover, W. J. 1980. Practical nonparametric statistics. Second edition. John Wiley and Sons, New York, New York.

Cromer, R. B., C. A. Gresham, M. Goddard, J. D. Landham, and H. G. Hanlin. 2007. Associations between two bottomland hardwood forest shrew species and hurricane-generated woody debris. Southeastern Naturalist 6(2): 235–246.

Demarais, S. and H. A. Jacobson. 1982. A field guide to spring-summer deer herd health evaluation in Mississippi. Federal Aid in Fish and Wildlife Restoration Completion Report, Project W-48-29. Mississippi State University, Mississippi State, Mississippi.

Diaz, H. F. and R. S. Pulwarty, editors. 1997. Hurricanes: climate and socioeconomic impacts. Springer-Verlag, New York, New York.

Dionne, M. C. Maurice, J. Gauthier, and F. Shaffer. 2008. Impact of Hurricane Wilma on migrating birds: the case of the chimney swift. The Wilson Journal of Ornithology 120(4):784–792.

Dunn, G. E. and B. I. Miller. 1964. Atlantic hurricanes. Revised edition. Louisiana State University Press, Baton Rouge, Louisiana.

Emanuel, K., S. Ravela, E. Vivant, and C. Risi. 2006. A statistical deterministic approach to hurricane risk assessment. Bulletin of the American Meteorological Society 87:299–313.

Faulkner, S., W. Barrow, B. Couvillian, W. Conner, L. Randall, and M. Baldwin. 2007. Impacts of Hurricane Katrina on floodplain forests of the Pearl River. Pages 124–130 *in* G. S. Farris, G. J. Smith, M. P. Crane, C. R. Demas, L. L. Robbins, and D. S. Lavoie, editors. Science and storms: the USGS response to the hurricanes of 2005. USGS Circular 1306, Reston, Virginia.

Folk, M. L. 1991. Habitat of the Key deer. Dissertation, Southern Illinois University, Carbondale.

Freund, R. J. and W. J. Wilson. 2003. Statistical methods, 2nd edition. Academic Press, San Diego, California.

Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nunez, and W. M. Gray. 2001. The recent increase in Atlantic hurricane activity: causes and implications. Science 293: 474–479.

Graumann, A., T. Houston, J. Lawrimore, D. Levinson, N. Lott, S. McCown, S. Stephens, and D. Wuertz, D. 2005. Hurricane Katrina: a climatological perspective, preliminary report. Technical Report 2005–01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C.

Hernandez, F., J. D. Vasquez, F. C. Bryant, A. A. Radomski, and R. Howard. 2002. Effects of

Hurricane Bret on northern bobwhite survival. Proceedings of the National Quail Symposium 5:87–90.

Labisky, R. F., K. E. Miller, and C. S. Hartless 1999. Effect of Hurricane Andrew on survival and movements of white-tailed deer in the Everglades. Journal of Wildlife Management 63 (3):872–879.

Langtimm, C. A. and C. A. Beck. 2003. Lower survival probabilities for adult Florida manatees in years with intense coastal storms. Ecological Applications 13(1): 257–268.

Loope, L., M. Duever, A. Herndon, J. Snyder, and D. Jansen. 1994. Hurricane impact on uplands and freshwater swampforest. Bioscience 44:238–246.

Lopez, R. R., N. J. Silvy, R. F. Labisky, and P. A. Frank. 2003. Hurricane impacts on Key deer in the Florida Keys. Journal of Wildlife Management 67(2): 280–288.

McDonald, C. 2008. White-tailed deer herd health evaluation report, John

C. Stennis Space Center, April 2008. Mississippi Department of Wildlife, Fisheries, and Parks, Jackson.

Mississippi Department of Wildlife, Fisheries, and Parks. 2008. Deer Program Report 2008. Mississippi Department of Wildlife, Fisheries, and Parks, Jackson, Mississippi.

Mitchell, W. A. 1986. Deer spotlight census: section 6.4.3. U.S. Army Corp of Engineers wildlife resources management manual. U.S. Army Engineer Waterways Experiment Station Technical Report EL-86-53, Vicksburg, Mississippi.

NASA. 2008. Integrated Natural Resource Management Plan for NASA John C. Stennis Space Center, Mississippi. Stennis Space Center, Picayune.

Nielsen, E. M. 2009. Rapid mapping of hurricane damage to forests. Pages 307–316 *in* R. E. McRoberts, G. A. Reams, P. C. Van Deusen, W. H. McWilliams, eds. Proceedings of the eighth annual forest inventory and analysis symposium. USDA Forest Service General Technical. Report WO-79, Washington, D.C.

Simpson, R. H. and H. Riehl. 1981. The Hurricane and its impact. Louisiana State University Press, Baton Rouge.