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IMPACT OF HURRICANE ISABEL ON BALD EAGLE NESTS AND REPRODUCTIVE PERFORMANCE IN THE LOWER CHESAPEAKE BAY

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Abstract. We evaluated the impact of Hurricane Isabel on nest loss and reproductive performance of Bald Eagles (*Haliaeetus leucocephalus*) in the lower Chesapeake Bay. Approximately 40% of Bald Eagle nest trees ($n = 527$) were damaged and 127 nests were lost during the storm. Nest loss was significantly higher than in years prior to and after the storm. Only 46% of pairs that lost nests attempted to breed the following season, compared to 85% of pairs that did not lose nests. Of the pairs that made breeding attempts, only 69% of pairs that lost nests during the hurricane produced young compared to 83% of pairs that did not lose nests. Average brood size was also reduced for pairs that lost nests. The disparity in reproductive performance between the two groups narrowed in the second breeding season after the storm. Hurricane Isabel had a significant but short-lived impact on the Bald Eagle breeding population in the lower Chesapeake Bay.

Key words: Bald Eagle, Chesapeake Bay, Haliaeetus leucocephalus*, Hurricane Isabel, natural disturbance, nest loss, reproductive performance.*

Impacto del Huracán Isabel Sobre los Nidos y el Desempeño Reproductivo de *Haliaeetus leucocephalus* en la Parte Baja de la Bahía de Chesapeake

Resumen. Evaluamos el impacto del Huracán Isabel sobre la pérdida de nidos y el desempeño reproductivo de *Haliaeetus leucocephalus* en la parte baja de la Bahía de Chesapeake. Durante la tormenta, aproximadamente el 40% de los árboles en los que se ubicaban nidos de *H. leucocephalus* ($n = 527$) se deterioraron, y 127 nidos se perdieron. La pérdida de nidos fue significativamente mayor que en años anteriores y posteriores a la tormenta. Sólo el 46% de las parejas que perdieron sus nidos intentó reproducirse en la temporada siguiente, en comparación con el 85% de las parejas que no perdieron sus nidos. De las parejas que hicieron intentos reproductivos, sólo el 69% de aquellas que perdieron sus nidos durante el huracán produjo crías, en comparación con el 83% de las parejas que no perdieron sus nidos. El tamaño promedio de la nidada también fue reducido para las parejas que perdieron sus nidos. La disparidad en el desempeño reproductivo entre los dos grupos se hizo más estrecha en la segunda temporada reproductiva posterior a la tormenta. El Huracán Isabel tuvo un impacto significativo pero de corta duración sobre la población reproductiva de *H. leucocephalus* de la parte baja de la Bahía de Chesapeake.

Disturbance is an ecosystem process that frequently operates across many ecological scales and is capable of exerting powerful selective pressure (Levin and Payne 1974, Pickett and White 1985, Wootton 1998). How a species responds to disturbance gives some indication of how susceptible the species is to environmental perturbations and has important implications for the conservation of populations. While some species may require periodic disturbance for system maintenance, others may exhibit catastrophic declines from a single disturbance event. Natural disturbances vary in frequency, intensity, duration, and scale (Lorimer and White 2003). Major hurricanes represent extremes along the disturbance-intensity continuum and are the largest disturbances experienced regularly by populations along the Atlantic coast. Most investigations of the effects of hurricanes have reported short-term responses to habitat disturbance (Torres and Leberg 1996, Greenberg and Lanham 2001), with relatively few studies comparing such responses to baseline information recorded prior to storm damage (Dunning and Watts 1991, Lynch 1991, Wunderle et al. 1992). Even fewer investigations have examined the impact of hurricanes or other major storms on reproductive performance (Jones et al. 2001, Penteriani et al. 2002).

Hurricane Isabel was one of the largest storms ever recorded in the Atlantic Ocean (Beven and Cobb 2003). The storm reached peak intensity with maximum sustained winds of 234 kph and made landfall near Cedar Island, North Carolina, on 18 September 2003. Due to the size, speed, and path of the storm, tropical storm-force winds were experienced over a vast land area, from coastal North Carolina through the eastern Great Lakes and New England. Coastal North Carolina and Virginia experienced hurricane-force winds for several hours, resulting in extensive damage to forests (R. Trickel,

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North Carolina Division of Forest Resources, unpubl. data).

We examined the impact of Hurricane Isabel on the resident Bald Eagle (*Haliaeetus leucocephalus*) population in the lower Chesapeake Bay. Bald Eagles build large nests and frequently select trees isolated from or higher than the surrounding forest for nest placement (Andrew and Mosher 1982). We measured the loss of nest structures to winds related to Hurricane Isabel and compared losses to those in years prior to and after the hurricane. We examined the impact of nest loss on reproductive performance by comparing breeding probabilities, breeding success, and brood size between territories with and without nest loss for the two years following the storm.

METHODS

Our study area included lands surrounding all major water bodies in the coastal plain of Virginia. The study area is described by Watts and Byrd (2002). We conducted systematic surveys for Bald Eagle nests and breeding activity during 1999–2005 as part of the Virginia monitoring program. We surveyed the study area using a standard two-flight approach (Fraser et al. 1983), in which the first flight documents nests and nesting activity and the second flight documents productivity. All nests were plotted on 7.5 min topographic maps and given unique alphanumeric codes. We conducted the first flight between late February and mid-March and the second flight between late April and mid-May (see Watts et al. [2006] for survey details). We present information on the loss of nests due to winds for periods prior to (1999–2003), just following (2004), and after (2005) Hurricane Isabel. To evaluate the influence of nest maintenance activity on nest losses due to winds, we considered ''occupied'' nests to be those that were active or occupied in the previous year and ''abandoned'' nests to be those that were unoccupied in the previous year (Postupalsky 1974). For the two breeding seasons following the hurricane (2004 and 2005), nesting probabilities and productivity were compared between territories that lost occupied nests and those that did not. In all years, when a nest was absent or empty, an intensive, area-restricted search was performed within approximately 1 km of the nest to locate new nests. We defined a breeding attempt by definitive evidence that eggs were laid (e.g., bird in incubating posture, eggs in nest, young in nest).

We compared proportions of nests lost to the hurricane and subsequent breeding probabilities. We compared the proportion of monitored nests that were lost to the hurricane with the proportion lost during each of the other years examined. Between-year comparisons were made separately for occupied and abandoned nests. The proportion of occupied and abandoned nests lost to the storm was also compared to evaluate the importance of nest maintenance on the likelihood of loss. Breeding probabilities of pairs that lost nests to the hurricane and those that did not were compared for the two years after the storm. All frequency comparisons were made using chi-squared tests. We compared brood size for pairs that did and did not lose nests and made subsequent breeding attempts using two-tailed *t*-tests. Means are presented ± SD, and the significance level was set at 0.05.

RESULTS

In the lower Chesapeake Bay, 127 Bald Eagle nests were lost to hurricane Isabel, including 69 occupied and 58 abandoned nests. Most of these nests (109) were blown down and the trees remained standing. However, nest trees and surrounding forests experienced widespread damage that varied in severity from minor limb damage to trees being snapped off at the base. Approximately 40% of nest trees examined (n = 527) had detectable damage. This included damage to small limbs in the outer crown (17%), damage to major limbs in the crown (12%), and damage to major limbs used for nest support (10%). Fourteen nest trees were uprooted and four were snapped off at the base. Thirteen nest trees appeared to be leaning at an angle greater than 20% (visually estimated during flights) as a result of the storm.

The percentage of nests lost during the year of the hurricane was significantly higher than in all other study years for both occupied (all $\chi^2_1 > 70$, all $P < 0.001$) and abandoned (all $\chi^2_1 > 18$, all $P < 0.001$) nests (Fig. 1). Average loss of occupied nests in years before and after the storm was 7% ± 1%, compared to 17% loss in the year of the storm. Average loss of abandoned nests was 29% ± 5% for other years, compared to 46% in the year of the storm. Abandoned nests were more likely to be lost than occupied nests during both the hurricane ($\chi^2_1 = 74.9$, $P < 0.001$) and other years ($\chi^2_1 = 462.4$, $P < 0.001$). Loss of occupied nests in the year following the storm was significantly lower than in the year prior to the storm, suggesting that the storm may have ''purged'' the more vulnerable nests ($\chi^2_1 = 9.5$, $P < 0.01$). This pattern was not observed for abandoned nests ($\chi^2_1 < 1.0$, $P = 0.83$).

Loss of occupied nests had a significant influence on reproductive performance the following breeding season. During the 2004 season, breeding attempts were documented for 85% of pairs (n = 306) that did not lose nests to the hurricane, compared to only 46% of pairs (n= 96) that did lose nests ($\chi^2_1 = 194.2$, $P < 0.001$). Of the 44 pairs that lost nests but made breeding attempts, 37 built new nests and seven used previously abandoned nests. These pairs were significantly less likely to produce young compared to pairs that did not lose nests ($\chi^2_1 = 24.2$, $P < 0.001$). Of the pairs that did not lose nests and made breeding attempts (n = 260), 83% produced at least one young, compared to 69% of pairs (n = 44) that did lose nests. Brood size was 2.0 ± 0.6 for pairs that did not lose nests compared to 1.7 ± 0.7 for pairs that did lose nests (two-tailed *t*-test, $t_{241} = 1.8$, $P = 0.07$).

The difference in reproductive performance that was evident in the 2004 breeding season was less pronounced by 2005. During the 2005 breeding season, 86% of pairs (n = 306) that did not lose nests and 73% of pairs (n = 96) that did lose nests to the hurricane made breeding attempts. Although this difference remained significant ($\chi^2_1 = 24.7$, $P <$

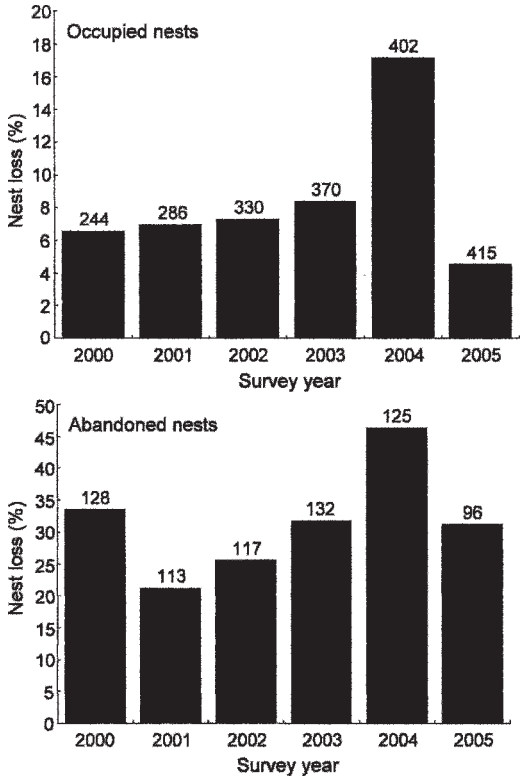

FIGURE 1. Loss of occupied and abandoned Bald Eagle nests in the lower Chesapeake Bay, 2000–2005. Sample sizes above bars indicate the number of nests monitored in the year prior to the survey year, and percent nest loss represents nests lost between successive survey years. Nest loss increased dramatically from 2003 to 2004, particularly for occupied nests, due to Hurricane Isabel. Overall, the percentage loss of abandoned nests was much higher than for occupied nests. Note that the scale of the *y* axis differs between graphs.

0.001), the difference between the two groups declined by 27%. Pairs that lost nests were no longer significantly less likely to produce young (87%) compared to pairs that did not lose nests (84%; $\chi^2_1 = 1.6$, $P = 0.21$). In addition, brood size was not significantly different between the two groups (two-tailed *t*-test, $t_{250} = 0.5$, $P = 0.63$). Brood size for pairs that did not lose nests was 1.9 ± 0.7, compared to 1.9 ± 0.5 for pairs that did lose nests.

DISCUSSION

Bald Eagles in the lower Chesapeake Bay often build nests in trees that are exposed to high winds and consequently are susceptible to being dislodged by winds on an annual basis. The Atlantic coast annually experiences 35–40 temperate and tropical storms with enough intensity to affect coastal habitats and the species that depend on them (Dolan et al. 1988). However, there is considerable seasonality in storm frequency such that more than 80% of large storms occur during the fall months (Dolan et al. 1988). Therefore, most Bald Eagle nest losses occur in late summer and early fall, affording pairs ample time to rebuild before the following breeding season. Hurricane Isabel caused considerable damage to forest habitats in the lower Chesapeake Bay and resulted in a spike in the loss of occupied eagle nests that was 2.5 times higher than the yearly average. Although this event occurred in early fall, many pairs did not rebuild, leading to a significant influence of nest loss on breeding probability. This difference in breeding probability continued to be significant for the second nesting season following the storm, although the disparity was much reduced. A longer monitoring period is needed to determine whether or not additional damaged territories will be reoccupied in the near future.

It is possible that, after losing nest structures, some pairs may have moved to a new location and made breeding attempts the following year. If so, we would have underestimated nesting probabilities for those pairs that lost nests. However, pairs were observed to be present during the breeding season in many of the territories that lost nests, indicating that they did not make breeding attempts elsewhere. Further, a good portion (73%, $n = 96$) of these pairs made breeding attempts in these territories the following year. The breeding survey documents the formation of new territories every year. The majority of these territories are occupied in subsequent years. There was no spike in the formation of new territories in the year following the hurricane and new territories that were located continued to be occupied in subsequent years, suggesting that birds did not move to new territories and then back to their original territories in later years. Lastly, the practice throughout the period of this study was to perform an area-restricted search to find new nests when a nest was lost or birds were not present in the vicinity. There is no reason to believe that the rate of moving to a new territory following nest loss from the storm was different from the rate following nest loss during any other year. In other words, the error caused by not finding a pair following nest loss in 2004 should have been the same as in other years.

Pairs that built new nests following the storm and attempted to breed the following season were less successful and raised smaller broods compared to pairs that did not lose nests. The underlying cause of this disparity is not clear. Although nest construction for eagles may entail considerable time and energetic expense (Herrick 1932), under time constraints they are capable of very rapid nest construction (Herrick 1932; BDW and MAB, pers. obs.). It seems unlikely that the energetic costs of construction affected success rate and brood size months later. It is possible that the hurricane differentially affected pairs that varied in reproductive potential and the loss of nests revealed existing differences rather than being the cause of the observed disparity in brood size.

Nests that were maintained during the year prior to the storm were less likely to be lost compared to

those that were not. Although some nest structures may persist for many years, even in the absence of regular maintenance, most become fragile and do not persist beyond 2–3 years after abandonment (Watts 2006). Thus, nest maintenance appears to serve not only to prepare the nest surface for incubation and brood rearing, but also in repairing structural damage and maintaining nest integrity. One of the most dramatic impacts of Hurricane Isabel was to "purge" most territories of unused nests. Loss of these alternate nests forced many pairs to build new nests.

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