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LONG-TERM CHANGES, 1958–2010, IN THE REPRODUCTION OF BALD EAGLES OF FLORIDA BAY, SOUTHERN COASTAL EVERGLADES

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ABSTRACT.—The population of Bald Eagles (*Haliaeetus leucocephalus*) breeding in Florida Bay, located within Everglades National Park, has been the subject of one of the longest running monitoring programs for any large raptor species worldwide, with reproductive data collected for 49 breeding seasons since 1958. The overall reproductive trends in this nesting population indicated that the population has transitioned from one at or near carrying capacity to one in decline, with territory occupancy decreasing as much as 43%. This contrasted with observed trends for the state of Florida, where populations increased >300% over the past 25 yr. The rate of nesting attempts in Florida Bay remained high (0.83 ± 0.11 [SD]; number of active territories/number of occupied territories) over the period. Mean annualized brood size was 1.48 ± 0.16 young/successful territory and mean productivity was 0.81 ± 0.21 young/occupied territory, which are comparable to those of other Bald Eagle populations. There were significant increases in ratios of active territories/occupied territories, successful territories/occupied territories, and young/occupied territory, despite decreased occupancy. Increases in these rates have allowed overall production of the Florida Bay population to remain stable; however, given the current decreasing trend in territory occupancy, this population should be considered at risk. Changes in Bald Eagle reproductive parameters corresponded with significant ecological changes documented in Florida Bay and southern coastal Everglades and may serve as possible long-term indicators for the health and recovery of the southern Everglades as restoration efforts progress.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *Everglades*; *Florida*; *nesting*; *population trend*; *reproductive rate*; *survey*.

CAMBIOS A LARGO PLAZO (1958–2010) EN LA REPRODUCCIÓN DE *HALIAEETUS LEUCOCEPHALUS* DE LA BAHÍA DE FLORIDA, EVERGLADES COSTEROS DEL SUR

RESUMEN.—La población reproductiva de *Haliaeetus leucocephalus* en la Bahía de Florida, ubicada dentro del Parque Nacional Everglades, ha sido sujeto de estudio de uno de los programas de monitoreo de mayor duración para cualquier rapaz grande en todo el mundo, con datos reproductivos colectados para 49 épocas reproductivas desde 1958. Las tendencias reproductivas generales en esta población reproductiva indicaron que la misma ha cambiado de ser una población en o cerca de su capacidad de carga a una en declive, con una disminución en la ocupación del territorio cercana al 43%. Esto contrastó con las tendencias observadas para el Estado de Florida, donde las poblaciones aumentaron >300% durante los últimos 25 años. La tasa de intentos de nidificación en la Bahía de Florida se mantuvo elevada (0.83 ± 0.11 [DE]; número de territorios activos/número de territorios ocupados) durante este período. El tamaño medio de nidada anual fue de 1.48 ± 0.16 pichones/territorio exitoso y la productividad media fue de 0.81 ± 0.21 pichones/territorio ocupado, los cuales son comparables con aquellos de otras poblaciones de *H.*

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leucocephalus. Se evidenciaron aumentos significativos en las proporciones de territorios activos/territorios ocupados, territorios exitosos/territorios ocupados y pichones/territorio ocupado, a pesar de la disminución en la ocupación del territorio. Los aumentos en estas tasas han permitido que la producción general de la población de la Bahía de Florida se mantenga estable; sin embargo, dada la actual tendencia de disminución en cuanto a la ocupación del territorio, esta población se debería considerar en riesgo. Los cambios en los parámetros reproductivos de *H. leucocephalus* se corresponden con los cambios ecológicos significativos documentados en la Bahía de Florida y en los Everglades costeros del sur y pueden servir como posibles indicadores a largo plazo de la salud y recuperación de los Everglades del sur a medida que progresan los esfuerzos de restauración.

[Traducción del equipo editorial]

The Bald Eagle (*Haliaeetus leucocephalus*) is an iconic species whose populations have exhibited dramatic declines and recoveries, and is one of the most well studied raptor species (Buehler 2000). In the late 1940s, Charles Broley (1947, 1950, 1958) linked dichloro-diphenyl-trichloroethane (DDT) and habitat destruction to declines in the number of successfully breeding Bald Eagle pairs. Surveys in 1963 found a total of only 417 pairs in the lower 48 states of the U.S.; occupied nests produced on average only 0.59 young (Sprunt 1963). Following the ban of DDT in 1972, along with other conservation and recovery efforts, Bald Eagle populations rebounded across much of their range with recovery and growth typifying most regional Bald Eagle populations in the lower 48 states. For example, in the Chesapeake Bay, the population grew from 73 pairs in 1977 to 601 pairs in 2001, with a doubling time of 8.2 yr (Watts et al. 2008). As a result of range-wide recovery, the Bald Eagle was officially removed from the Endangered Species Act (ESA) in August of 2007 (U.S. Fish and Wildlife Service [USFWS] 2007a).

In Florida, the southeastern-most part of their range, the population has recovered from a low of only 88 pairs in 1973, when state-wide monitoring began, to more than 1300 estimated in 2008 (Florida Fish and Wildlife Conservation Commission [FWC] 2008). The USFWS Southeastern States Bald Eagle Recovery Plan 1989 concluded that although state Bald Eagle populations in the southeast U.S. had declined 25% to 100% from historic levels, Florida retained a significant nesting population of about 350 pairs (USFWS 1995, USFWS 1999). Robertson (1978) had estimated that the original population in Florida exceeded 1000 nesting pairs. The state of Florida currently supports about 70% of the nesting population in the southeastern U.S. and 11% in the lower 48 states (FWC 2008).

Bald Eagles form breeding pairs that defend exclusive territories and exhibit mate and site fidelity (e.g., Stalmaster 1987, Jenkins and Jackman 1993, Buehler 2000). In Florida, Bald Eagles exhibit a high degree of philopatry with relatively short natal dispersal distances (Wood 2009). A highly mobile species, the Bald Eagle has demonstrated ecologically flexibility with the ability to utilize a diversity of habitats of varying quality throughout its range (Buehler 2000). Florida eagle habitats vary from inland lake or river, to coastal mangroves and shallow estuaries. Although the Bald Eagle population trend for the state of Florida continues to be one of strong recovery and growth, a historically important regional population of the southern coastal region of the Everglades in Florida Bay shows a contrasting population trend.

Study Area and Methods

Study Area. At the southern edge of the greater Everglades ecosystem is the 2200-km^2 area known as Florida Bay (Fig. 1). Located between the southern tip of the Florida mainland and the Florida Keys, this shallow mangrove estuary lies primarily within Everglades National Park (EVER, established in 1947), and much of the rest in the Florida Keys National Marine Sanctuary (FKNMS, established in 1990). There are approximately 237 mangrove islets (keys), ranging from 0.1 to 144 ha (Enos 1989) in Florida Bay that are home to an historic nesting population of Bald Eagles, and represent the extreme southeastern range of the species. During the study period (1958–2010), 30 breeding territories were identified in Florida Bay; these generally consist of an individual key or a small group of keys. Despite the habitat protection provided within EVER and FKNMS, Florida Bay is directly impacted by the natural upstream hydrology of the greater Everglades and the anthropogenic changes to that hydrology that have occurred (McIvor et al. 1994, Hall et al. 1999, Fourqurean and Robblee 1999, Rudnick et al. 2005). During the 1960–70s the population seemed, to local experts, to be in a wild,

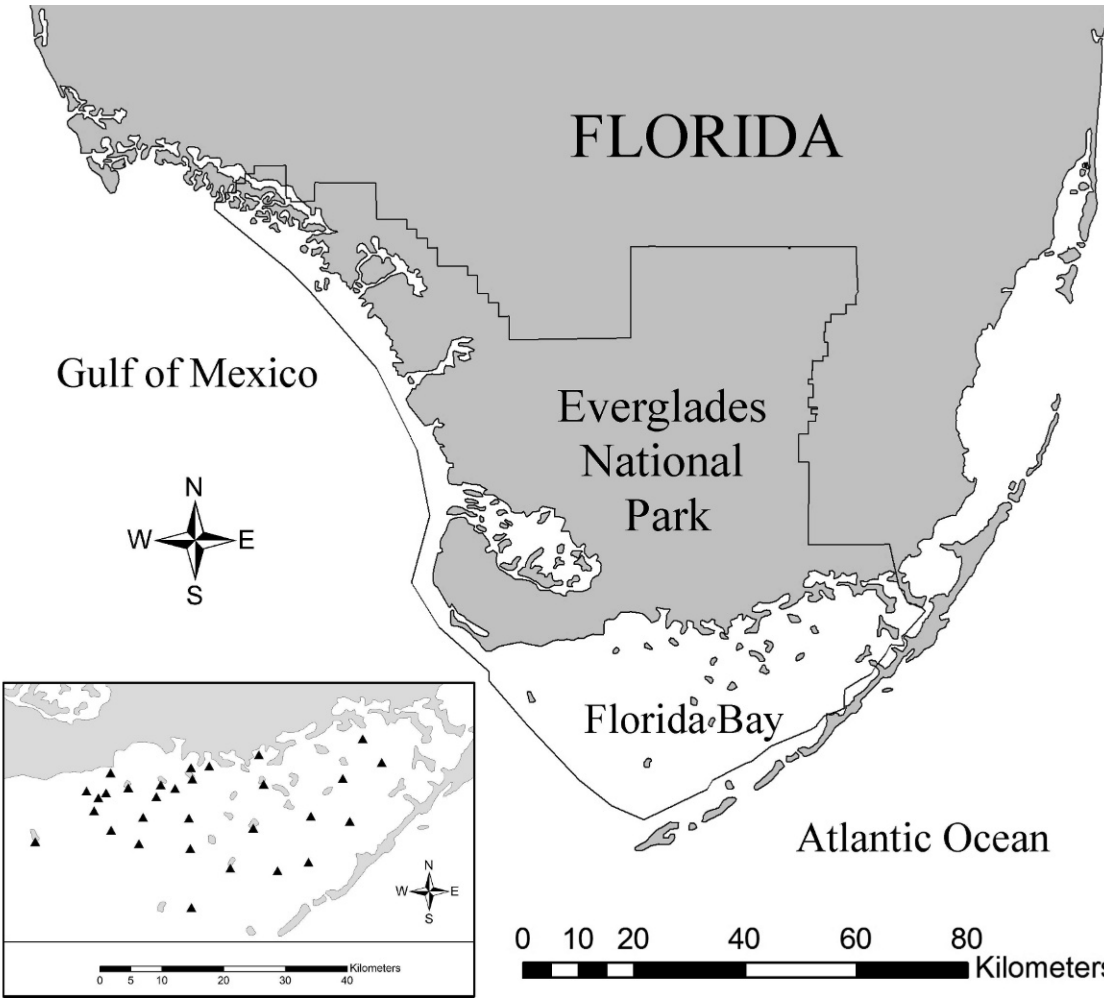

Figure 1. The Bald Eagle study area in Florida Bay, in the southern coastal system of Everglades National Park, Florida, U.S.A. and location of 30 breeding territories identified during the study period (1958–2010).

undisturbed state that was relatively free from the effects of pesticides (Robertson 1978, Curnutt 1991, 1996) and may have been at carrying capacity (Ogden 1975).

Recently, changes in reproductive parameters from historical benchmarks have been observed. These changes, coupled with regional ecosystem degradation, have led us to examine trends in Bald Eagle occupancy, nesting activity, nesting success, and productivity in Florida Bay during the breeding seasons 1958–2010. A common difficulty inherent in most species' recovery efforts is determining historical population levels, as most population survey efforts occur after populations have already diminished. Here, we provide a synthesis of the long-term reproductive trends in a regional Bald Eagle population that is apparently declining and whose historical population is known.

Surveys. Surveys of the Bald Eagle breeding population in Florida Bay were initiated by EVER personnel in 1958 in response to growing concern over declining eagle populations in the state of Florida and nationwide. Systematic and intensive aerial surveys were conducted by fixed wing aircraft (Cessna 182, J3 Cub, or Lake Buccaneer, flying at about 244 m) to detect eagle presence on known breeding territories and other potential nest sites (keys which had not been used previously). Monthly surveys were conducted each year from October through May or June (e.g., 1972 season is October 1972–June 1973). The 1980, 1981, 1984, and 1985 breeding seasons were surveyed less frequently and were excluded from analyses. During the study period from 1958–2010, 49 of the 53 breeding seasons, 30 individual territories were documented. The most recent territory was added in 1973.

Ground surveys and photo documentation were conducted during the survey period when necessary and feasible, to supplement and confirm aerial surveys. Aerial surveys, when limited to early and late breeding season flights, can underestimate occupancy and reproductive success (Grier et al. 1981, Fraser et al. 1984, Nesbitt et al. 1998). Sampling error was minimized by conducting multiple surveys (mean 5–7 surveys per nest site) over the breeding season, and surveying all potential nesting habitat with multiple flights in combination with ground surveys. Over 53 yr the EVER nest surveys have been conducted by a succession of different personnel using the same basic protocol with direct observations of individual birds and nests. These raw data were transferred and formatted in a custom Access database from field notebooks, EVER archives, and reports.

Definitions of Reproductive Parameters and Analyses. Based on previous work (Postupalsky 1974, Steenhof and Newton 2007), we define nesting activity and reproductive success during each nesting season as follows. Breeding territories were considered ''*occupied*'' if a pair of adults was observed in the territory on at least one visit during the breeding season, or if at least one adult was seen in the territory and there was evidence of recent nest maintenance (e.g., fresh lining, structural maintenance). Territories were defined as ''*unoccupied*'' if they did not meet the criteria of occupied. An occupied territory was considered "*active*'' if there was observation of an adult in an incubating posture on the nest, or if eggs or young were present. A territory was defined as ''*successful*'' if one or more young of fledgling size were present.

We defined occupancy rate, activity rate, and success rate as the percentage of occupied, active, and successful territories surveyed per breeding season. We defined nesting success as the percentage of occupied nests that contained ≥1 young and productivity as the number of young per occupied nest. Brood size was defined as the number of young per successful nest.

Statistical Analyses. The annual variation in the number of occupied territories was calculated as the log ratio of occupied territories between years $\ln(Oc_{t+1}/Oc_t)$. A univariate, nonparametric, Mann-Kendall test was used to determine statistical significance of monotone temporal trends (Kendall and Gibbons 1990). To identify differences among decades, the ratio of productivity and occupancy was tested using a one-way analysis of variance (ANOVA); comparisons among years were made using the Tukey-Kramer method (Sokal and Rohlf 1995). Residual inspection of the data showed that assumptions for normality and heteroscedascity were met. Results were deemed significant if $P \leq 0.05$.

Results

Overall Reproductive Rates. From 1958–2010, 1389 territory-years were monitored during 49 of 53 Bald Eagle breeding seasons. We analyzed the reproductive outcome for a total of 1059 occupied territories. The annual number of occupied territories ranged from a high of 28 (1974 and 1983) to a low of 12 (2001), with a mean of 21.6 ± 4.56 (SD). Annual territory occupancy rates ranged from a low of 0.40 in 2001, to 1.00 in 1959 and 1969, with a mean of 0.77 ± 0.16. For the occupied territories, we documented 866 breeding attempts (active territories) representing an annual mean of 0.83 ± 0.11 (active territories/occupied territories), which ranged from 0.56–1.0 over the study period. Overall annual rate of breeding success, defined as the proportion of active territories that were successful in fledging ≥1 young, was 0.67 ± 0.15. Nesting success, occupied territories that were successful in fledging ≥1 young, had an overall annual rate of 0.55 ± 0.14. A total of 828 young were fledged during the 49 breeding seasons with a mean of 16.9 ± 4.1 young per season. The overall productivity per season was 0.81 ± 0.21 young/occupied territory and the mean brood size per season was 1.48 ± 0.16 young/successful nest.

Changes in Territory Occupancy, Breeding, and Success. During the period from the early 1960s until the mid-1980s, the population was characterized by high occupancy rates and was thought to be at or near carrying capacity for Florida Bay (Sprunt et al. 1973, Ogden 1975, Curnutt 1991). This period of population stability was characterized by small annual variation in occupancy (≤ ± 0.10; Fig. 2). Since the mid-1980s, however, there has been a dramatic increase in variation of annual occupancy (Levene's test for equality of variance; *tau* = 2.449, df = 46, $P < 0.01$). Initial variability in annual occupancy variance in the data set

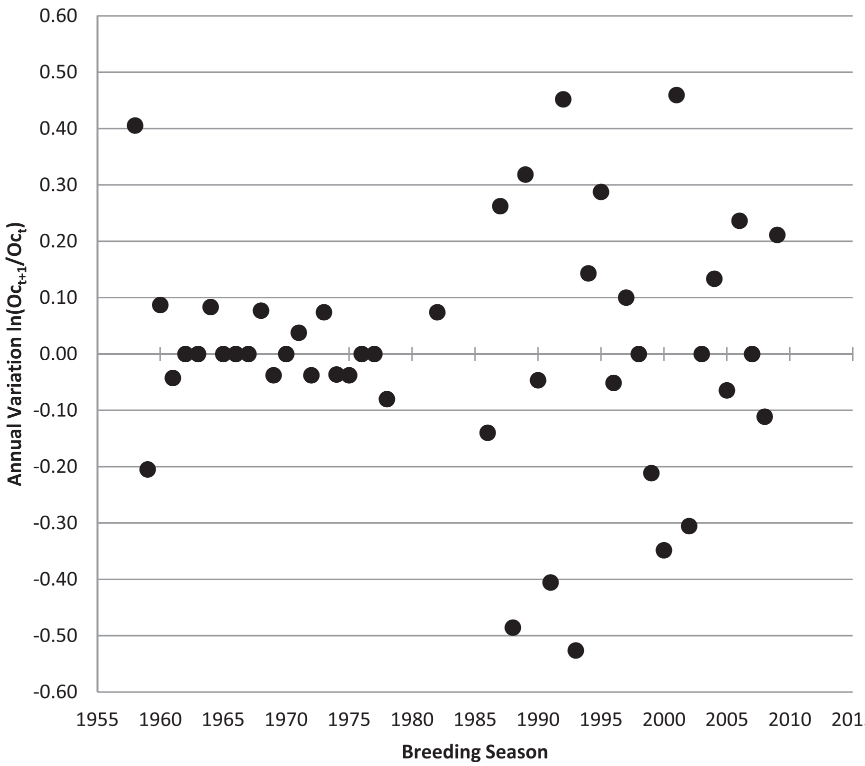

Figure 2. Annual variation in the number of occupied territories (Oc) calculated as $\ln(Oc_{t+1}/Oc_t)$.

(pre-1960) was due to the discovery of new territories in the first few years of surveys.

Within the study period, the annual occupancy remained >80% until 2001, when a decline to 40% was observed (Fig. 3). The highest five-year occupancy period of the study (1972–76, 26.8 ± 0.83 occupied territories) had an occupancy rate of 0.925 ± 0.036. By comparison, the final five-year period of the study (2006–10, 17.5 ± 1.9 territories) had an occupancy rate of 0.60 ± 0.08, a 32% decrease from historical highs. The period immediately preceding the final five years (2001–05, 15.0 ± 2.65 territories) had the lowest five-year occupancy rate in the study, 0.5 ± 0.08, a 43% decrease from the historical high. A Mann-Kendall test revealed that this overall decrease in occupancy rates was significant ($tau = -0.397$, $P \leq 0.001$, $n = 49$).

The annual activity rate also showed a significant decrease over the study period (Mann-Kendall test, $tau = -0.385$, $P \leq 0.001$, $n = 49$; Fig. 3); however, we documented a high mean rate of breeding attempts 0.83 ± 0.11 (active/occupied) over all years. The progression from an occupied territory to an active territory (breeding attempt) represents an important step in the breeding process. The 1958–2010 rate of breeding attempts (active/occupied) showed a significant increase (Mann-Kendall test, $tau = 0.236$, $P \leq 0.018$, $n = 49$). This was due to the decreasing number of occupied territories without a concomitant decrease in the number of active territories, which resulted in an increased rate of breeding attempts (i.e., a greater percentage of occupied territories became active in recent years).

Although the rate of occupancy declined in the mid-1980s, the annual success rate did not change significantly 1958–2010 (Mann-Kendall test, $tau = -0.177$, $P \leq 0.077$, $n = 49$; Fig. 3). As a result, the ratio of successful/occupied nests significantly increased during the study period (Mann-Kendall test, $tau = 0.248$, $P \leq 0.012$, $n = 49$). This increase was due to a loss in the number of occupied nests without a loss in the number of successful nests. The mean nesting success (successful territories/occupied territories) from 1960–75 was 0.48 ± 0.11 and for the last 15 yr (1995–2010) has been 0.59 ± 0.13. The transition from an active territory to a

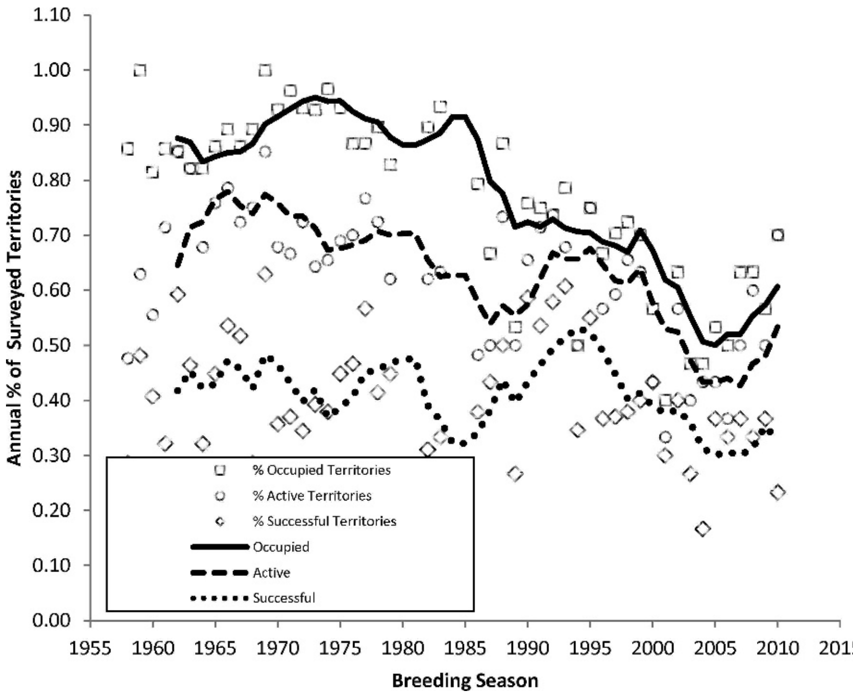

Figure 3. Percentage of surveyed territories occupied (Mann-Kendall test, *tau* = −0.397, $P \leq 0.001$, $n = 49$), percentage of surveyed territories active (Mann-Kendall test, *tau* = −0.385, $P \leq 0.001$, $n = 49$), and percentage of surveyed territories successfully producing at least one young (Mann-Kendall test, *tau* = −0.177, $P \leq 0.077$, $n = 49$) shown as 5-yr moving averages for the period 1958–2010.

successful territory (breeding success), which reflects the ability to successfully raise young to fledgling size, has not changed significantly during the 53-yr period (0.67 ± 0.21 successful territories/active territories, Mann-Kendall test, *tau* = 0.175, $P \leq 0.079$, $n = 49$). For the period 1960–75, the breeding success was 0.60 ± 0.10, and for 1995–2010 was 0.69 ± 0.18.

Production of Young. The number of young produced each year in Florida Bay had a mean of 16.9 ± 4.1, with a high of 28 in 1969 and a low of 8 in 2004. Overall, Florida Bay territories yielded a mean brood size of 1.48 ± 0.16, which showed no significant trend (Mann-Kendall test, *tau* = 0.166, $P \leq 0.099$, $n = 49$) and a mean productivity of 0.81 ± 0.21 young/occupied territory, which increased significantly (Mann-Kendall test, *tau* = 0.315, $P \leq 0.002$, $n = 49$) over the study period (Fig. 4). Productivity increased beginning in the mid-1980s (Fig. 4). This increase in productivity coincided with a decrease in the number of occupied territories during the same period. The number of young produced per active territory also increased (Mann-Kendall test, *tau* = 0.24, $P \leq 0.016$, $n = 49$; Fig. 4).

To investigate temporal changes, we examined the relationship between the mean annual occupancy (number of pairs present on territory) and annual productivity (young/occupied territory) by decade (Fig. 5). There was a significant difference in the number of occupied territories and productivity from 1958 to 2010 ($P \leq 0.0001$). The years 1958–89 and 1990–2010 made up two statistically distinct groups. The period from 1958–89 ($n = 28$ yr) had a mean productivity of 0.70 ± 0.15 young/occupied territory and a mean annual occupancy of 24.3 ± 2.9. The period from 1990–2010 ($n = 21$) had a mean productivity of 0.96 ± 0.20 and a mean annual occupancy of 17.4 ± 3.04 pairs.

DISCUSSION

The Bald Eagle population in Florida Bay shifted from a period of reproductive stability pre-1980s to a period of declining nesting population and increased variability since then. During the time period when most Bald Eagle populations in the contiguous United States were in severe decline, the Florida Bay population remained robust and was

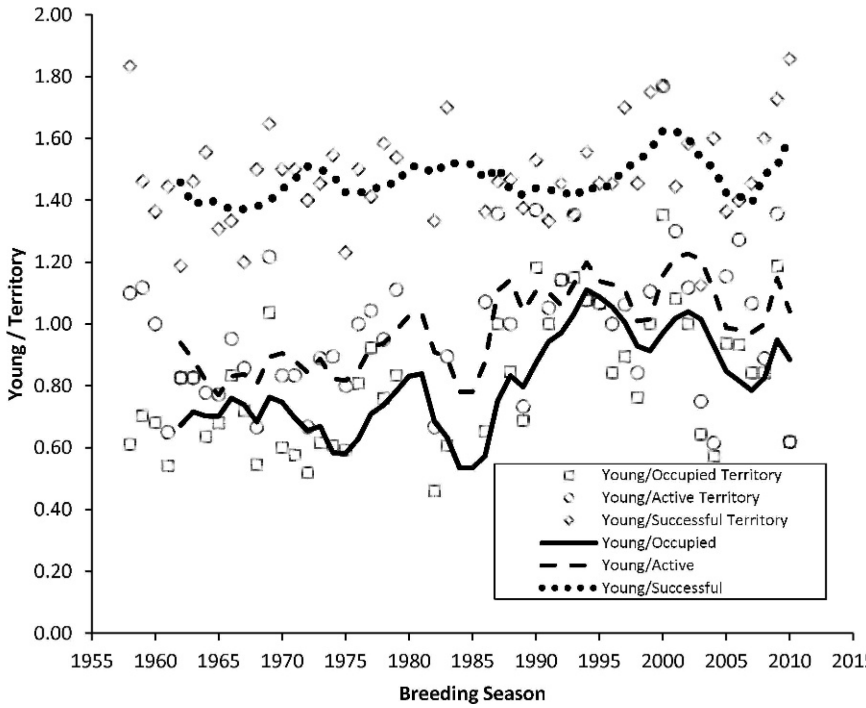

Figure 4. The production ratios of young/successful territory (Mann-Kendall test, *tau* = 0.166, $P \leq 0.099$, $n = 49$), young/active territory (Mann-Kendall test, *tau* = 0.24, $P \leq 0.016$, $n = 49$), and young/occupied territory (Mann-Kendall test, *tau* = 0.315, $P \leq 0.002$, $n = 49$) shown as 5-yr moving averages for the period 1958–2010.

considered at or near the carrying capacity for the Florida Bay system. DDT appears to have had little, if any, effect on the Florida Bay population, which remained stable during the 1960s, 1970s, and into the 1980s. Changes in annual occupancy variation showed a transitional downward shift from a population with high stability to a population in flux with increased annual occupancy variation. The failure of adults to occupy territories is believed to be the main factor driving the breeding dynamics in Florida Bay.

The parameters often used to describe reproductive rates of Bald Eagle populations, are nesting success (successful/occupied), productivity (young/occupied territory), and brood size (young/successful territory). In Florida Bay, overall nesting success (0.55 ± 0.14) was greater than the 0.5 level suggested as the minimum for population maintenance for Bald Eagles (Sprunt et al. 1973: used ''active'' in sense of occupied) and was greater than 0.5 for the last 15 yr of the study period (1996–2010, 0.58 ± 0.12). Data from EVER (1961–72) were included as one of six populations used by Sprunt et al. (1973) to generate their widely accepted benchmarks for Bald Eagle population maintenance. Florida Bay data indicated that occupied territories became active and successful at rates suitable for population maintenance, and were comparable to those of other regions. Nesting success in North America has ranged from 0.45 in Minnesota and Arizona (Grim and Kallemeyn 1995, Driscoll et al. 1999), 0.44–0.77 in Alaska (Steidl et al. 1997, Zwiefelhofer 2007), 0.63 in Colorado and Wyoming (Kralovec et al. 1992), 0.65 in Washington state (Watson et al. 2002), and 0.71 in the Chesapeake Bay (Watts et al. 2008). In Florida, nesting success averages 0.74 (Nesbitt 2001) and the state's management goal is 0.68 nesting success (Brush and Nesbitt 2009).

Productivity >0.7 young per occupied territory is often cited in the literature as necessary for population maintenance (Sprunt et al. 1973) and >1.0 for achieving population restoration and management goals (Buehler et al. 1991). We documented an average productivity of 0.81 ± 0.21 young/occupied territory, which has increased for the period

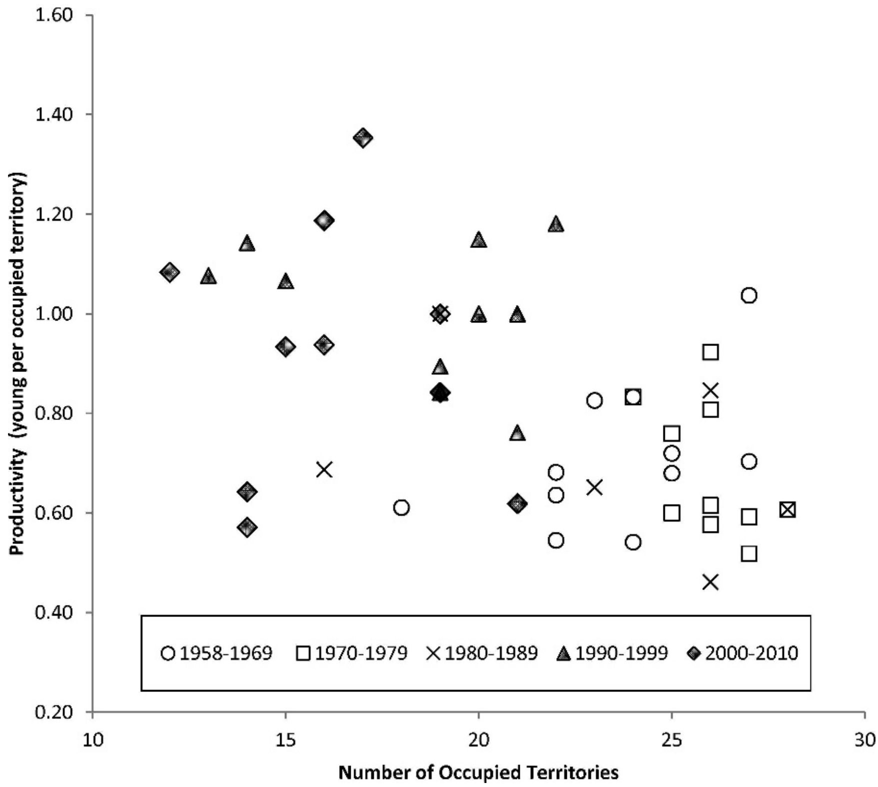

Figure 5. Productivity as a function of occupancy from 1958–2010. Markers with shading and those without signify statistically similar groupings ($P \leq 0.05$).

1995–2010 to 0.91 ± 0.21. These rates were comparable to productivity in other regions, e.g., 0.68 in Minnesota (Grim and Kallemeyn 1995), 0.69 in Arizona (Driscoll et al. 1999), 0.77 in Alaska (Steidl et al. 1997), 0.95 Washington (Watson et al. 2002), 1.21 in Colorado and Wyoming (Kralovec et al. 1992), and 1.3 in the Chesapeake Bay (Watts et al. 2008). Productivity of Florida's Bald Eagle population has averaged 1.17 for 1999–2008 (Brush and Nesbitt 2009).

Similarly, a benchmark of 1.5 young/successful territory is generally cited as typical of a healthy population of eagles (Buehler 2000). We documented an average brood size of 1.48 ± 0.16 young per successful territory, which was very stable across time periods in Florida Bay and which was similar to values for other populations such as Alaska (1.47; Steidl et al. 1997), Washington (1.49; Watson et al. 2002), Arizona (1.5; Driscoll et al. 1999), Florida (1.55; Brush and Nesbitt 2009), and Chesapeake Bay (1.7; Watts et al. 2008).

Although nesting success, productivity, and brood size of the Florida Bay population were similar to those in other populations, caution must be taken when comparing these parameters often cited as benchmarks for population health and stability. The reproductive performance of a population is ultimately gauged by its reproductive output, which is determined by the relationship between nesting success and brood size. Of the three frequently cited benchmarks (nesting success, productivity, and brood size), productivity (>0.7 young/occupied territory) is the most appropriate. Because brood size in Bald Eagles remains fairly constant, we interpret increases in nesting success leading to increases in productivity as indicative of healthy populations. There are two possible ways that population productivity (young/occupied territory) may increase. The first is by increasing the total number of young produced, which is a result of increased nest success. The second is by maintaining a steady production level (young) while decreasing the number of occupied nests contributing to the parameter (decreasing occupancy). Although a steady production of young is considered good, the loss of contributing territories is considered unfavorable, and our study indicated that it is the latter that has occurred in the Florida Bay population. If the number of contributing territories continues to decrease, total production will eventually suffer.

One possible factor contributing to these changes might be the loss of territories that had historically low reproductive performance, or were occupied only for a few years. These territories may be suboptimal, and as a result may be occupied by young adults making their first nesting attempts, which may not be successful. Another possible factor is increased territoriality by pairs occupying ''active territories'' in response to a reduced carrying capacity for Florida Bay. A reduction in availability of resources (food) may lead to an increase in territory size and may limit recruitment of young birds or pairs to the population. Both these factors would lead to a breeding population consisting of mostly older pairs, which typically have higher breeding success and occupy higher-quality territories, and thus would maintain high productivity. Further analysis of individual territories, including the age and identity of the breeding birds and their reproductive rates, would be required to examine this hypothesis.

For species such as eagles, which exhibit late maturation, long lifespan, and low fecundity, changes in breeding patterns often precede changes in population size. Decrease in the age at first breeding has been proposed as an indicator of changes in breeding populations of Bonelli's Eagle (*Hieraaetus fasciatus*), and was correlated with decreased productivity (Balbontín et al. 2003). Recent unpublished reports of some mixed-age Bald Eagle pairs (immature/mature) in Florida Bay need further investigation; they may be an indication that the number of potential mature mates has decreased. A second line of evidence that would suggest a loss in the number of mature eagles maintaining territories in Florida Bay is the abandonment of the year-round communal roost of Bald Eagles; this roost was located near Mahogany Hammock, on the mainland of EVER (Curnutt 1992). Approximately 40 nonbreeding eagles roosted there during the 1990 breeding season (77% subadults). Curnutt (1992) and Robertson (unpubl. data) hypothesized at the time that the aggregation of subadults/nonbreeders may be characteristic of all pristine populations of large raptors, which mature slowly and live a long time, as occurrence of breeding vacancies in such populations was rare. In southeastern Alaska during the 1970s, Hansen and Hodges (1985) found high rates of nonbreeding adult Bald Eagles with stable population densities and suggested that the surplus of nonbreeders may be an indication of food limitations that produce more individuals than available breeding sites. No eagles roosted at Mahogany Hammock during the 2009 or 2010 breeding seasons and the roost may not have been used since 2001. In 2001, a nesting pair established a nesting territory at the site, and it is possible they discouraged the subadults/nonbreeders from roosting there. Alternatively, the roost may have been abandoned after a reduction in local food availability, as nonbreeding eagles congregate and often form roosts close to reliable food resources (Isaacs and Anthony 1987, Keister et al. 1987, Wilson and Gessaman 2003).

During the period 1987–91, dramatic and rapid ecological changes occurred in Florida Bay (Hall et al. 1999, Fourqurean and Robblee 1999), which coincided with the decline in occupancy found in the Bald Eagle data. The first was the massive seagrass (*Thalassia testudinum)* die-offs in 1987 across much of Florida Bay (Robblee et al. 1991), which have been triggered by multiple environmental stressors including hypersalinity and high summer temperatures among others (Zieman et al. 1999, Madden et al. 2009). The seagrass die-off was followed by a cascade of other ecological events, which transformed Florida Bay in 1991 from a primarily clear water system to one with extensive and persistent turbidity and phytoplankton blooms (Fourqurean and Robblee 1999). The release of nutrients and sediments from the loss of seagrass is a likely contributor to the increased number of algal blooms (Madden et al. 2009). Phytoplankton blooms were more intense and covered larger areas of Florida Bay during the winter months (Butler et al. 1995), which is the breeding season for Florida Bay Bald Eagles. The associated increase in turbidity could also have had a negative effect on Bald Eagle foraging by reducing their ability to visually detect fish prey. In more recent years, blooms in the northeastern region of Florida Bay have also occurred, while conditions in western Florida Bay have improved, as indicated by chlorophyll *a* biomass (Boyer et al. 2009).

Changes in freshwater inputs have caused changes in the salinity patterns in Florida Bay (Kelble et al. 2007), which in turn influences and shapes a variety of ecological processes (Zieman et al. 1999). Because the effects of these changes often affect multiple trophic levels, fish-eating birds in Florida Bay, such as the Bald Eagle, are particularly sensitive to fluctuations in salinity level and freshwater flow (Matheson et al. 1999, Crozier and Gawlik 2003, Davis et al. 2005, Frederick et al. 2009, Lorenz et al. 2009). For example, distributions and productivity of the spotted seatrout (*Cynoscion nebulosus*) a contributing prey item within Florida Bay, vary with salinity (Thayer et al. 1999, Powell 2003). Distributions of other important fish prey species such as hardhead catfish (*Arius*) and mullet (*Mugil*), are also affected by salinity levels (Sogard et al. 1989, Armstrong et al. 1996). Populations of wading birds, another important prey item for eagles, have also undergone decreases in size and reproductive rate in Florida Bay and the southern Everglades (Powell and Powell 1986, Powell et al. 1989, Ogden 1994). For example, Florida Bay populations of the Roseate Spoonbill (*Ajaia ajaja*) have exhibited a decline in the number of nests over the same time period as the present Bald Eagle study period (Lorenz et al. 2009, J. Lorenz pers. comm.). Roseate Spoonbill reproductive rates also correlated with species composition, abundance, and availability of prey fish, each of which is a function of hydrological conditions and salinity (Powell et al. 1989, Lorenz 2000, Lorenz and Serafy 2006, Lorenz et al. 2009). In the Chesapeake Bay, salinity levels were correlated with breeding densities of Bald Eagles (Watts et al. 2006), with provisioning rates and instantaneous growth rates of first-hatched nestlings (Markham and Watts 2008b), with biomass of prey items delivered to Bald Eagle nests, but not with prey composition (Markham and Watts 2008a). Salinity was also correlated with differences in regional population growth of Bald Eagles and other piscivorous birds within the Chesapeake Bay ecosystem (Viverette et al. 2007). Although there are a small number of foraging studies on freshwater lakes from central and north Florida (McEwan and Hirth 1980, Nesbitt et al. 2004, FWC 2008), there is very limited information on foraging by Bald Eagles in Florida's mangrove estuaries, such as Florida Bay.

A key stage in reproduction for Bald Eagle pairs is the occupation of a territory. Due to the declining number of occupied territories in Florida Bay and because of the negative effects these declines may have on the population's reproductive output, continued long-term monitoring of Bald Eagle territories, reproductive success, and nest locations in Florida Bay and Everglades National Park is important. The similarity in timing of changes occurring both in the Florida Bay ecosystem and its Bald Eagle population warrants further investigation as the Bald Eagle may serve as a bioindicator of ecosystem change. Future research should emphasize understanding the environmental factors that influence the decisions by adults to occupy particular territories. In the case of mangrove estuaries such as Florida Bay, this requires a better understanding of the Bald Eagle's foraging ecology in the southern coastal Everglades/Florida Bay and the relationship between the upsteam freshwater ecosystem and the estuary-breeding eagles.

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