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Evaluation of biological benefits and social consequences of Bald Eagle protection standards in Virginia

B. D. Watts
The Center for Conservation Biology, bdwatt@wm.edu

EVALUATION OF THE BIOLOGICAL BENEFITS AND SOCIAL CONSEQUENCES OF BALD EAGLE PROTECTION STANDARDS IN VIRGINIA

CENTER FOR CONSERVATION BIOLOGY
COLLEGE OF WILLIAM AND MARY

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Bryan D. Watts
Center for Conservation Biology
College of William and Mary
Williamsburg, VA 23187-8795

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Cover Photo: *Bald Eagle nest on Potomac River by Bryan Watts*

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Executive Summary

Management guidelines intended to protect Bald Eagles on private lands must attempt to strike a balance between benefits to the breeding population and the burden imposed on society. Since reaching a low in the early 1970s the Virginia Bald Eagle population has exhibited an exponential recovery with an overall ten-fold increase in breeding pairs. The dramatic recovery is placing a rapidly expanding burden on the regulatory agencies to implement current management guidelines and society to comply with guidelines. Protection standards currently in use were developed in an earlier phase of recovery when limited information was available. The primary objective of this project is to evaluate both the social and biological implications of current Virginia guidelines. Twenty-five years of Bald Eagle survey information was used to analyze trends relative to guidelines.

Bald Eagle pairs in Virginia exhibit a 27% annual turnover rate in nesting substrate such that the number of nest structures is, on average, more than 40% higher than the number of breeding pairs. However, average life expectancy of nests at abandonment is only 1.46 years. Because there is a 3-year policy for declaration of an abandoned nest required for the dissolution of management buffers, the management standard that protects all trees containing any nest material seems to provide little value. Given the burden on regulatory agencies to track nest structures in order to implement this standard, a change in the guidelines should be considered.

The 3-year rule regarding a determination of abandonment was established under the belief that there was a sharp decline in the probability of re-occupation following the third year. The probability distribution of re-occupation following nest abandonment approximates a continuous, negative exponential with no functional breaks. Although the probability that a pair will ever return after 3 years have passed is less than 10%, the probability after 2 years is only 13%, after 4 years is 7.5%, and after 5 years is less than 5%. Because there are no obvious breaks in the distribution, establishment of the length for a waiting period is somewhat arbitrary.

Lands surrounding Bald Eagle nests that are considered under “management restrictions” have increased exponentially along with the breeding population. The economic value of these lands has also increased due to both the expansion of lands under restrictions and the increase in real estate valuations in recent years. In 2003, the collective value of lands within secondary management buffers surrounding active nests exceeded 1.7 billion dollars. The magnitude of this societal burden demands an effort to ensure that guidelines are both efficient and effective.

Despite the evidence that Bald Eagles prefer to nest in areas away from human development, an increasing number of pairs are nesting in such locations. This study demonstrates that urban pairs represent a small fraction of the overall population. More than 80% of the population nests in areas with less than 1% impervious surface in management buffers. Only 5% of pairs nested in areas with more than 2% impervious surface. This study concluded that pairs breeding in areas with the highest coverage of impervious surface, were at least as productive as other pairs in the population.

BACKGROUND

Context

Wildlife management guidelines intended to protect species that occur primarily on private lands must attempt to strike a balance between benefits to the target species and the burden imposed on society. Since their elevation to the federal threatened and endangered species list, guidelines protecting nesting Bald Eagles have used a combination of spatial buffers and time-of-year restrictions intended to reduce disturbance and its impacts on abandonment and productivity. In Virginia, primary (229 m radius) and secondary (400 m radius) management zones are established around active nest trees with specific restrictions imposed during the nesting season. Management buffers are maintained and nest trees are protected for a period of 3 years after a nest has been abandoned. Documented nest trees are protected beyond 3 years post abandonment, as long as, nest material remains.

Since reaching a low in the early 1970s the Chesapeake Bay Bald Eagle population has exhibited a rapid recovery with an overall ten-fold increase in breeding pairs. This increase has been exponential with an average doubling time of just over 8 years (Watts et al., in press). This rate of growth is comparable to that experienced by other populations within the portion of the breeding range where the species has been federally listed. During the 15-year period between 1982 and 1997, average growth rate within the conterminous United States was 8.6% (Buehler 2000). The Chesapeake Bay population has now recovered to the size estimated during the 1930s (Tyrell 1936, Abbott 1978a). Population size thresholds outlined in the Chesapeake Bay Bald Eagle Recovery Plan (Byrd et al. 1990) for federal “downlisting” (175-200) and “delisting” (300-400) were met in 1988 and 1992, respectively, for the broader Chesapeake Bay Recovery Region (Millar 1995, 1999).

The dramatic recovery of the Bald Eagle population is placing a rapidly expanding burden on the regulatory agencies to implement current management guidelines and society to comply with guidelines. Protection standards currently in use were developed in an earlier phase of recovery when limited information was available. Since continuing to implement such protocols will inevitably place increased burdens on both regulatory agencies and landowners, it is prudent to evaluate the social costs and biological benefits of such action.

Objectives

The primary objective of this project is to evaluate both the social and biological implications of current Virginia guidelines developed for the management of Bald Eagle breeding territories. This includes an evaluation of the benefits of nest protection standards using more than 25 years of Bald Eagle nesting data collected in Virginia and the burden to society in the collective land area and its value that falls under management restrictions. An additional objective is to quantify the proportion of the breeding population that occurs in “urban” locations and to evaluate its reproductive performance relative to the broader state population.

METHODS

Bald Eagle Data

All of the data used to examine nest tree use, nest loss patterns, and the amount of land included within management buffers was derived from the Virginia Bald Eagle breeding survey. The survey has been conducted annually since 1977 (Watts and Byrd 2005). The survey measures breeding activity and productivity via a standard 2-flight approach (Fraser et al. 1983). The first flight is conducted between late February and mid-March to locate active nests. A high-wing Cessna 172 aircraft is used to systematically overfly the land surface at an altitude of approximately 100 m to detect eagle nests. The aircraft is maneuvered systematically between the shoreline and a distance of approximately 1 km to cover the most probable breeding locations. All Bald Eagle nests detected are plotted on 7.5 min topographic maps and given a unique alpha-numeric code. Each nest is examined to determine its condition and activity status. A breeding territory is considered to be "occupied" if a pair of birds is observed in association with the nest and there is evidence of recent nest maintenance (e.g. well-formed cup, fresh lining, structural maintenance). Nests are considered to be "active" if a bird is observed in an incubating posture or if eggs or young are detected in the nest (Postupalsky 1974). The second survey flight is conducted from late April through mid-May to check active nests for productivity. A high-wing Cessna 172 is flown low over the nest allowing observers to examine nest contents. The number of eaglets present is recorded along with their approximate ages.

The primary focus area for the Virginia Bald Eagle breeding survey includes the tidal reaches of Chesapeake Bay tributaries and the lower Delmarva Peninsula. All Chesapeake Bay tributaries in Virginia are systematically surveyed to the extent of tidal influence. These drainages encompass nearly all historic records of breeding eagles in Virginia and continue to support the vast majority of the population. Throughout the 1990's, several areas have been added to the core survey area including Back Bay/North Landing River area, Lake Drummond, Kerr Reservoir, Lake Chesdin, Swift Creek Reservoir, Diascund Reservoir, and Lake Manassas. No attempts have been made to systematically survey the piedmont and mountain regions of Virginia.

Nest Protection Standards

Depending on the specific question to be addressed data from different time periods was extracted from the annual Bald Eagle survey. The entire data set was used to evaluate return probabilities and turnover rates. Return probabilities were evaluated by compiling the time intervals between nest abandonment and nest re-occupation if and when a nest tree was ever re-occupied. Return probabilities were compiled to examine both accumulated probabilities (probabilities that pairs would ever return) over time and time-specific probabilities (probability that a pair would return in a given year). Turnover rates in nest trees were quantified by compiling the number of nests that were not occupied in a subsequent year compared to the number of active nests or occupied territories for that year.

Survey information from 1999-2003 was used to evaluate survivorship of abandoned nests because a special effort was made during this time period to examine the condition and persistence of all nest structures. Information on nest persistence after abandonment was compiled in order to perform a cross-sectional life table (Dempster 1975) to examine l_x (number surviving to beginning of age interval) and e_x (average, age-specific life expectancy)

Bald Eagle Management Buffers

The collective area of land contained within management buffers was quantified for each year of the survey (1977-2002). The amount of land within primary (229 m radius) and secondary (400 m radius) buffers was quantified by placing boundaries around each nest using Arc 3.2 (ESRI), overlaying the buffer on digital maps, and cutting out water areas to reveal the area remaining in both wetlands and uplands. This information was compiled for each nest and year and then stratified according to supporting jurisdiction.

Valuation of lands within Bald Eagle management buffers was estimated using the land areas derived above and property values provided in the Virginia Assessment/Sales Ratio Studies. The collective values of these lands were extrapolated for 4 years including 1991, 1995, 1999, and 2003 (Virginia Department of Taxation 1991, 1995, 1999, 2003). The collective land area within primary and secondary buffers was compiled by jurisdiction and multiplied by the average, per acre value for each jurisdiction.

Bald Eagles within Urban Settings

The amount of human activity within management buffers was estimated using the impervious surface digital coverage available within the most recent (2001) National Land Cover Data (NLCD). The area of coverage for impervious surface was determined within the secondary management zone for each nest active in 2001. The coverage was then converted to a percentage using the land area within the buffer zone. The distribution of cover values was examined and subdivided to represent a range of human activity. In order to gain a representative sample of reproductive performance, success and productivity was extracted for each nest/territory between 2000 and 2001. Breeding success was compared across the range of impervious surface values using all breeding attempts over the 3-year period. Average brood size was compared over this same period using a one-way ANOVA.

RESULTS

Patterns Related to Nest Tree Protection Standards

Nest abandonment and relocation rates for Bald Eagles are relatively high in Virginia. Between 1977 and 2002 the probability that an active nest would be used in the following year was 0.72 (N = 3,473) such that the mean, annual abandonment rate was 27.9 ± 1.78 (S.E.) percent. Over this time period there has been considerable year-to-year variation in relocation rates with individual years varying from 15.9 to 48.5% (Figure 1). Examination of the residuals about the mean indicates that there has been a decline in the magnitude of the variation through time. All of these values represent population averages. Individual nests may be occupied from as little as a single year to decades.

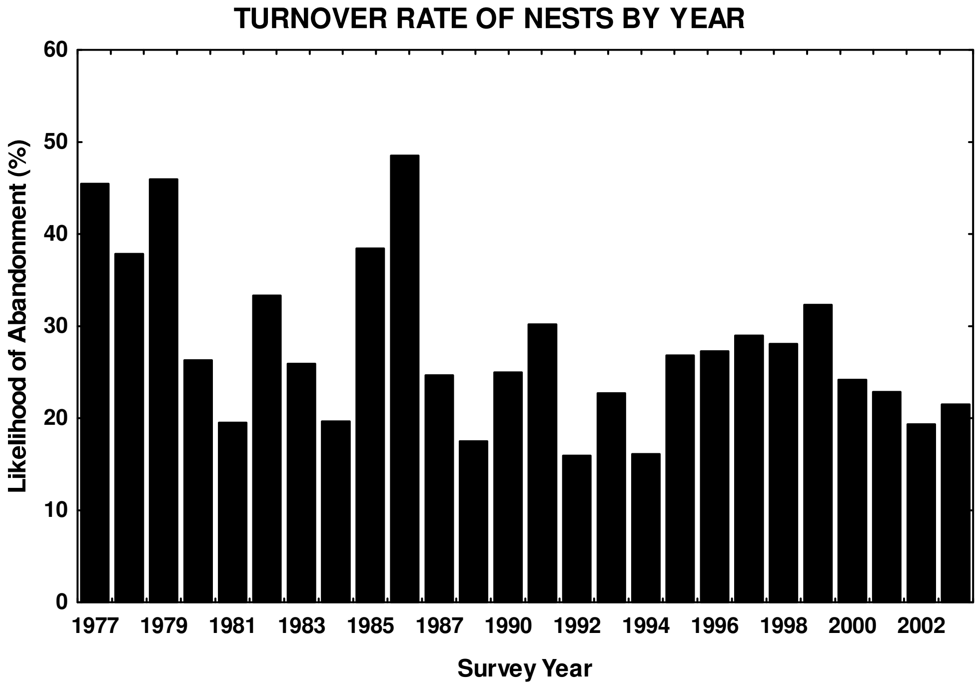


Figure 1. Turnover rates of nest structures by year. Turnover is the likelihood of abandonment calculated as the number of nests abandoned/active nests X 100.

One of the consequences of having such a high turnover rate in nests is that Virginia supports a large number of abandoned nest structures annually that are protected under current guidelines. In 2003, 521 nest structures were documented in Virginia, only 371 of which were active. Between 1999 and 2003 the number of total nest structures was on average 43.2 ± 2.48% higher than the number of active nests (Figure 2). Approximately 5% of the nest structures remaining each year are remnant or partial nests. These nests rarely survive until the following year. Of 124 remnants recorded between 1999 and 2003, only 6 (4.8%) were present the following year.

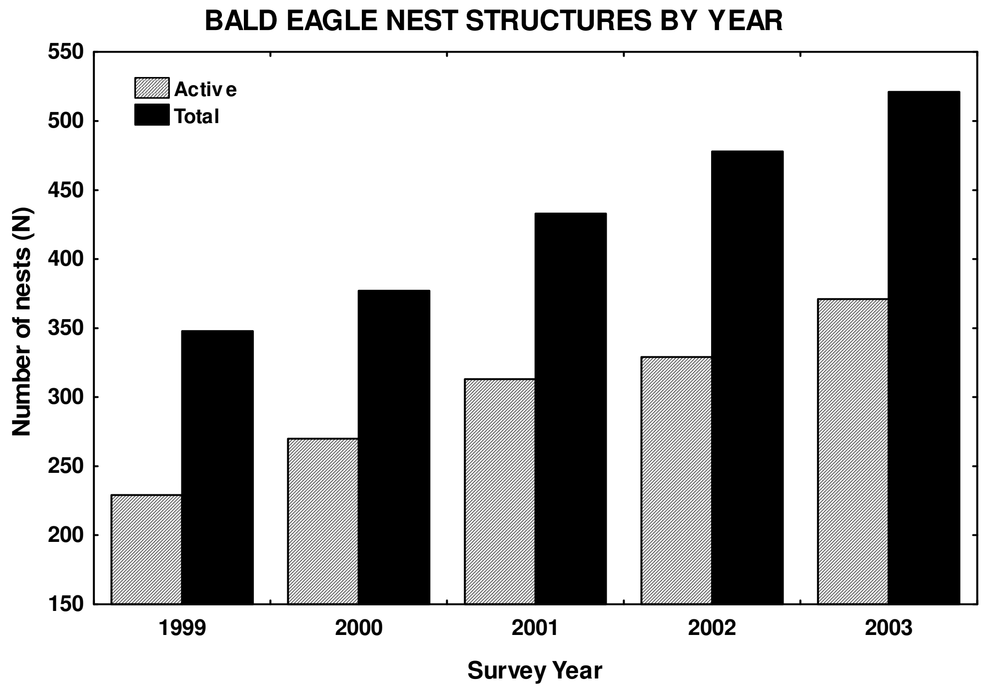
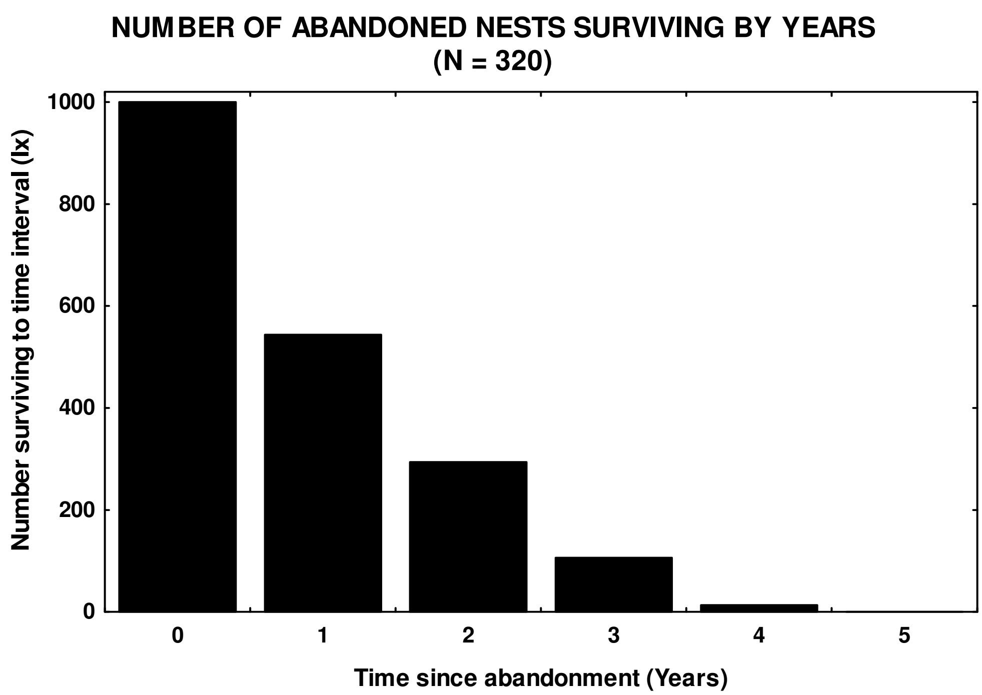


Figure 2. Number of nest structures present within the population (1999-2003). Total refers to active nests + abandoned nests.

Once abandoned, nest structures do not survive for long periods of time. From a cohort of 320 abandoned nests that were followed until no structure remained none were present after 4 years (Figure 3). This loss rate results in a fairly steep survivorship ($\log(l_x)$) curve (Figure 4). At the time of abandonment, life expectancy (e_x) for nest structures is only 1.46 years.

Figure 3. Number of abandoned nests surviving to the beginning of age classes.



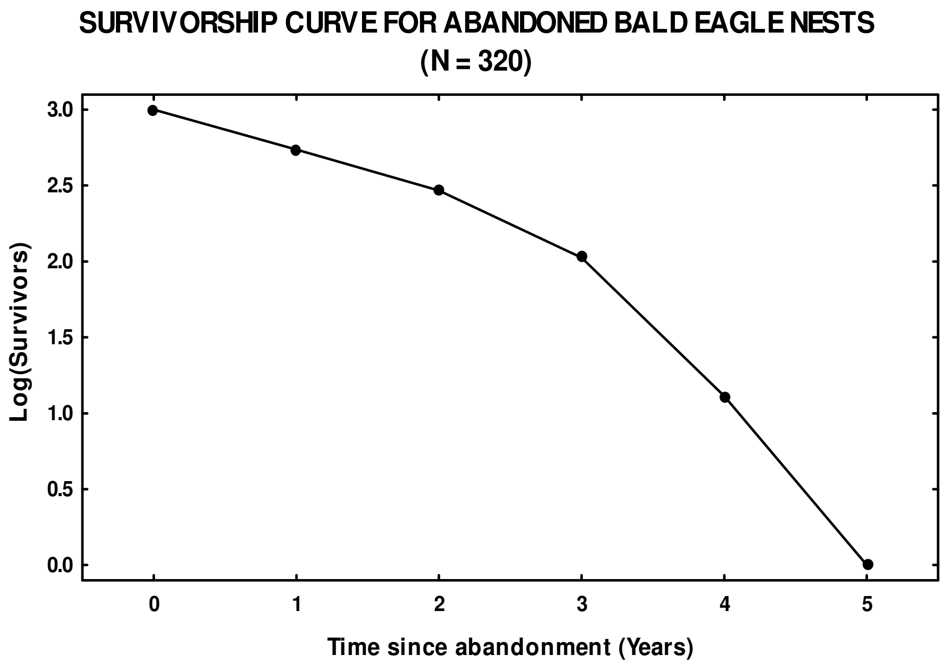
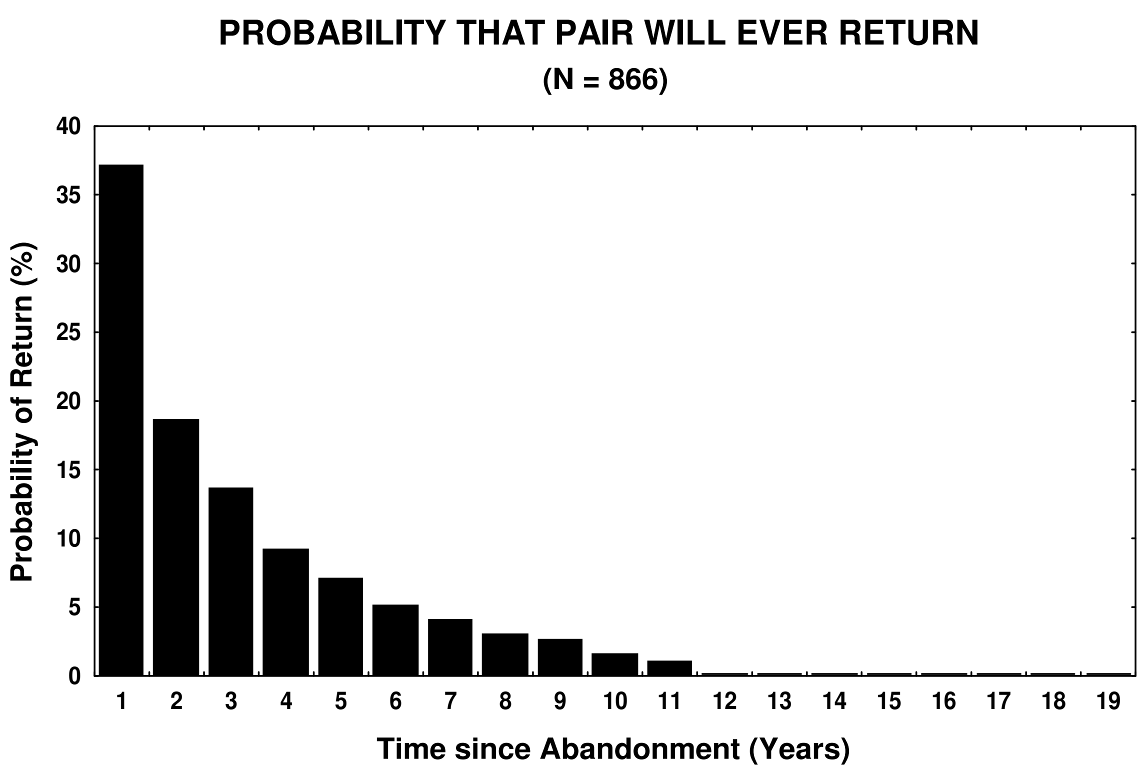


Figure 4. Survivorship curve (Log survivors) for abandoned Bald Eagle nests.

The likelihood that a pair will ever return to a nest tree after a nest has been abandoned is low (<37%, N=866). This likelihood declines with each additional year after abandonment (Figure 5). The relationship between time since abandonment and likelihood of return approximates the negative exponential with no obvious break points.

Figure 5. Accumulated probability distribution of pairs ever returning to abandoned nest structures.



Beyond 3 years after abandonment the likelihood is less than 10% that the tree will be used again. The survey has documented some extended intervals between abandonment and re-use that reflect the fact that suitable nest trees are often in limited supply. The likelihood that a pair will return in a specific year drops dramatically from 18.5% the second year to 5% in the third year (Figure 6).

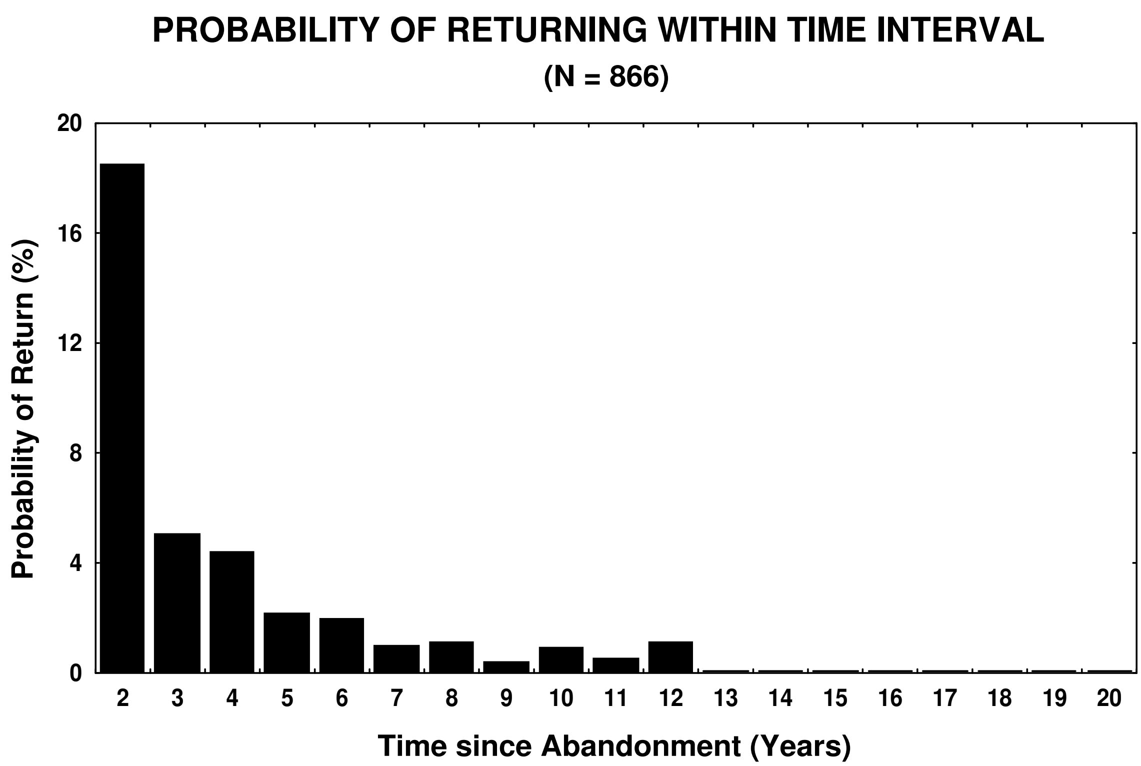


Figure 6. Distribution of return probabilities for specific time intervals.

Land within management buffers

In 2002, the collective amount of land falling within Bald Eagle management buffers was 1,087.1 ha within primary buffer zones and 4,152.5 ha within secondary buffer zones. This represents a 10-fold increase from 1977 when primary and secondary buffers contained only 103.8 and 408.8 ha respectively (Figure 7). This rate of increase corresponds closely to the increase in the breeding population over this time period.

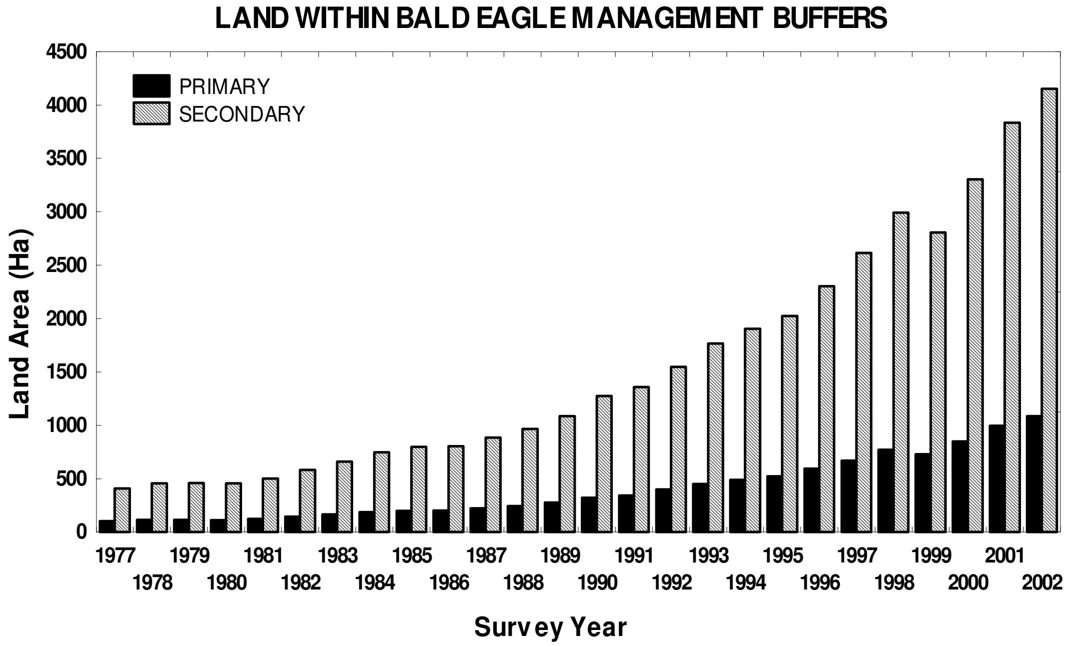


Figure 7. Collective land area falling with primary and secondary Bald Eagle management buffers by year.

Valuations of management buffers

In 2003, the value of land within active Bald Eagle management buffers in Virginia was very high. The collective land value within primary management buffers was more than 575 million dollars and within secondary management buffers was more than 1 billion 747 million dollars. Values by jurisdiction varied from a high of more than 197 million (primary buffer area) in Fairfax County to 139 thousand in Sussex County (Table 1). This level of spatial variation in the value of lands under management reflects not only the variation in the number of pairs across jurisdictions but more importantly the large differences in land values. Mean value per pair was 2.57 $\pm$ 0.702 (mean $\pm$ SE) million dollars within primary buffers and 7.87 $\pm$ 1.394 million dollars within secondary buffers. These values varied widely among jurisdictions (Table 1). There is an inverse relationship between the value of land per pair and the number of pairs by jurisdiction (Figure 8). This relationship likely reflects both the positive association between land values and urban centers and the avoidance of urban centers by eagles.

The value of lands under “management restrictions” has increased nearly 7.3 fold between 1991 and 2003 (Figure 9). This dramatic increase reflects both the increase in the nesting population and the rapid increase in real estate values over this time. The number of pairs under management increased from 109 to 352 or 3.2 fold over this time while the average value per acre across jurisdictions increased 2 fold. Although this is the average for all jurisdictions, some locations increased at faster rates (Table 2). For example, land values in King George County increased more than 6 fold during this time.

Table 1. The collective value of management buffers and average per pair values by Virginia jurisdictions.

Jurisdiction	Nests	Total Value (Prim Buffer)	Value per Pair (Prim Buffer)	Total Value (Sec Buffer)	Value per Pair (Sec Buffer)
Accomack	7	2,563,396	366,199	7,826,649	1,118,093
Amherst	1	245,309	245,309	759,872	759,872
Caroline	11	2,437,490	221,590	7,374,375	670,398
Charles City	19	3,476,397	182,968	10,196,415	536,653
Chesapeake	3	5,691,443	1,897,148	18,260,410	6,086,803
Chesterfield	5	13,599,948	2,719,990	39,855,200	7,971,040
Richmond City	1	14,250,585	14,250,585	40,528,831	40,528,831
Essex	19	4,074,728	214,459	12,519,545	658,923
Fairfax	8	197,256,234	24,657,029	599,511,104	74,938,888
Gloucester	4	2,938,978	734,744	8,976,057	2,244,014
Halifax	2	464,182	232,091	1,437,859	718,930
Hampton	2	14,093,356	7,046,678	38,760,118	19,380,059
Hanover	1	902,452	902,452	3,112,572	3,112,572
Henrico	4	22,173,767	5,543,442	62,513,291	15,628,323
Hopewell	1	8,289,013	8,289,013	25,676,185	25,676,185
Isle of Wight	6	2,979,846	496,641	8,565,964	1,427,661
James City	15	39,003,031	2,600,202	116,282,726	7,752,182
King & Queen	7	4,414,998	630,714	13,013,563	1,859,080
King George	26	3,131,480	120,442	9,282,219	357,008
King William	15	3,039,024	202,602	9,175,495	611,700
Lancaster	8	5,764,115	720,514	16,854,600	2,106,825
Mathews	3	2,317,495	772,498	7,112,582	2,370,861
Mecklenburg	2	256,981	128,491	709,200	354,600
Middlesex	14	9,495,102	678,222	29,046,984	2,074,785
New Kent	11	4,518,508	410,773	13,712,319	1,246,574
Newport News	2	17,240,591	8,620,296	53,404,741	26,702,370
Norfolk	1	5,463,232	5,463,232	23,863,964	23,863,964
Northampton	2	1,314,468	657,234	4,071,719	2,035,860
Northumberland	18	21,690,039	1,205,002	69,447,941	3,858,219
Page	1	294,962	294,962	913,680	913,680
Powhatan	1	486,065	486,065	1,505,642	1,505,642
Prince Edward	1	186,649	186,649	578,168	578,168
Prince George	10	3,650,982	365,098	11,276,973	1,127,697
Prince William	7	36,946,742	5,278,106	111,410,984	15,915,855
Richmond	27	5,907,347	218,791	18,085,255	669,824
Shenandoah	1	342,198	342,198	1,059,999	1,059,999
Stafford	9	21,549,129	2,394,348	65,225,572	7,247,286
Suffolk	6	3,301,876	550,313	10,096,084	1,682,681
Surry	12	5,125,571	427,131	15,506,131	1,292,178

Table 1. Continued

Jurisdiction	Nests	Total Value (Prim Buffer)	Value per Pair (Prim Buffer)	Total Value (Sec Buffer)	Value per Pair (Sec Buffer)
Sussex	2	139,462	69,731	481,189	240,595
Virginia Beach	6	39,005,644	6,500,941	118,542,833	19,757,139
Westmoreland	41	18,208,548	444,111	56,357,778	1,374,580
York	10	27,696,855	2,769,685	84,813,076	8,481,308
Total	**352**	**575,928,218**		**1,747,705,865**	

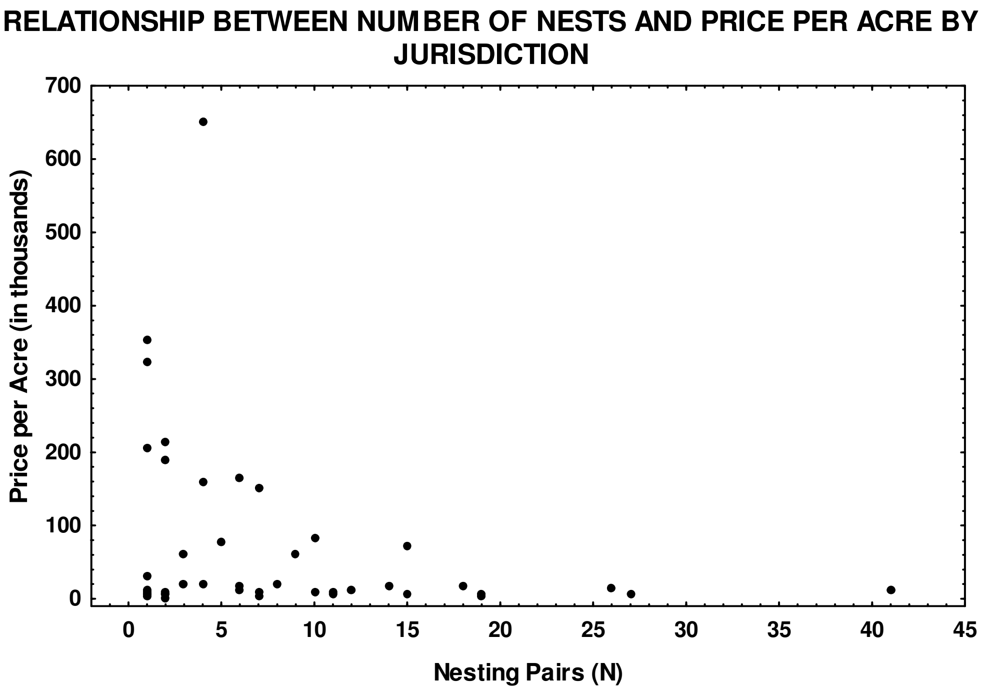


Figure 8. Relationship between the number of nests and the value of land by jurisdiction.

Table 2. Number of Bald Eagle pairs and price per acre in 1991 and 2003 for Virginia jurisdictions.

Jurisdiction	Nesting Pairs (1991)	Price per Acre (1991)	Nesting Pairs (2003)	Price per Acre (2003)
Accomack	5	$4,750.75	7	$10,034.59
Amherst	0	$2,917.92	1	$6,077.71
Caroline	5	$2,636.60	11	$5,723.46
Charles City	2	$2,411.87	19	$5,128.20
Chesapeake	0	$32,324.52	3	$62,228.77
Chesterfield	0	$38,968.54	5	$77,934.43
City of Richmond	0	$217,909.22	1	$353,069.35
Essex	5	$3,124.41	19	$5,750.79

Table 2. Continued

Jurisdiction	Nesting Pairs (1991)	Price per Acre (1991)	Nesting Pairs (2003)	Price per Acre (2003)
Fairfax	3	$319,137.17	8	$651,772.15
Gloucester	2	$9,750.13	4	$19,433.70
Halifax	1	$1,652.15	2	$5,750.24
Hampton*	0	$124,978.52	2	$188,363.48
Hanover	0	$11,563.33	1	$31,786.56
Henrico	1	$74,437.24	4	$158,088.20
Hopewell	0	$101,944.90	1	$205,366.76
Isle of Wight*	0	$6,047.67	6	$12,790.08
James City	5	$28,884.60	15	$71,789.52
King & Queen	1	$3,894.79	7	$3,140.67
King George	13	$2,569.91	26	$15,744.74
King William	4	$3,063.84	15	$5,510.02
Lancaster	2	$12,148.90	8	$20,277.26
Mathews	0	$10,633.34	3	$19,286.58
Mecklenburg	0	$2,414.21	2	$5,232.56
Middlesex	6	$8,630.28	14	$17,216.18
New Kent	4	$4,626.33	11	$10,670.65
Newport News*	1	$136,601.64	2	$213,574.54
Norfolk*	0	$209,528.58	1	$322,695.32
Northampton	3	$4,669.21	2	$10,214.85
Northumberland	4	$8,338.61	18	$16,283.49
Page	0	$4,358.25	1	$7,307.92
Powhatan	0	$4,409.76	1	$12,042.63
Prince Edward	0	$2,461.45	1	$4,624.38
Prince George	5	$4,703.90	10	$10,090.52
Prince William	1	$63,372.80	7	$151,999.17
Richmond	11	$2,797.96	27	$5,760.27
Shenandoah	0	$5,718.34	1	$8,478.23
Stafford	4	$20,646.34	9	$60,549.29
Suffolk	1	$7,967.99	6	$18,332.45
Surry	5	$8,666.35	12	$10,941.81
Sussex	0	$1,197.73	2	$2,166.63
Virginia Beach*	0	$91,485.64	6	$165,912.98
Westmoreland	14	$5,798.76	41	$11,546.65
York	1	$38,070.33	10	$81,880.13

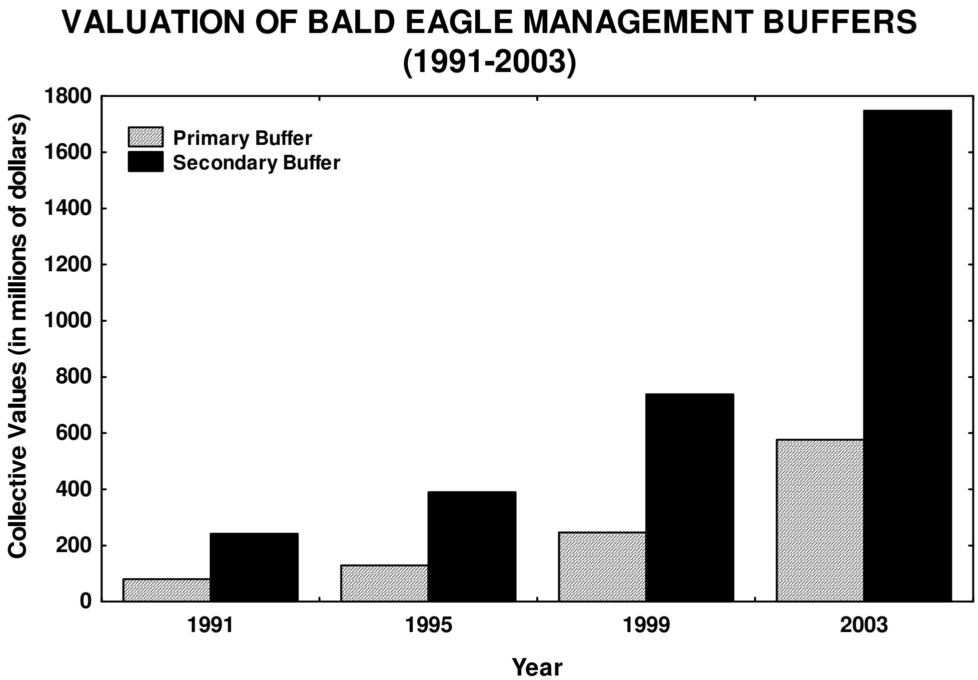


Figure 9. Collective valuations of land within primary and secondary buffers through time.

Bald Eagles within Urban Settings

In general, impervious surface coverage within secondary management buffers was very low. In 2001, 80% of the active nests had less than 1% coverage of impervious surface including 62% with none (Figure 10). Only 5% of nests had more than 2% impervious surface and none had more than 5% coverage within buffer areas. When evaluated across the gradient of impervious surface available, breeding success showed a positive trend with increasing impervious surface (Figure 11). Although success increased by more than 8% when pairs with no impervious surface were compared to pairs with >2% impervious surface, this trend was not statistically significant ($X^2 = 1.07$, df = 3, $P > 0.1$). A similar pattern occurred with reproductive rate (Figure 12). Average productivity increased by more than 25% with increasing impervious surface but this trend was not statistically significant (one-way ANOVA, df = 3, $F = 1.60$, $P > 0.1$).

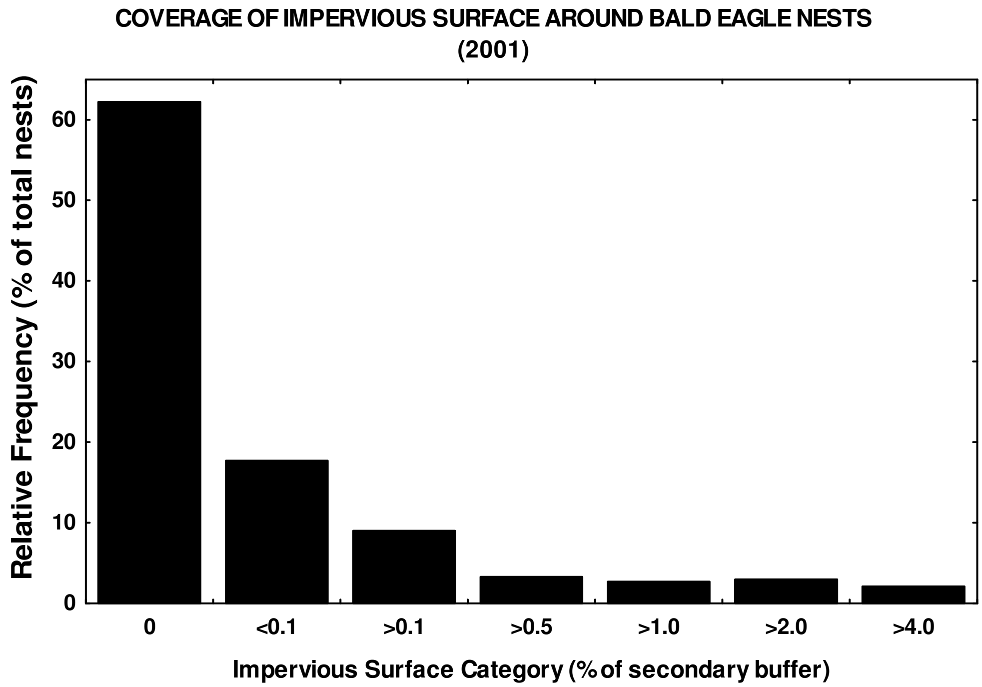


Figure 10. Relative frequency of Bald Eagle nests across a range of impervious surface cover.

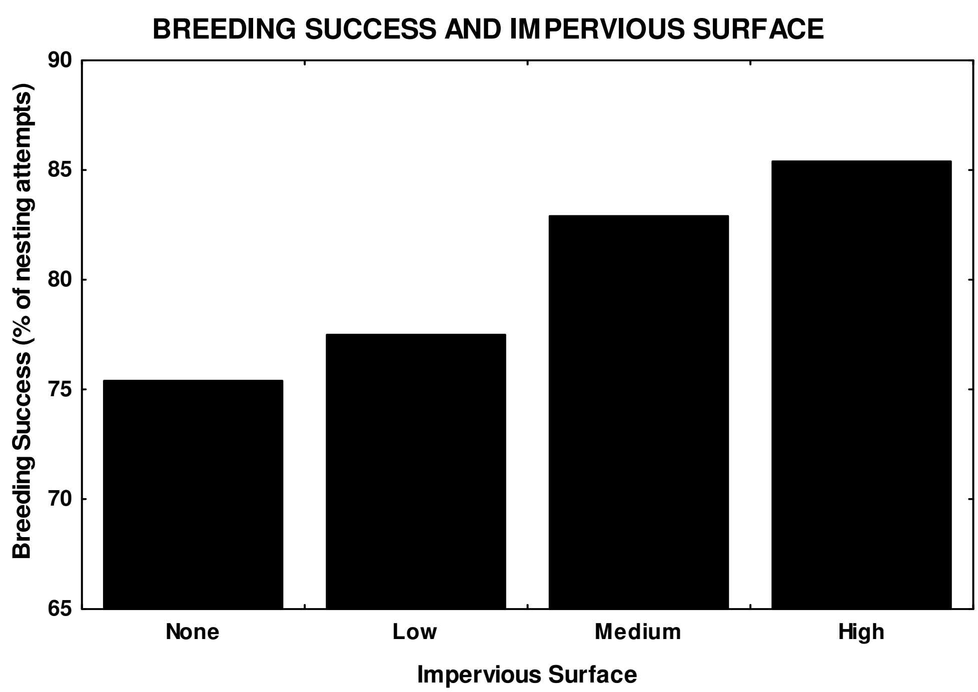


Figure 11. Breeding success from 2000 to 2002 for pairs across a gradient of impervious surface cover. Categories with impervious surface are Low - < 1.0%, Medium – 1.0-1.0% and High - > 2.0%.

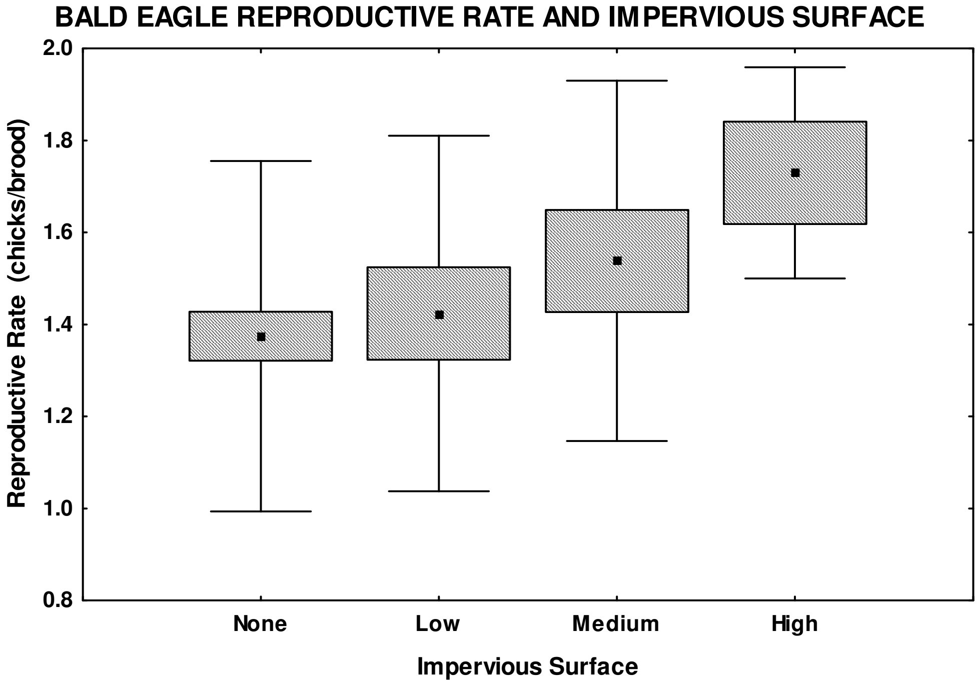


Figure 12. Reproductive performance of Bald Eagle pairs between 2000 and 2002 across a gradient of impervious surface cover. Categories with impervious surface are Low - < 1.0%, Medium – 1.0-1.0% and High - > 2.0%.

DISCUSSION

Bald Eagles within the tidal reach of the Chesapeake Bay including Virginia have experienced a dramatic recovery since the 1970s (Watts et al. 2005). Between 1977 and 2002 the average, annual rate of increase has been 9.4%. This level of growth is comparable to that experienced by other populations within the portion of the breeding range where the species has been federally listed (Buehler 2000). Two consequences of this rapid recovery are 1) an increase in the effort by regulatory agencies to apply management guidelines and 2) an increase in the burden borne by society to abide by management guidelines. These consequences manifest themselves in the increase in nest trees that are protected under management guidelines and the amount of land that falls within protected buffers and so is subject to use restrictions.

The high turnover in nest tree use within this population has lead to a substantial number of nest trees that, on an annual basis, is well beyond the number of breeding pairs. On average, the number of trees containing Bald Eagle nest structures each year is 43.2% higher than the number of breeding pairs. In order to implement the clause in the management guidelines that protects documented nest trees that have any remaining structures, the burden is on the regulatory agencies to track nest structures through time. In 2003, there were 521 trees documented to support either abandoned or active eagle nests. Average life expectancy for a nest structure after abandonment was determined to be 1.46 years. Of 320 abandoned nest structures that were tracked for 5 years, just over 1% of the nests were still present after 3 years and none were present after 4 years. Given the current guideline to protect trees and buffer areas for 3 years post abandonment, relatively little is gained with the clause to protect trees as long as a portion of the nest remains. Nest trees are important resources for eagles and all documented nest trees should be protected in perpetuity or for the standard 3-year period. A change in the guideline either way would reduce the burden on the regulatory agencies to track nest structures.

The 3-year rule for declaring a nest abandoned and withdrawing protection buffers was established under the belief that there was a substantial reduction in the likelihood that a pair would return to an abandoned nest after that period. Examination of 866 instances of nest abandonment between 1977 and 2002 shows that the probability distribution of re-use with time approximates a negative exponential with no real functional breaks. Although the probability that a pair will ever return after 3 years have passed is less than 10%, the probability after 2 years is only 13%, after 4 years is 7.5%, and after 5 years is less than 5%. Because there are no obvious breaks in the distribution, establishment of the length for a waiting period is somewhat arbitrary. A 3-year period would result in a 90% likelihood that the pair would not return while a 5-year period would carry a 95% likelihood.

The size of management buffers around Bald Eagle nests coupled with the size of the breeding population together determine the amount of land that is under management restrictions and the level of burden that is place on society to comply with regulations. The size of management buffers around Bald Eagle nests have been established based on long-standing views concerning the amount and proximity of disturbance that pairs will tolerate before causing abandonment of the nest site or a reduction in reproductive performance. The amount of land falling within primary and secondary management buffers around Bald Eagle nests has increased exponentially along with the breeding population. Between 1977 and 2003 the collective amount of land within secondary buffers increased more than 10 fold reaching more than 4,000 ha or 10,000 acres by 2003.

The value of lands that fall within Bald Eagle management buffers has increased exponentially due to both an increase in the total land area within buffers and the acceleration in real estate prices over the past 2 decades. In 2003, land within secondary management buffers had a collective value estimated to be more than 1.7 billion dollars. This is an increase in valuations of lands within buffer zones of 1.17 billion dollars just since 1991. Much of this value is derived from a few nests located within urbanizing jurisdictions. For example, the value per nest in Fairfax County exceeded 10 million dollars in 2003. Dramatic variation in land values between jurisdictions needs to be further evaluated with respect to current management guidelines.

The availability of undeveloped waterfront property has become the dominant limiting factor for Bald Eagles in the Chesapeake Bay. Human activity is the best predictor of eagle distribution within the tidal portion of the Bay. Indicators of human activity such as housing and road density, shoreline use, and boating activity have been related to nest distribution (Watts et al. 1994), shoreline use (Buehler et al. 1991, Watts and Whelan 1997), and the likelihood of nest abandonment (Therres et al. 1993) or re-colonization (Watts, unpublished data). Since Bald Eagles began their most dramatic decline in the 1950s, the human population within the tidal reach of the Bay has increased by more than 50% (http://www.census.gov). A preliminary review of development occurring around eagle nests in the lower Chesapeake Bay shows that development had occurred in 55% of shoreline areas by the late 1980's (Byrd et al. 1990). Similarly, Buehler et al. (1991) found that in northern areas of the Bay, 75.6% of the shoreline had developments within 500 m. Application of a habitat suitability model to the James River in 1991 revealed that more than 50% of the available area was not suitable for eagle breeding due to human use (Watts et al. 1994).

In recent years, there have been an increasing number of eagle pairs nesting in close proximity to human activity. However, as this investigation shows, these pairs represent a very small portion of the overall population. In 2001, more than 80% of the population nested in areas with less than 1% coverage of impervious surface. Based on success rate and productivity, pairs on the far end of the gradient of impervious surface appear to be performing as well if not better than pairs nesting in isolated areas away from human development. The underlying factors responsible for the positive relationship between productivity and impervious surface are not clear at this time but as the eagle population continues to increase, small patches of habitat that are isolated from other eagles may prove to be refuges from resource competition.

CONCLUSIONS

The total number of Bald Eagle nest trees has increased exponentially along with the breeding population but on average is more than 40% higher than the number of breeding pairs. The inflated number results from a more than 27% annual turnover rate of nesting structures. The number of trees under management restrictions is kept in check somewhat by the low survivorship of nests after abandonment. Average life expectancy of nests at abandonment is only 1.46 years. Due to these interactions and the 3-year policy for declaration of an abandoned nest, the management standard that protects all trees with any nest material seems to provide little value. Given the burden on regulatory agencies to track nest structures in order to implement this standard, a change in the guidelines should be considered.

The 3-year rule regarding a determination of abandonment was established under the belief that there was a sharp decline in the probability of re-occupation following the third year. The probability distribution of re-occupation following nest abandonment approximates a continuous, negative exponential with no functional breaks leaving the establishment of a waiting period to be an arbitrary decision based on an acceptably, low likelihood of return. The probability of return after 3 years is less than 10%.

Lands surrounding Bald Eagle nests that are considered under "management restrictions" have increased exponentially along with the breeding population. The economic value of these lands has also increased exponentially due to both the expansion of lands under restrictions and the increase in real estate valuations in recent years. In 2003, the collective value of lands within secondary management buffers surrounding active nests exceeded 1.7 billion dollars. The magnitude of this societal burden demands an effort to ensure that guidelines are both efficient and effective.

Despite the evidence that Bald Eagles prefer to nest in areas away from human development, an increasing number of pairs are nesting in such locations. This study demonstrates that urban pairs represent a small fraction of the overall population. More than 80% of the population nests in areas with less than 1% impervious surface in management buffers. Only 5% of pairs nested in areas with more than 2% impervious surface. Despite their rarity, there has been growing interest in the question as to whether or not these "urban" pairs are reproductively viable. This study concluded that pairs on the far end of the impervious surface gradient were at least as productive as other pairs in the population.

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Appendix I: Value of lands within Bald Eagle management buffers by jurisdiction in 1991. Primary buffer includes 228 m around nest. Secondary buffer includes 402 m around nest.

Jurisdiction	Nests	Primary Buffer	Secondary Buffer
Accomack	5	870,565	2,713,443
Caroline	5	485,962	1,415,770
Charles City	2	193,878	559,814
Essex	5	630,537	1,953,162
Fairfax	3	38,643,043	119,099,120
Gloucester	2	787,070	2,329,296
Halifax	1	66,684	206,562
Henrico	1	3,004,436	9,306,590
James City	5	5,668,863	16,242,446
King & Queen	1	81,947	241,708
King George	13	1,968,781	6,046,521
King William	4	446,953	1,280,400
Lancaster	2	980,708	2,905,458
Middlesex	6	1,917,243	5,838,678
New Kent	4	713,264	2,118,706
Newport News	1	3,604,098	10,780,875
Northampton	3	959,816	2,985,506
Northumberland	4	4,526,639	14,021,118
Prince George	5	850,173	2,518,223
Prince William	1	2,557,853	7,643,140
Richmond	11	1,232,286	3,749,258
Stafford	4	3,122,800	8,986,443
Suffolk	1	248,482	835,093
Surry	5	1,536,709	4,583,641
Westmoreland	14	3,174,404	9,816,402
York	1	979,854	3,923,604
Total	**109**	**$79,253,047**	**$242,100,979**

Appendix II: Value of lands within Bald Eagle management buffers by jurisdiction in 1995. Primary buffer includes 228 m around nest. Secondary buffer includes 402 m around nest.

Jurisdiction	Nests	Primary Buffer	Secondary Buffer
Accomack	8	1,290,701	4,149,580
Caroline	6	731,468	2,154,267
Charles City	8	792,418	2,310,861
Essex	12	1,795,611	5,611,761
Fairfax	5	58,653,208	180,163,378
Fauquier	1	452,372	1,342,782
Gloucester	3	1,406,455	4,356,659
Halifax	1	140,145	434,115
Hanover	1	454,604	1,567,935
Henrico	2	6,919,452	21,433,810
Isle of Wight	2	578,612	1,792,318
James City	6	8,485,184	25,002,213
King & Queen	1	285,614	735,951
King George	14	1,013,539	2,966,368
King William	6	869,352	2,630,738
Lancaster	3	1,330,718	3,789,225
Mathews	1	243,906	831,788
Middlesex	5	2,015,199	6,140,934
New Kent	4	878,777	2,561,470
Newport News	1	3,936,468	11,775,087
Northampton	5	1,865,148	5,791,103
Northumberland	5	5,655,217	16,850,162
Prince George	7	1,554,021	4,670,310
Prince William	2	5,107,433	14,601,398
Richmond	9	1,242,258	3,686,834
Stafford	4	3,493,588	9,438,462
Suffolk	1	304,646	1,023,849
Surry	4	1,378,921	4,103,735
Virginia Beach	2	7,705,804	23,950,462
Westmoreland	19	4,957,601	15,265,946
York	2	3,030,060	8,934,737
Total	**150**	**$128,568,500**	**$390,068,237**

Appendix III: Value of lands within Bald Eagle management buffers by jurisdiction in 1999. Primary buffer includes 228 m around nest. Secondary buffer includes 402 m around nest.

Jurisdiction	Nests	Primary Buffer	Secondary Buffer
Accomack	7	1,279,462	4,105,466
Albemarle	1	630,505	1,953,062
Caroline	9	1,154,422	3,474,750
Charles City	14	1,975,851	6,002,306
Chesterfield	6	12,657,947	37,427,181
Essex	13	2,058,455	6,467,598
Fairfax	7	102,923,912	306,286,521
Fauquier	1	515,855	1,531,217
Gloucester	4	2,150,222	6,627,478
Halifax	2	406,032	1,257,732
Hampton	1	6,335,875	19,626,111
Hanover	2	1,489,156	4,828,921
Henrico	3	11,581,473	35,242,256
Isle of Wight	3	948,781	2,767,103
James City	6	11,249,388	33,735,804
King & Queen	3	976,907	2,731,663
King George	24	1,899,520	5,643,698
King William	8	1,264,812	3,783,497
Lancaster	2	1,065,239	3,243,563
Mathews	2	989,624	2,755,288
Mecklenburg	3	336,875	1,074,246
Middlesex	7	3,124,301	9,582,045
New Kent	6	1,795,989	5,318,138
Newport News	1	4,354,916	13,026,786
Northampton	5	1,821,235	5,407,932
Northumberland	6	7,150,030	22,608,712
Nottoway	1	113,602	351,896
Portsmouth	1	6,103,951	18,907,699
Powhatan	1	327,974	1,015,939
Prince Edward	1	141,295	437,677
Prince George	9	2,390,599	7,107,823
Prince William	4	10,411,081	31,363,894
Richmond	16	2,479,463	7,304,823
Stafford	8	9,752,663	27,359,129
Suffolk	2	817,210	2,552,839
Surry	8	3,039,288	9,207,737
Sussex	1	38,196	158,828
Virginia Beach	3	13,755,060	42,702,529
Westmoreland	22	6,461,857	19,593,775

Appendix IV: Value of lands within Bald Eagle management buffers by jurisdiction in 2003. Primary buffer includes 228 m around nest. Secondary buffer includes 402 m around nest.

Jurisdiction	Nests	Primary Buffer	Secondary Buffer
Accomack	7	2,563,396	7,826,649
Amherst	1	245,309	759,872
Caroline	11	2,437,490	7,374,375
Charles City	19	3,476,397	10,196,415
Chesapeake	3	5,691,443	18,260,410
Chesterfield	5	13,599,948	39,855,200
City of Richmon	1	14,250,585	40,528,831
Essex	19	4,074,728	12,519,545
Fairfax	8	197,256,234	599,511,104
Gloucester	4	2,938,978	8,976,057
Halifax	2	464,182	1,437,859
Hampton	2	14,093,356	38,760,118
Hanover	1	902,452	3,112,572
Henrico	4	22,173,767	62,513,291
Hopewell	1	8,289,013	25,676,185
Isle of Wight	6	2,979,846	8,565,964
James City	15	39,003,031	116,282,726
King & Queen	7	4,414,998	13,013,563
King George	26	3,131,480	9,282,219
King William	15	3,039,024	9,175,495
Lancaster	8	5,764,115	16,854,600
Mathews	3	2,317,495	7,112,582
Mecklenburg	2	256,981	709,200
Middlesex	14	9,495,102	29,046,984
New Kent	11	4,518,508	13,712,319
Newport News	2	17,240,591	53,404,741
Norfolk	1	5,463,232	23,863,964
Northampton	2	1,314,468	4,071,719
Northumberland	18	21,690,039	69,447,941
Page	1	294,962	913,680
Powhatan	1	486,065	1,505,642
Prince Edward	1	186,649	578,168
Prince George	10	3,650,982	11,276,973
Prince William	7	36,946,742	111,410,984
Richmond	27	5,907,347	18,085,255
Shenandoah	1	342,198	1,059,999
Stafford	9	21,549,129	65,225,572
Suffolk	6	3,301,876	10,096,084
Surry	12	5,125,571	15,506,131

Appendix IV: Continued.

Jurisdiction	Nests	Primary Buffer	Secondary Buffer
Sussex	2	139,462	481,189
Virginia Beach	6	39,005,644	118,542,833
Westmoreland	41	18,208,548	56,357,778
York	10	27,696,855	84,813,076
Total	**352**	**$575,928,218**	**$1,747,705,865**