



## Commentary

# Nest Turnover Rates and List-Frame Decay in Bald Eagles: Implications for the National Monitoring Plan

BRYAN D. WATTS,<sup>1</sup> *Center for Conservation Biology, College of William and Mary and Virginia Commonwealth University, Williamsburg, VA 23187-8795, USA*

ADAM E. DUERR, *Center for Conservation Biology, College of William and Mary and Virginia Commonwealth University, Williamsburg, VA 23187-8795, USA*

**ABSTRACT** In accordance with federal regulations, the United States Fish and Wildlife Service developed a postdelisting monitoring plan for the bald eagle (*Haliaeetus leucocephalus*) designed to detect a change in the number of occupied nests on a national scale. The plan employs a dual-frame approach to the survey design where a list frame (list of known nests) and an area frame (set of survey plots) are used in concert to estimate the number of occupied nests in 5-year intervals over a 20-year period. The plan offers no provisions for changes in list-frame integrity, nor does it contemplate the impact of such changes on survey performance. We used a long-term data set to quantify occupancy patterns for nests in Virginia, USA, and evaluated their influence on integrity of the list frame and performance of the proposed dual-frame monitoring approach. The average annual turnover rate for nests was 0.261, resulting in a rapid decay of the list frame. Decay of the list frame leads to a functional collapse of the dual-frame approach, down to the area-frame survey alone, early within the monitoring time horizon. This early decay of the list frame implies that the area-frame coverage needed to maintain the same statistical power as stated in the monitoring plan would have to be increased by a factor of 3 to 5 beyond that recommended in the current plan. Remedies for this deficiency undermine the cost benefit associated with inclusion of the list frame. We examined response of the dual-frame survey to variation in nest turnover rates and population growth rates and defined a state space where time to collapse is beyond the proposed 20-year time horizon. Because, under realistic estimates of turnover rates, the dual-frame approach collapses to the area frame within the proposed monitoring window, we recommend that the costs of list-frame maintenance be included in the procedure to optimize allocation of survey effort.

**KEY WORDS** bald eagle, dual-frame survey, *Haliaeetus leucocephalus*, monitoring plan, nest turnover, population monitoring.

Under the Endangered Species Act (ESA), the United States Fish and Wildlife Service (FWS) is legally mandated to develop a monitoring plan for all species removed from the federal list of threatened and endangered species (16 United States Code 1531 et seq). On 28 June 2007, the FWS formally removed the bald eagle (*Haliaeetus leucocephalus*) from protective status under ESA (72 Federal Register 37346). Coincident with publishing the final rule to delist, the FWS published a notice of availability of a draft postdelisting monitoring plan (72 Federal Register 37373; U.S. Fish and Wildlife Service Bald Eagle Monitoring Team 2007). The goal of the plan is to estimate changes in the number of occupied bald eagle nests in the contiguous 48 states on a national scale. The statistical objective is to achieve an 80% probability of detecting a  $\geq 25\%$  change in number of occupied bald eagle nests between successive 5-year intervals over a 20-year period.

The national monitoring plan utilizes a dual-frame approach to estimate number of occupied nests by combining a list frame (i.e., list of known nests, each with its respective status information for a given time period) with an area frame (i.e., group of randomly selected survey plots; Hartley 1962). Number of occupied nests within the list frame is estimated during a survey of the list frame. Area-frame surveys provide an estimate of the proportion of eagle nests that overlap with the list frame. This combined approach is intended to both strengthen the overall survey result by offsetting the weaknesses of each individual frame

with the strengths of the other and increase efficiency by reducing effort required to achieve a given level of confidence in the estimated number of occupied nests (Kott and Vogel 1995). In concept, efficiency is improved if the list frame is less costly to sample compared to the area frame and if using the list frame reduces the size of the area required to be sampled to achieve a desired level of confidence (Haines and Pollock 1998). The national monitoring plan proposes to survey a list of known nests (list frame) and adjust this survey with a sample of survey plots (area frame) drawn from available strata to improve estimation while minimizing costs associated with total area samples.

As proposed by the national monitoring plan, efficiencies achieved by employing the dual-frame approach depend on integrity of the list frame (Haines and Pollock 1998). The dual-frame approach presumes that either nest use is stable through time (list frame is static) or that the list is frequently updated to reflect ongoing changes in distribution of breeding pairs. The national monitoring plan does not contemplate nest turnover or its consequences on survey design or results. We define nest turnover as failure of eagles to reuse a nest from one year to the next. Bald eagles exhibit considerable variation in nest turnover rates due in part to variation in rates of nest loss. For example, average life expectancy of nests constructed in southern Florida, USA (Curnutt and Robertson 1994) and Saskatchewan, Canada (Gerrard et al. 1983) is 5 years compared to 13 years in Alaska, USA (Stalmaster 1987). Nest turnover rates also vary across the breeding range. In Florida between 1939 and

<sup>1</sup> E-mail: [bdwatt@wm.edu](mailto:bdwatt@wm.edu)

1946, average annual turnover rate was 22.4% (Broley 1947). In Maine (USA), average annual turnover rate between 1972 and 1978 was 28.2% (Todd 1979). In 3 counties where eagle nests are most dense in Florida, 26% of nests during the 2005–2006 nesting season were no longer in place during the 2006–2007 nesting season (Brush and Nesbitt 2007). In interior Alaska, 32% of successful breeders and 68% of unsuccessful breeders used a different nest tree the following year (Steidl et al. 1997). In southeastern Alaska, average annual nest turnover rate was 62.7% (Hodges 1982). We used a long-term data set to quantify occupancy patterns for bald eagle nests and evaluated their influence on integrity of the list frame and performance of the proposed dual-frame monitoring approach for bald eagles. We extended these results by examining sensitivity of the dual frame to variation in both turnover rate and population growth rate to define the state space where application of the dual frame would be favorable.

## STUDY AREA

Our study area included lands surrounding all major water bodies in the coastal plain of Virginia, USA, that have been delineated as important breeding habitat for eagles. Watts et al. (2006, 2008) fully described our study area.

## METHODS

We used data from the annual bald eagle breeding survey in Virginia to evaluate patterns in nest turnover. The survey measured breeding activity and productivity via a standard 2-flight approach (Fraser et al. 1983). Surveyors conducted the first flight between late February and mid-March from a high-wing Cessna 172 aircraft (Cessna Aircraft Company, Wichita, KS). Surveyors overflew the land surface at an altitude of approximately 100 m to systematically search for new nests and to locate known nests. All nests that were occupied in the previous year were relocated unless they no longer remained in the nest tree. Surveyors plotted on 7.5-minute topographic maps all bald eagle nests detected and assigned each a unique alpha-numeric code. Surveyors examined each nest to determine its condition and activity status. Surveyors considered a nest to be occupied if a pair of birds was observed in association with the nest and there was evidence of recent nest maintenance (e.g., well-formed cup, fresh lining, structural maintenance) or breeding activity (e.g., incubating posture, eggs or young detected; Postupalsky 1974). If surveyors found that a nest occupied in the previous year was empty or absent, they performed an area-restricted search to locate a potentially new nest within the territory. They searched nest substrate within approximately 1 km of the nest tree. This search area included a distance  $>2$  standard deviations beyond the mean relocation distance, which would have included the entire nest territory as defined by Steenhof and Newton (2007), an area that contains, or historically contained,  $\geq 1$  nests within the home range of a mated pair: a confined locality where nests are found, usually in successive years, and where  $\leq 1$  pair is known to have bred at one time.

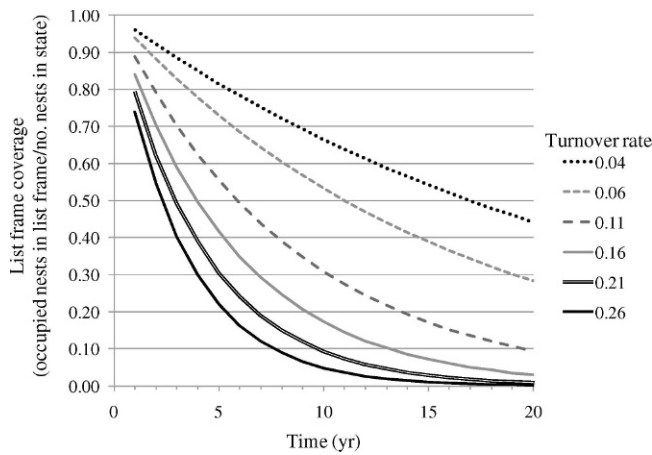
We estimated the annual rate that eagles reused a nest from year to year based on observations of 1,463 nests (1977–2007) included in the Virginia survey. The reuse rate was the proportion of years that a nest was occupied from one year to the next beginning with the first year a nest was included in the survey and ending with the year after the nest was last occupied. The turnover rate ( $1 - \text{reuse rate}$ ) was the rate at which bald eagles abandoned a nest. We assumed the annual rate of turnover was constant over time. We then used the turnover rate to project the expected decay of the Virginia list frame over the 20-year survey period outlined in the national monitoring plan. To assess sensitivity of the list frame to a range of turnover rates, we calculated proportions of nests in a list frame expected to be occupied over 20 years. We used our estimate of annual turnover rate from the Virginia population and evaluated a broader range of rates from 0.01 to 0.46.

We evaluated the influence of list-frame decay on performance of the proposed dual-frame approach by simulating surveys of the list and area frames for Virginia. We assumed that the nest list was surveyed entirely with a detection probability of 1 and that occupancy rates of nests will decline over time in accordance with our estimate of nest turnover. We also assumed that the area frame (group of survey plots) was surveyed entirely and that detection probability of nests within the plots was 1. We further assumed that pairs within the area frame relocated according to the population-wide turnover rate and that relocations were detected with a probability of 1. We evaluated sensitivity of the dual-frame survey results to variation in turnover rate, population growth rate, and size of area frame. We evaluated the influence of population growth rates ( $r$ ) over a range of  $-0.15$  to  $0.20$ . To evaluate performance across a range of combined turnover and population growth rates, we used an area-frame size required to include 7.5% of bald eagle nests in Virginia as recommended in the national monitoring plan.

## RESULTS

Average annual turnover rate for bald eagle nests in Virginia was high, resulting in a rapid decay of the list frame. Probability of a nest being used in subsequent years was 0.739 (SE = 0.006) leading to an annual turnover rate for nests of 0.261. This rate caused a decay of the list frame such that the proportion of nests on the list that remained occupied after 5 years and 20 years was 0.220 and 0.002, respectively. The rate of list-frame decay was sensitive to the turnover rate of nests such that even a modest turnover rate of 6% resulted in a degradation of the list to below the 40% threshold indicated in the national monitoring plan as being valuable to the dual-frame approach (Fig. 1). Decline in occupancy of the list frame may be contrasted with the actual population growth, which was 0.10 from 1977 to 2007.

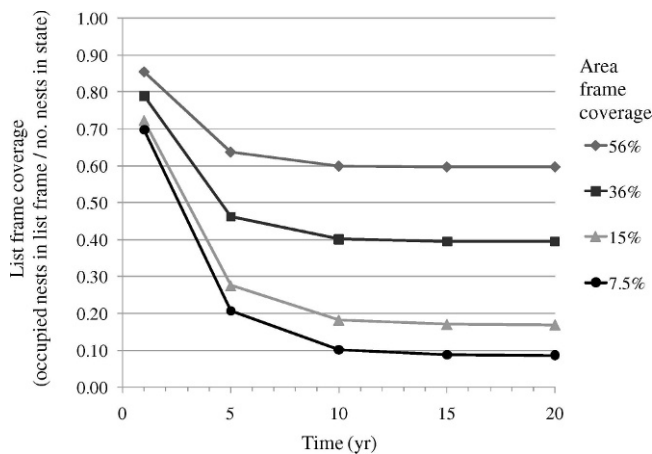
Performance of a dual-frame survey was sensitive to relative size of the designated area frame. Without a resetting or maintenance of the list frame, the list-frame decays and converges on the area frame leading to a



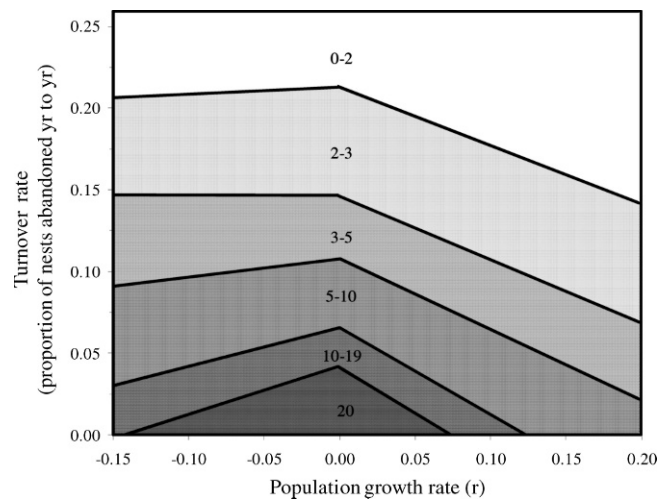
**Figure 1.** Proportion of bald eagle nests expected to remain occupied over a 20-year time frame for turnover rates (annual rate of abandonment) that vary from 0.04 to 0.26. We estimated nest turnover rate in Virginia, USA, at 0.261 from 1977 to 2007.

functional collapse of the dual-frame approach to the area frame alone (Fig. 2). This convergence results from a decline in the portion of the nests within the list frame that overlaps with the area frame over time. Assuming that nests within the area frame have a detection probability of 1 (the most conservative estimate with respect to list-frame decay), all relocations of nests within the overlap portion of the list frame will be detected and periodically reset during area-frame surveys. However, it should be noted that as turnover of the nests that overlap between the list and area frames continues, an increasing portion of the nests within the area frame would be from the nonoverlapping variety, limiting the synergistic benefit of the 2 survey frames.

Performance of the dual-frame survey was sensitive to both nest turnover rate and population growth rate. We developed a performance state space that related these 2 dimensions and mapped the time it took for the dual frame



**Figure 2.** Sensitivity of list-frame coverage for bald eagles to area-frame coverage. New nests were added to the list in proportion to area-frame coverage (proportion of total nests covered by area-frame surveys) during surveys completed every 5 years. In modeling changes to nest occupancy, we used annual turnover rates of 0.261 and a population growth rate of 0.10 that we observed in Virginia, USA. The postdelisting monitoring plan recommends area-frame coverage of 7.5% for Virginia.



**Figure 3.** Response of time required for the dual-frame approach to collapse to the area-frame within the state space defined by bald eagle nest turnover rate and population growth rate. Each shaded region indicates number of years in which the list frame continues to provide benefit to the dual-frame approach. Only when population growth rate is low (near or below zero) and nest turnover rate is low ( $<0.05$ ) will the list frame continue to contribute to the dual frame for the entire 20-year time horizon of the survey. Values are based on the 7.5% area-frame coverage suggested for Virginia, USA, in the national plan.

to collapse to the area frame alone and depicted the combination of conditions favorable for the dual frame (i.e., time window where there is a benefit of including the list frame; Fig. 3). In general, when both growth and turnover rates were high, time to collapse was short relative to the 20-year time horizon. Only when both rates were low was the benefit of the dual-frame approach sustained through the target time window outlined in the national plan. Neither values reported in the literature nor our values for Virginia approach this set of conditions.

## DISCUSSION

The national bald eagle monitoring plan specifies the nest as the sampling unit and includes nests that states reported along with the last known status of the nests as the national list frame (Otto and Sauer 2007). The plan relies on the network of partnership agencies and organizations to maintain the list, where maintenance is defined as updating status information on nests within the list frame. This approach assumes a near static list frame. With regard to bald eagle ecology, this assumption constitutes a clear logic error that cascades throughout the plan, leading to several questionable conclusions.

As configured in the national plan, the dual-frame approach derives a statistical advantage in power over the area frame alone when the list frame includes a large portion of occupied nests. This advantage translates into cost efficiency by substantially reducing the size of the area frame that must be sampled to achieve a given level of confidence in detecting a population change. However, as the list-frame coverage declines, this advantage diminishes such that when list-frame coverage reaches only 40% the dual frame offers little advantage over the area frame alone

(Otto and Sauer 2007). Coverage of the list frame will be <40% in <10 years based on all biologically reasonable combinations of population growth and nest turnover rates. To compensate for the collapse of the dual-frame approach, the size of the area frame would have to be increased by a factor of 3 to 5 beyond that recommended in the current plan to maintain the statistical objective defined therein (based on survey scenario assessments presented in Otto and Saur [2007]).

Unless the list frame is recompiled (area resurveyed to add relocations) with regularity it provides little value to bald eagle monitoring beyond traditional area sampling approaches. Proponents of the dual-frame approach assume that the list is updated and provided to surveyors and recommend that an independent survey be conducted to maintain an updated (recompiled) nest list (Haines and Pollock 1998, Alpizar-Jara et al. 2005). Turnover rates from the Virginia survey support this position and suggest that without list maintenance, even under the most optimistic set of conditions, the value of including the list in the monitoring program diminishes rapidly and the dual frame functionally collapses to the area frame. Although the age of information in the list frame is not presented in the national plan, given that the plan was developed in 2004, it is likely that the dual frame will have effectively collapsed to the area frame prior to the first scheduled survey. If so, the plan overestimates capacity of the design to detect a population change.

One of the primary advantages attributed to the dual-frame approach over traditional area surveys is cost efficiency (Haines and Pollock 1998, Otto and Sauer 2007). However, decay of the list frame due to nest turnover places the approach in a catch 22 in terms of cost savings. Recompiling the list frame with a frequency adequate to overcome the underlying turnover rate would require a dedicated survey of at least a sample of known territories to locate new nests, undermining expected cost savings. Without such surveys, value of the list frame diminishes, forcing an increase in the area frame, once again undermining expected cost savings.

## MANAGEMENT IMPLICATIONS

Architects of the national bald eagle monitoring plan are in the unenviable position of attempting to design a robust monitoring program with specific statistical objectives using a deteriorating and varied network of monitoring schemes. The network of programs for monitoring bald eagles throughout the country is composed of surveys that vary in both scale and approach from covering individual land parcels to broad regions and from systematic aerial surveys to lists of public reports. The national plan attempts to build on this network by adding some components designed to strengthen the information collected. However, under most biological conditions expected during the monitoring period, without regular maintenance of the list frame that appears to require substantial survey effort, the national monitoring plan presents an optimistic assessment of the statistical power available to detect a population change. Because detecting a population decline is the rationale for

mandating postdelisting monitoring under the Endangered Species Act, a reassessment of nest turnover rates and their impact on survey design seems warranted. It also seems likely that the resource levels needed to achieve the agreed upon objectives of the plan will be higher than those currently outlined. Therefore, we recommend revising the optimization procedure to allocate survey effort between list- and area-frame coverage to include costs of updating the list frame between 5-year surveys to provide a realistic estimate of monitoring.

## ACKNOWLEDGMENTS

Financial support for the Virginia annual bald eagle survey was provided by the Virginia Department of Game & Inland Fisheries, the United States FWS, the United States Department of Defense, the United States Army Corps of Engineers, and the Center for Conservation Biology. Funding was provided, in part, through Federal Aid in Wildlife Restoration grants and contributions to the Chesapeake Bay and Endangered Species Fund. M. Byrd participated directly in the survey for >30 years. Regular survey pilots were S. Beck, C. Crabbe, M. Crabbe, and C. Shermer. We thank the many private citizens and government employees who provided information and assistance over the years. We also thank J. Grier, K. Steenhof, and B. Steidl for constructive reviews that improved this manuscript.

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*Associate Editor: Steidl.*