U.S. Fish & Wildlife Service

Post-delisting Monitoring Plan for the Bald Eagle (*Haliaeetus leucocephalus*) in the Contiguous 48 States

Cover Photo: Bald eagle adult and two chicks. Photo by Brad Tedrick, Illinois Department of Natural Resources.

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Summary

The Post-delisting Monitoring Plan (Plan) will monitor the status of the bald eagle by collecting data on occupied nests over a 20-year period with sampling events held once every 5 years starting in early 2009. The Plan will continue the nest check monitoring activities conducted by the States over the past years and add census of area sample plots. The area sample plots will be selected from eagle habitat across the contiguous 48 States based on known nesting density. The set of known occupied nests (list frame) will be combined with the numbers of newly identified occupied nests from the area plot samples (area frame) to provide a dual frame estimate (Appendix 1). Statistically combining the results of these two data sets will provide a single estimate for the bald eagle population of the contiguous 48 States that more closely represents the actual nesting population of bald eagles than either the traditional nest check for occupancy or area plot sampling alone, based on our pilot studies in Maine, Minnesota, Florida, Washington and Missouri (Appendix 1). Reduction in future nest check monitoring (list frame) by the States will be compensated by sampling the list frame during the area plot surveys. In addition, dual observer sampling protocols are recommended to reduce bias (Appendix 2). Some States, particularly those with sparse numbers of nesting pairs, are currently collecting data in a highly accurate manner and may not need to employ the dual frame methodology. Data from these States will be included as a complete census.

The Plan recommends that the State agencies continue the occupied nest survey data collection and submission and assist with the area surveys while the U.S. Fish and Wildlife Service (Service) coordinates the area survey, manages the database, provides expertise including dual frame sampling design and data analysis, and initially funds the area sampling. This Plan is not intended to replace specific plans to manage eagles or monitor them in a different manner for specific management purposes.

The sample design is based on an 80 percent chance of detecting a 25 percent or greater change in occupied bald eagle nests over any period, measured at five-year intervals. We believe this is a goal that will both ensure recovery and be cost-effective. Were this degree of decline to occur with no further increase, the bald eagle population would still be at a level recognized as recovered (from 9,789 occupied nests when the bald eagle was delisted in 2007 to 7,342 occupied nests, a 25 percent reduction) based on a population estimate of 6,471 when the initial proposal to delist was published in 2000. If such declines are detected, the Service’s Bald Eagle Monitoring Team in conjunction with the States will investigate causes of these declines, including consideration of natural population cycles, weather, productivity, contaminants, other mortality factors, habitat changes or any other significant evidence. The result of the investigation will be to determine if the population of bald eagles in the contiguous 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the Endangered Species Act (ESA). At the end of the 20 year monitoring program, we will conduct a final review. It is the intention of the Service to work with all our partners toward maintaining continued species population expansion and management.

Acknowledgements

This monitoring plan was written by the U.S. Fish and Wildlife Service Bald Eagle Monitoring Team: Jody Millar, National Coordinator (Region 3), Suzanne Audet (Region 1), Greg Beatty (Region 2), Allan Mueller, Candace Martino, Alfredo Begazo (Region 4), Craig Koppie (Region 5), Dan Mulhern (Region 6), Phil Schempf (Region 7), and Mary Klee (Region 9); Mark Otto, Migratory Birds program, and John Sauer, US Geological Survey-Biological Resources. The States of Maine, Minnesota, Florida, Washington, and Missouri provided critical support in participating in the pilot program.

Background

Between 1952 and 1957 Charles Broley, an avid eagle watcher, reported that about 80 percent of the bald eagle (*Haliaeetus leucocephalus*) nests in Florida he had been watching failed to produce any young. By 1958, nesting adult eagles were so scarce in his study area that he only found 10 nesting pairs where he had found 47 the previous year, and had found 125 nesting pairs 15 years earlier (Carson 1962). This monitoring information was ultimately linked to a deadly insecticide in widespread use at that time: DDT (Carson 1962).

Subsequent bald eagle surveys conducted in the 1960s by the National Audubon Society and others documented poor nesting success and low numbers of nesting pairs, prompting the Secretary of the Interior to publish a Federal Register notice (32 FR 4001) on March 11, 1967 listing bald eagles south of 40^{o} N. latitude as endangered under the Endangered Species Preservation Act of 1966 (Pub. L. No. 89-699, 80 Stat. 926). Bald eagles north of this line were not included because northern populations were not considered endangered at that time.

In the 1970s, bald eagle surveys conducted by the Service, other cooperating agencies, and conservation organizations revealed that the bald eagle population was declining throughout the contiguous 48 States. On December 31, 1972, DDT was banned from use in the United States by the Environmental Protection Agency. The following year, the Endangered Species Act of 1973 (16 U.S.C. 1531-1544) (ESA) was passed. In 1978, the bald eagle was listed throughout the contiguous 48 States as endangered except in Michigan, Minnesota, Wisconsin, Washington, and Oregon, where it was listed as threatened (43 FR 6233, February 14, 1978).

Listing under the ESA and banning of DDT and other harmful organochlorine chemicals resulted in significant increases in the breeding population of bald eagles throughout the contiguous 48 States. On February 7, 1990, the Service published an advance notice of a proposed rule to reclassify the bald eagle from endangered to threatened in 43 States where it was classified endangered and to retain threatened status for the remaining five States (55 FR 4209). On July 12, 1994, the Service published the proposed rule for this reclassification (59 FR 35584), and the final rule was published on July 12, 1995 (60 FR

36000). After reclassification, bald eagles continued to improve to the point where the Service believed the species no longer meets the definition of a threatened species. On July 6, 1999, the Service published a proposed rule (64 FR 36454) to delist the bald eagle in the contiguous 48 States, and requested public comments. The comment period on the proposal to delist was reopened on February 16, 2006 (71 FR 8238). The final rule on delisting and the Notice of Availability for the draft monitoring plan were published simultaneously in the Federal Register (72 FR 37346) on July 9, 2007. That July notice opened a public comment period on the draft post-delisting monitoring plan. After the comment period closed on October 9, 2007, the Service reviewed each comment received and edited the Plan appropriately.

On March 6, 2008, the U.S. District Court for the District of Arizona ordered bald eagles in the Sonoran Desert of central Arizona to again be protected as threatened under the ESA, pending further review by the Service. To comply with the court order, on May 1, 2008, the Service published a final rule in the Federal Register (73 FR 23966) listing the potential Sonoran Desert bald eagle distinct population segment in central Arizona as threatened. On May 20, 2008, the Service published a Federal Register notice (73 FR 29096) initiating a status review of bald eagles in the Sonoran Desert area of central Arizona and northwestern Mexico. Under the court order, the Service will issue a 12-month petition finding on whether listing the Sonoran Desert bald eagle under the ESA is warranted, and if listing is warranted, then whether those bald eagles should be listed as threatened or endangered. For the purposes of this monitoring plan, our approach to include these eagles into our population estimate will not be altered by its listing status.

In the years since Charles Broley's discovery of declining eagle numbers in Florida, the States, Tribes, Service, and our non-governmental partners have engaged in the difficult and costly task of monitoring nesting bald eagles. In the ensuing 25 years since listing, many States have monitored nesting bald eagles for their entire State annually. With the recovery of the bald eagle and removal from the Federal List of Threatened and Endangered Species, many States have since reduced their monitoring efforts.

Post-Delisting Monitoring Requirement of the Endangered Species Act

Post-delisting monitoring is a requirement of the ESA. Section 4(g)(1) requires the Service to…

> *implement a system in cooperation with the States to monitor effectively for not less than five years the status of all species which have recovered to the point at which the measures provided pursuant to this Act are not longer necessary.*

The Plan described herein exceeds the minimum requirement set forth by the ESA by effectively monitoring the status of the bald eagle over a 20-year period using five sampling events.

History of Plan Development and Pilot Studies

A draft monitoring plan was provided in the proposed rule to delist bald eagles on July 6, 1999 (64 FR 36454). Slightly more than ten percent of all comments we received on that proposal were concerned with post-delisting monitoring and the draft monitoring plan. Since then, the monitoring plan has been revised in such a way that it is responsive to the comments we received.

In September 2000, a bald eagle monitoring workshop was held at the Service's Patuxent Wildlife Research Center in Maryland, attended primarily by State biologists involved with bald eagle monitoring. As a result of that workshop, the Service in cooperation with the U.S. Geological Survey's Biological Resources Division (USGS-BRD), proposed a pilot study. The pilot study, funded by the USGS for 2004 and 2005, incorporated methods traditionally used by some States to monitor occupied bald eagle nests while adding an area sample plot census.

The first pilot study was conducted in cooperation with the Maine Department of Inland Fisheries and Wildlife in spring 2004. In addition to Maine's yearly aerial survey of bald eagle nests (list survey), forty-one 10 kilometer (km) x 10 km area plots were surveyed from the air (area survey) using a dual observer method. Estimates from the area survey, from Maine's list of bald eagle occupied nests, and a combination of those data were compared and analyzed. Those results were presented at a second workshop held at the Patuxent Wildlife Research Center in October 2004. The purpose of this workshop was to review results from the first pilot study and to discuss approaches and possible changes for a broader pilot study to be conducted in winter/spring 2005. Biologists from State natural resource agencies were invited to this workshop, but emphasis was placed on representatives from the States proposed for pilot studies in 2005: Florida, Minnesota, and Washington.

As a result of that workshop, a second pilot study was implemented in three States (Florida, Minnesota, and Washington) during the 2005 nesting season. The 2004 and the 2005 pilot studies detected 18 to 40 percent more occupied nests with greater precision using the dual frame approach than calculated for either area or list frame sampling alone (Appendix 1, p.22). Thus, the dual frame approach to sampling was selected as superior for the bald eagle post-delisting monitoring plan.

To implement this monitoring plan, we propose to cooperate with and provide technical assistance to our State, Tribal, Federal, and non-governmental partners in all aspects of planning and implementing a dual frame approach to bald eagle monitoring. This plan does not monitor causal factors such as habitat modification or disturbance as defined under the Bald and Golden Eagle Protection Act. For additional information on protections for bald eagles under the Bald and Golden Eagle Protection Act (BGEPA), please refer to the Service's National Bald Eagle Management Guidelines (72 FR 31156) and regulatory definition of the term "disturb" (72 FR 31132) that were published in the Federal Register on June 5, 2007. Existing take authorizations for bald eagles issued under the ESA became covered under the BEGPA via a final rule published in the Federal Register on May 20, 2008 (73 FR 29075).

Additionally, this Plan does not replace specific plans to monitor bald eagles more regularly or in a different manner for specific management purposes. We encourage partners with existing plans that meet or exceed this Plan's monitoring standards to work with us to continue using their own monitoring and conservation efforts, especially where continuation of those plans will ensure consistency and comparability with existing data sets.

Purpose and Goal

The purpose of post-delisting monitoring is to determine if at any time the population of bald eagles in the contiguous 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the ESA. The population of bald eagles in the contiguous 48 States will be estimated by monitoring changes in the number of occupied bald eagle nests in the contiguous 48 States. The goal of the bald eagle post-delisting monitoring plan is to detect a 25 percent or greater change in occupied bald eagle nests over any period, measured at five-year intervals based on an 80 percent chance of detecting such a change. We believe this is a goal that both ensures recovery and is cost-effective. If a 25 percent decline is measured, it means a reduction to a level still recognized as recovered (from 9,789 occupied nests in 2007 to 7,342 occupied nests, a 25 percent reduction) based on a population estimate of 6,471 when the initial proposal to delist was published in 2000, and assuming no further population increase preceding the decline. If such declines are detected, the Service in conjunction with the States will investigate causes of those declines. At the end of the 20-year monitoring program, we will coordinate with States and our other partners to conduct a final review and provide recommendations to insure a properly managed population of the recovered bald eagle.

Implementation

Bald eagle monitoring will require a well coordinated national effort, involving the States, Tribes, Federal agencies, and other cooperators. The following describes the roles and responsibilities of the parties involved in bald eagle monitoring under this Plan.

Service Bald Eagle Monitoring Team

The Service's national bald eagle monitoring team (Team) comprised of a national coordinator, regional coordinators from each of the Service's seven Regions, and a biometrician (a biological statistician) has been formed to develop and implement the Plan. The Midwest Region of the Service is the lead Region for this effort (Appendix 4). This Team will work closely with the States and all other interested parties, particularly during each 5th-year monitoring effort, to ensure that Plan implementation is well-coordinated and efficient. States will be directly involved in collecting, reviewing, and analyzing survey data, as well as identifying significant issues and developing recommendations to address these issues.

The role of the Service's national coordinator is to coordinate within the Service and with States, Tribes, other Federal agencies, and non-governmental organizations. Together with the Team members, the coordinator recommended draft and final Plans to the Service's Directorate. The Team will communicate with State resource agencies and cooperators; coordinate the planning, implementation, and analysis of the surveys and summarize the monitoring results in cooperation with States and other cooperators; and prepare interim and final reports on the monitoring results. The team is tasked with making recommendations based on survey results, seeking partnerships to implement the Plan, advocating for resources to carry out the monitoring program, and developing partnerships for any needed studies.

The role of the Service biometrician is to develop and maintain a national database on the States' known bald eagle nest list data (spatial and non-spatial); design the surveys based on State boundaries and Bird Conservation Regions as a means of stratifying high, low, and trace nesting density; coordinate and maintain a national database of the survey data from the various States; and conduct the data analysis, interpretation, and summary for the national surveys.

The Service will fund the area frame surveys for the initial baseline survey in 2009, including the use of aircraft and pilots from the Service's Migratory Birds program to complete the surveys. We will continue to work with the States, Tribes, and our other partners to secure funding for future surveys.

<u>Coordination with States</u>

Section 4(g)(1) of the ESA states that "The Secretary shall implement a system *in cooperation with the States* (emphasis added) to monitor effectively for not less than five years the status of all species which have recovered to the point at which the measures provided pursuant to this Act are no longer necessary…" The Service worked with the States to develop this Plan.

As described in the Background, this Plan is the product of comments from the initial proposal to delist the bald eagle, two workshops, and two seasons of pilot studies involving four States. This Plan was framed based on the results of those efforts. Early in the Plan development process, Service Team members contacted the States within their respective regions to determine a coordinator for each State with whom we could coordinate our efforts. States were asked to summarize their bald eagle monitoring protocol and to provide their most recent survey data. The Service Team also solicited suggestions regarding Plan content, methods, and format from the State biologists. Once a draft plan was developed, the Non-game Technical Committees of the Pacific, Central, Mississippi, and Atlantic Flyway Councils were asked to provide peer review. The Non-game Technical Committees of the various flyway councils are composed primarily of State biologists. Service Team members presented updates and answered questions on the draft Bald Eagle Post-delisting Monitoring Plan at the flyway councils' biannual meeting in March 2007. States were formally requested to provide review and comments during the public review period. In addition to the technical committee peer review comments from the flyway councils, 12 States provided comments on the draft Plan.

The Team's national and regional coordinators will work closely with the State coordinators and other cooperators to provide technical assistance on implementing the Plan and submitting the data after each monitoring period. In coordination with the States, the Service will propose adjustments to the sampling design, if necessary. This effort will also require the Service biometrician to work closely with the State coordinators and the Team to select sample areas and maximize sampling efficiency. For those years that fall between the monitoring years outlined in this Plan, the Service will have an ongoing request for occupied nest monitoring data that can be entered into a secure, web-based database (Appendix 3). Data on productivity and any information regarding major habitat changes, contaminants, or mortality events collected by States or other partners may also be submitted to the Team at any time.

For the baseline monitoring/first year of sampling in 2009, the States will be asked to:

- Update their nest lists and enter this data on the secure web site.
- Provide experienced bald eagle observers for the aerial part of the survey and participate in training;
- Provide input on refining stratum boundaries, definitions of bald eagle habitat specific to the State, and identification of breeding season dates; and
- Reconcile list nests found in the area samples and enter that data into the secure web site.

<u>Coordination with Tribes</u>

The Service values the cooperation and participation of the Tribes in our bald eagle recovery efforts, including post-delisting monitoring. Bald eagles are important to the Tribes for cultural, religious, and ceremonial purposes, giving the Tribes a vested interest in the continued conservation of the species. While the geographic boundaries of the States will be the basis of the national monitoring effort, information on nest occupancy on tribal lands has been and will continue to be important information. We encourage the Tribes to maintain updated lists of nests on their lands and share that information with the States and the Service. Prior to initiation of the nest surveys, the Service will coordinate with Tribes regarding any randomly selected area plots that may fall on tribal lands.

<u>Coordination with Other Partners</u>

Bald eagle monitoring in most States has been carried out by a combination of Federal agencies, Tribes, private organizations, and individuals. While the Service, in cooperation with the States, is responsible for post-delisting monitoring of bald eagles, continued participation and cooperation of all our partners is important for monitoring success. We anticipate that the combined efforts of all of our partners working together will provide the necessary resources to implement this Plan.

Other Monitoring Efforts

While the dual frame methodology is the formal strategy being recommended to monitor the breeding population of bald eagles, there are other local and national efforts that will continue to assist in evaluating the status of the bald eagle population. Many States have annual flight surveys to count nesting bald eagles. Some States will conduct a second flight to assess productivity. Wintering bald eagle surveys have been conducted since 1979 and the National Bald Eagle Winter Survey has become institutionalized in many States across the country (Steenhof et al. 2002). This effort provides an opportunity to identify and manage for important eagle wintering areas, and provides information on wintering distribution, abundance, and age class. Biologists at important bird migration points have been tracking migrating bald eagles for many years. Service National Wildlife Refuges and other land managers track productivity as well as nesting and migrating bald eagles. Continuing these efforts post-delisting and providing that information to the Team members will improve our ability to evaluate the status of the bald eagle.

Methods

Sampling Design: The Dual Frame Method

These methods are described in more detail in Appendix 1, Contiguous 48 States Bald Eagle Breeding Pair Survey Design. A generalized description of the methodology follows.

The Service will work with States, Tribes, Federal agencies, and other partners to conduct a survey of occupied bald eagle nests that incorporates information from two sampling strategies. The first strategy uses the list of all currently known occupied bald eagle nest locations. This is called the list frame and is the method employed for the last 25 to 30 years by the States. The second strategy uses aerial surveys to count occupied bald eagle nest locations from randomly selected plots. This is called the area frame (Haines and Pollock 1998). A frame is a set of all possible elements from which we can sample. Data gathered in these two sampling frames allows aggregation of numbers from occupied nests found in the list and occupied nests found in the area frames, resulting in an estimate of the total number of occupied nests that is more accurate than the use of either frame alone based on results from the pilot studies (Appendix 1).

List Frame

The list frame for this Plan is a summary of all currently known occupied bald eagle nests for the contiguous 48 States. This includes the current State occupied nest lists and will include all future updates to those lists. The list will be updated by States and partners conducting bald eagle nesting surveys in the manner that those surveys were conducted while the bald eagle was still listed under the ESA. Each State will enter updates to the list into a secure, web-based database. The updates will include confirmation of activity at known nest sites and the addition of new occupied nests found either through the nest surveys, or by nest locations found during the area frame survey that were previously unknown. Historically, States conduct bald eagle nest surveys at varying levels of effort and at varying time intervals. Thus, the list frame will be composed of data collected in different years and of varying intensity. Should confidence in the list frame erode over time due to reduced survey effort, the list may need to be sampled concurrent with the area frame to provide an estimate of nests that are in the list frame.

Area Frame

The area frame is composed of randomly selected plots within which bald eagle habitat is carefully surveyed for all occupied bald eagle nests. The plots are 10 km x 10 km each (or equivalent area), selected from a grid matrix that has been overlaid on a habitat stratum. The strata are used to increase sampling efficiency, and are based on State boundaries and Bird Conservation Regions (BCRs). The BCRs group regions with similar environmental features (Sauer et al. 2003). To accommodate State-specific needs, we divided BCRs into States, and use these State-BCR units as our initial strata (Appendix 1, Figure 1). The State-BCR strata are further divided into High, Low, and Trace categories based on bald eagle habitat quality and nesting density (Appendix 1, Figure 2). Appendix 2 outlines the protocol for collecting area frame data for this Plan. Observations of nest occupancy collected in this area-based sample will contain both new nests and nests that also occur in the list frame.

Dual Frame

The dual frame method of analysis combines sample information from both the list frame and the area frame to arrive at a more precise estimate of occupied nest density across the entire study area (Haines and Pollock 1998). To conduct the analysis, occupied nests identified in the area frame sampling are separated into the two categories: the overlap (nests in the plots that also occur in the list) and nonoverlap (nests that are newly found in the plots). The nonoverlap nests are identified, and are used to estimate the total number of nests not in the list. The sum of the estimates from the area frame and the list frame are used to determine a total number of occupied eagle nests within the study area.

Monitoring Study Area

The goal of this Plan is to detect changes in the number of occupied bald eagle nests in the contiguous 48 States. The study area is the entire contiguous 48 States because one population was identified as the listed entity at the time of removal from the Federal List of Threatened and Endangered Species. Sampling at this scale will be more cost-effective than sampling at a regional or smaller scale.

A GIS-based map has been developed depicting bald eagle nesting density in the contiguous 48 States (see Appendix 1, Figure 3), which is the study area. The map is based on the most recent nesting data collected at different times in different ways from each State and compiled into one list for the contiguous 48 States (list frame).

Frequency and Duration of Sampling

If we used a narrow interpretation of the ESA's requirement for monitoring a minimum of five years after delisting, this would result in monitoring for one breeding cycle. The bald eagle's distinctive white head and tail are not fully visible until four to five years of age when eagles are considered to have reached sexual maturity. In some areas of the country, birds in sub-adult plumage have been known to form pair bonds, defend territories, and construct nests. In other regions with dense populations and competition for nest sites, eagles may not breed until six or seven years old (Buehler 2000). Thus, though the exact breeding cycle varies, the majority of bald eagles reach maturity at 5.5 years of age (Buehler 2000). In order to assess several generations of bald eagles after delisting, this Plan recommends monitoring bald eagle nesting populations at five-year intervals (which would follow the development cycle to maturity for one generation), for four generations or a total of 20 years.

Many States monitor bald eagle nests on an annual basis because the surveys provide valuable resource data. Comments we have received from a number of States, however, indicates that their future bald eagle monitoring will be greatly reduced due to its recovery and the need to allocate funding to other areas. Thus, five-year survey intervals will provide more data for states where surveys are not otherwise planned. It may also provide a cost savings for other States if they can use these data at five-year intervals to satisfy their needs.

Sampling the List Frame

The Plan recommends States maintain their lists of known nest sites. It is expected that this will be done with varying degrees of effort. Ideally, the number of occupied nests in the list would be determined through a periodic census of all nests on the list. In States where lists are not maintained, known nest sites can be sampled as part of the area survey.

Sampling the Area Frame

The area frame must be sampled to obtain unbiased estimates of the total number of occupied nests. To do this, the Service's biometrician will determine area frame plot numbers for each stratum in coordination with the States. Some plots initially selected for the area sample may have characteristics that make them unreasonable to sample. For example, the plot may be too far from an airport to be cost effective or allow for safe reserves of fuel. Plots near urban areas could contain too many obstructions such as transmission lines or cell towers to permit safe survey conditions. Therefore, we will initially select an additional 10 percent of plots to sample to ensure alternate plots are available if different plots are necessary. For example, if 10 plots will be sufficient to meet the stated goals for precision and accuracy, we will plan to sample 11 plots, assuming that logistical or safety issues may preclude sampling at one plot. Should all plots be feasible, sampling will cease when the minimum number of plots first selected has been sampled.

Protocols

The area frames will be sampled using protocols consistent with those developed during the pilot studies. A detailed discussion of standard operating procedures is included as Appendix 2. A double observer protocol will be implemented for the area frame sampling whenever possible to estimate the proportion of nests missed during that area sampling event (Nichols et al. 2000). Protocols for double observer sampling are also presented in Appendix 2. Aircraft observers should be familiar with the terrain and nesting habitats of eagles in their area. The front seat observer should be the primary data recorder. All occupied nests and the number of visible young should be recorded. The aircraft should be flown at 200 to 700 feet above ground level (agl) at about 100 mph or 87 knots. Only the parts of plots that are composed of potential eagle habitat will be flown. Flight paths will be defined on maps prior to conducting the surveys. We note that protocols for assessing occupancy status of a nest may differ regionally, and timing of surveys will also differ regionally. Consequently, protocols for sampling must be reviewed regionally for consistency as part of survey implementation.

Reproductive Terminology

Standard terminology for describing the status of bald eagle nests and territories is essential, especially if a meaningful comparison is to be made of the data collected by different workers over many years and throughout the nation. The following definitions are derived from Postapulsky (1974), Fraser (1978), Steenhof and Kochert (1982), and Steenhof (1987). They are entirely separate from, and should not be substituted for, definitions in other bald eagle documents developed by the Service.

Active nest (breeding): A nest where eggs have been laid. Activity patterns are diagnostic of breeding eagles (or those with an "active" nest). This category excludes non-nesting territorial pairs or eagles that may go through the early motions of nest building and mating, but without laying eggs. From egg-laying to hatching, incubation typically lasts 35 days (Stalmaster 1987).

Alternate nest: One of several nest structures within a breeding area of one pair of eagles. Alternate nests may be found on adjacent trees, snags, man-made towers, or on the same or adjacent cliffs. Depending on the size of the breeding territory, some alternate nests can be up to a few miles away.

Bald eagle nesting habitat: For this study, bald eagle nesting habitat will need to be defined for each region to assure sampling efficiency. In general, bald eagle nesting habitat will include a description of typical nesting structure for the region and proximity to a food source, usually a larger sized water body. The pilot States generally defined bald eagle nesting habitat as supercanopy or sturdy-structured trees within one mile of water bodies greater than 35 acres and rivers greater than 330 feet in width and all coastal waters with suitable nesting substructures nearby. However, local or regional habitat parameters will have to be modified with input from local biologists to fit local conditions, including in much of the arid Southwest.

Breeding area (nesting/breeding territories): An area that contains or that was previously known to contain one or more nests within the territorial range of a mated pair of eagles.

Nest: A structure, composed largely of sticks, built by bald eagles for breeding.

Unoccupied breeding area/territory/nest: A nest or group of alternate nests at which none of the activity patterns diagnostic of an occupied nest were observed in a given breeding season. Breeding areas must be previously determined to be occupied before they can be recognized and classified as unoccupied.

Occupied nest: Any nest where at least one of the following activity patterns was observed during the breeding season:

- a recently repaired nest with fresh sticks or fresh boughs on top;
- one adult sitting low in the nest, apparently incubating;
- one or two adults present on or near the nest;
- one adult and one bird in immature plumage at or near a nest, if mating behavior (display flights, nest repair, coition) was observed;
- eggs were laid (detection of eggs or eggshell fragments);
- any field sign that indicate eggs were laid or nestlings hatched; or
- young were raised

The total number of occupied nests is the index of abundance for this survey. Efforts will be made to survey during the period when adults are most likely to be incubating and the identification of occupancy is most often confirmed with the presence of one or more adults. Observers will make note of nests that are found but where bald eagles are not present. Distinctions between repaired and not repaired empty nests will be made in addition to any uncertainties such as questioning whether the empty nest is that of an osprey. In case of doubt, the default determination will be negative.

Data Quality

The survey data sets used in the Bald Eagle Post-delisting Monitoring Plan will adhere to the Service's data quality standards in naming variables and in choosing values those variables can take (www.fws.gov/stand). The metadata for our spatial data will be written according to the Federal Government Data Committee standards http://www.fgdc.gov/metadata/geospatial-metadata-standards.

Habitat

The Service will not monitor changes in bald eagle habitat directly. However, the Team, in conjunction with the States and other partners, will accept and review data indicating significant changes in bald eagle habitat in the contiguous 48 States. Should a 25 percent decline in the bald eagle population occur, the Service will consider habitat data when determining potential causal factors for the decline.

Contaminants

The Service worked with the USGS-BRD to develop a searchable database/library dedicated to contaminants investigations of bald eagle, osprey (*Pandion haliaetus*), and peregrine falcons (*Falco peregrinus*). The objective was to create a readily available source of information to consider should the bald eagle (or peregrine) population decline. Osprey contaminants data are relevant to bald eagles as they occupy a similar niche.

The USGS identified, acquired, and assigned keywords for published and unpublished literature about contaminants in bald eagles, osprey, and peregrine falcons. The USGS's Richard R. Olendorff Memorial Library in Boise, Idaho currently maintains several hundred references relevant to this topic as part of the Raptor Information System. New and existing references were assigned contaminant-related keywords, established by the Service's contaminants biologists. These keywords are listed on the contaminants database page at the following website: http://ris.wr.usgs.gov/Contaminants.asp . Citations for all new references were incorporated into the existing Raptor Information System database and are served from the existing website (http://ris.wr.usgs.gov/). Many of the citations include links to the full text of articles that are being served on the World Wide Web. We will also seek resources from the National Biological Information Infrastructure (NBII) to serve the PDF files and abstracts as well as the citations from a separate web site. Keeping this database relevant will require periodic updating. A Service environmental contaminants biologist will coordinate this effort (see Appendix 4, Region 5 contacts).

References from the contaminants database can be retrieved by entering the first keyword in the keyword search box using the autocomplete function. Enter additional keywords from the keyword popup list, then type in FWSEC as the final keyword in the keyword box. Not entering FWSEC will bring up references about other species as well as abstracts and popular articles about the subject species.

By creating this database, biologists in the position of recommending regulatory actions based on post-delisting monitoring trends will have a clear overview of the most recent findings of contaminant effects on these three species. Deleterious effects resulting from contaminant exposure was a major reason the bald eagle and peregrine falcon were listed under the ESA. Data demonstrating reduction in contaminant exposure supported the proposal to delist the bald eagle and peregrine falcon. Should additional studies be needed during post-delisting monitoring, the database will clarify what has been studied and what has not.

Ongoing and Potential Sources of Mortality

In species with a long life span and a relatively low reproductive rate like the bald eagle, adult mortality can be a very important factor in determining the stability of a population (Stalmaster 1987). Bald eagles (and many other raptors) are killed as a result of trauma from collisions with power lines, vehicles, and other obstacles; electrocution; disease; poisoning; shooting; and other factors.

As part of the Plan, bald eagle mortality will be tracked to alert the Team to new and potentially significant sources of mortality. We will request information on bald eagle deaths from sources that are known to encounter dead eagles most frequently: State wildlife conservation agencies; Service law enforcement officers; wildlife rehabilitators; the National Wildlife Health Center in Madison, Wisconsin; and the National Fish and Wildlife Forensic Laboratory in Ashland, Oregon. If an unusually large number of mortalities occur, the Service and its partners will consider the information in regards to specific causes and/or locations for investigation of patterns and possible corrective action, if necessary.

Response Trigger

The Service has established the following Plan goal as the response trigger for additional investigation:

> A 25 percent or greater decline in occupied bald eagle nests between any two periods measured at 5-year intervals detected with a power of 80 percent and an error rate of 10 percent.

If such declines are detected, the Service's Bald Eagle Monitoring Team will coordinate with the States to investigate causes of these declines, including consideration of natural population cycles, weather, productivity, contaminants, mortality factors, habitat changes, data from other monitoring efforts, or any other significant evidence. At the end of the 20-year monitoring program, we will coordinate with States and our partners to conduct a final review and provide recommendations to insure a properly managed bald eagle population. Any relisting decision by the Service will be made by evaluating the status of the bald eagle relative to the ESA's five listing factors (ESA § 4(a)(1)).

Reporting

The Service will issue a report detailing the results of the first breeding population survey, which will serve as our baseline for future comparison. This report will be available to the public in printed form and on the internet at http://www.fws.gov/migratorybirds/BaldEagle.htm within one year of survey completion. The report will include a description of the geographic areas surveyed, the survey protocol, and an estimate of the breeding population of bald eagles in the contiguous 48 States.

Every five years, the Service intends to issue a report following completion of the updated continental breeding population sampling. This report will contain information similar to the baseline report, including an updated breeding population estimate and comparison with previous data, and will be available to the public. Reports will also suggest ways to improve sampling protocols or other aspects of the Plan design, if necessary, and will provide updates to the Plan.

Each report will include comments on the need for any investigative action and the relationship between the survey results and the response trigger. This Plan is designed to detect substantial declines in occupied nests with reasonable certainty and precision. If the response trigger is met or exceeded, the Service will consult with the States and other partners and make recommendations for future actions. If necessary, an evaluation of the threats to bald eagles will be made using the five factors required under the ESA to list a species on the Federal List of Threatened and Endangered Species.

The Service intends to also provide a summary report on bald eagle mortality every five years. Bald eagle mortality reports will describe the number and causes of reported eagle deaths during the five-year period, cumulative deaths reported since the completion of baseline monitoring, and the geographic distribution of the reported deaths. Emphasis will be on concentrations of multiple deaths. In this way, specific causes and/or locations of high eagle mortality may be identified for investigation of patterns and possible corrective action, if necessary.

At the end of the 20-year monitoring period, the Service will review all available information to determine if continuation of monitoring is appropriate. The decision to continue or end the monitoring program will be explained in the final monitoring report, which will be made available to the public as described above.

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Appendix 1

Contiguous 48 States Bald Eagle Breeding Pair Survey Design

by Mark C. Otto and John R. Sauer

Introduction

Bald eagle biologists have focused on site-specific monitoring of eagle nest sites both to monitor population change and to catalog areas for management of the species (Bartish 1994). These site-specific efforts form a critical resource for eagle monitoring, and the Plan seeks to maintain these lists of eagle nest sites and to assess their occupancy status. However, particularly in areas where eagles are increasing, sampling these lists is not an adequate monitoring program, as many possibly occupied nests exist that are not in the lists. Consequently, while the delisting criteria are based on the existing lists, and they form a critical component of the monitoring program, additional sampling is recommended in conjunction with the list sampling to obtain unbiased estimates of occupied eagle nests. This dual-frame approach provides estimates of occupied eagle nest abundances that are not limited to the list of nests, and provides a flexible strategy for estimating abundance that is not limited to regions where the lists are maintained. Pilot studies were conducted to assess the feasibility of the dual-frame sampling design.

Generally, eagle pairs choose one nest of a possible number of nests in their territories to occupy and use for brood-rearing in a given season. Many States collect information on territories along with information on the nests. Because information on territories is not collected consistently across all States and because we cannot assign territories to new nests found on the area survey, we use occupied nests as our sampling unit. We assume that determining the number of occupied nests is equivalent to determining number of territories. This imposes a dependence among local nests in occupancy, as only a single nest in a territory will be occupied. Practically, this lack of independence does not affect the estimation when we sample nests instead of territories.

Geographic information about suitable bald eagle breeding habitat and existing nests can be used to develop an efficient sample design for the species. We recommend that the sample design: (1) stratify by regions (physiographic strata within States) to permit more intensive samples in regions with a higher density of bald eagle nests; (2) use a dual-frame design to sample known nest sites but also conduct an area-based sample to estimate the total number of nests; (3) use habitat information within regions to further focus sampling efforts; and (4) account for nests not observed by estimating detection probabilities using double observer survey methods (Thompson 2004).

Dual-frame sampling uses a sample from the list of known nests, in combination with additional sampling, to estimate the total number of occupied nests. For the additional sampling, the study area is divided into plots, and a sample of these plots is randomly selected and censused for occupied eagle nests. This set of plots is known as a sample frame, and the selected plots are a random sample from this frame. In accordance with statistical sampling theory (Lohr 1999), results from the sample plots allow us to calculate an estimate for the entire study area. The additional information from the sample from the list of nests, however, can be incorporated into the estimation. If nests that are on the list but are also known to be in the sample plots are identified and removed from the sample (a process known as unduplication), the remaining occupied nests observed in the plots can be used to estimate the total number of occupied nests not in the list. The occupied nests in the list and the occupied nests seen only on the plots can be added to provide an estimate of the total number of occupied nests.

Additional effort is required during the area surveys to ensure that we account for occupied nests that are in the sampled area but are not seen during sampling. Use of a protocol involving two independent observers (double-observer sampling, Nichols et al. 2000) permits estimation of the number of nests that are not observed. For more details on the double-observer survey method, refer to Appendix 2.

To assess the feasibility of using a dual-frame sample design for bald eagle post-delisting monitoring, the Biological Resources Division of the U.S. Geological Survey (USGS) and the Service conducted pilot surveys over three years (2004–2006) in five States (Maine, Florida, Minnesota, Washington, and Missouri). Based on the results of these pilot studies, the overall sampling approach described here was developed. The pilot data were also used to predict the effort needed in a national delisting monitoring program.

In this appendix, we discuss the pilot study results, the national design, and the effects of list coverage of the nest list on the cost-variance functions. The proposed design expands on the approach used in the pilot surveys to a national monitoring program for bald eagles. The discussion includes: (1) stratification and how it can be simplified; (2) list frame (all known nests from State nest lists in the contiguous 48 States) and how they can be clustered within plots to reduce flying time; (3) area frame (all 10 km x 10 km plots covering the contiguous 48 States); and (4) estimation of detection probability using double observer techniques with the area survey.

Pilot Studies

Pilot studies were conducted in Maine in 2004, and Florida, Minnesota, and Washington in 2005. Additionally, biologists in Missouri volunteered to test the methods in 2006. The pilot studies were designed to test the effectiveness of the Haines and Pollock (1998) dual-frame design in a variety of geographic areas. The States involved in the pilot studies differed both in eagle abundance and in the completeness of their list frames, providing a variety of situations for evaluating the dual-frame approach. The eagle nest surveys for the pilot studies were collaborations among USGS, Service, and State biologists experienced in bald eagle surveys. The State biologists were consulted on design issues, conducted surveys of their list frames, and were observers for the area frame components of the surveys.

For the list frame, State biologists censused or sampled the known nests from the ground, helicopter, or plane as had been done in previous surveys. The number of occupied nests was determined from the product of the number of nests in the list frame and the proportion of occupied nests estimated during the survey. If the list was censused (all nests checked), the variance was zero; if the list was sampled, the variances were determined according to the methods described by Thompson (1992, p. 35).

To implement the dual-frame protocol, an aerial survey of 10 km x 10 km plots was conducted over the same strata as the list frame survey. To select plots: (1) each State was divided into a grid of 10 km x 10 km plots; (2) the plots were assigned to strata based on the predominant habitat type in each plot; (3) nest densities and their standard deviations for each stratum were obtained from the previous list frame; and (4) optimal allocations for the area frame were determined according to survey sample design theory (Lohr 1999, p. 104). Consequently, higher density, more variable, and less costly strata were sampled more intensively. Random samples of plots were drawn in proportion to the optimal allocation in (4).

All eagle habitat (as defined by the State biologists) in each sample plot was examined during the aerial survey. A double-observer protocol was developed and implemented to estimate the number of nests missed during the survey. Observers in the front and rear right side seats of the aircraft made independent observations of bald eagles and eagle nests. The observations were reconciled immediately after the aircraft had passed the nest. The "capture history" (i.e. seen-seen, seen-not seen, etc.) of each observation was recorded (see Appendix 2, Standard Operating Procedures). Detection probabilities for individual observers and both observers together were obtained using the software program DOBSERV (Nichols et al. 2000, http://www.mbr-pwrc.usgs.gov/software.html). Including observer detection in the sample allocation specifies that lower detection probability and more variable detection probability strata should be sampled more intensively.

The dual-frame estimate was obtained from combining the list frame with the area frame surveys by unduplication. Unduplication removes all the nest observations that were on both the list and the area frames and leaves only the number of new nests. After the unduplication, list and area estimates become independent from each other because they have no common observations. The list and area totals can then be added to estimate the total number of nests. List and area variances can also be summed to estimate a total variance.

Pilot Study Results

Results indicate that the dual-frame approach with detectability estimation is useful in providing both (1) an estimate of the number of occupied nests that are not included in the list of nests and (2) an estimate of the detection rate of nests when sampling plots. The variances of the dual-frame estimates were smaller than both the mean squared error of the list total and the sample variance of the area survey. Dual-frame estimates of the total number of nests were 421 in Maine in 2004, 1,481 in Florida (using the 2003 nest list), 1,327 in Minnesota and 1,939 in Washington in 2005, and 123 for Missouri in 2006.

Detection rates varied among States and due to differences in survey techniques, but generally were $\geq$ 95 percent for both observers combined.

The dual-frame sampling design can be applied throughout the contiguous United States in a manner similar to that conducted at the State level during the pilot studies. Using the dual-frame method to estimate population size throughout the contiguous U.S. will require close coordination with the States. Cooperation is needed to continually update the recently compiled nest list. Assistance from State biologists will be needed to ensure that bald eagle habitat is properly defined for each area and to confirm or modify the stratification. Experienced bald eagle observers will be needed to conduct the surveys. If experienced State pilots will be used for surveying, coordination and effort will be needed to set up the recording hardware and software and implement the double observer protocol. Finally, biologists familiar with the nest lists will be especially helpful in surveying nests on the list and in reconciling the observations in the area survey with those in the list.

Goals of Sampling

The goal of post-delisting monitoring is to estimate changes in the number of occupied bald eagle nests in the contiguous 48 States. Because bald eagle populations have been increasing over most of their range, changes in rate of increase may be an important first indicator, and can be estimated by comparing the result from any two sample periods. This survey methodology is designed to detect a 25 percent relative population decline in the total number of occupied nests in the contiguous 48 States between any two sampling periods 80 percent of the time with a 10 percent chance of getting a significant decline just by chance. Statistical methods and pilot data described here provide a rigorous framework for predicting the number of areas that need to be sampled to meet this goal.

Stratification

Bald eagle distribution and nesting density varies widely both within and among States. The Plan uses physiographic regions developed for bird conservation (Bird Conservation Regions, or BCRs; U.S. North American Bird Conservation Initiative Monitoring Subcommittee 2007) as strata for developing eagle survey plots throughout the contiguous United States. The BCRs group regions with similar habitats and other environmental features, and allow for a more consistent regional grouping of habitats than State boundaries.

To accommodate State-specific needs, we divided BCRs into States (e.g., we considered DE, MD Coastal Plain as a separate stratum from VA Coastal Plain), and used these State-BCR units as initial strata (Figure 1). Washington, Oregon, Florida and Maine have tailored their State strata based on their biologists' knowledge. We then aggregated these State-BCR units to larger strata using a clustering procedure that assessed similarity in the State-BCR units from information on eagle abundance (Table 1). For each State-BCR, the eagle nest list data were overlain on a 10 km x 10 km grid (corresponding to the proposed plot size) and used to estimate mean and variance of eagle nests in Table 2.

After each combining, the overall standard error could be assessed, and large increases in overall standard error indicate a lack of value in the grouping. In this analysis, we chose to stop combining when 18 State-BCRs remained as separate strata, and we combined the aggregated units into a low-abundance stratum. We further separated the ~~18~~ contiguous lowest-density strata into a "trace" stratum, a region containing only 14 nests in the stratum (Figure 2). We view these aggregate strata as reasonable regions for implementing an initial survey design. Aggregating the similar strata will improve the estimation by avoiding imprecisely estimating numbers of nests in many small strata.

Variation in plot densities in the aggregated strata is still higher than we would expect for count data. This suggests that further stratification would be useful. State biologists, particularly those in States containing the 18 primary strata are encouraged to refine these strata using their knowledge of eagle populations and habitat use by the species. Also, if amount of habitat or shoreline are highly correlated with density of occupied nests, we should weight the sample selection by the correlated variables. Finally, we can obtain sub-regional or other small area occupied nest estimates (e.g., estimates in portions of aggregated strata) by post-stratification (Lohr 1999, p. 114) or small-area estimation (Lohr 1999, p. 397).

List Frame

State biologists have provided lists of nests with their locations, last known status, and year of the observation. The list frame can be sampled or censused to estimate the number of known nests that are occupied. Sampling from the list frame is efficient because locations are known and nests can be observed by flying directly from one nest to the next. Figure 3 illustrates the distribution of nests collated from State lists.

Because sampling the list is a major cost associated with an eagle monitoring program, we explored an approach to grouping the list nests for sampling. Efficiency can be gained by grouping the nests from the lists into "clusters," then sampling the clusters of nests in conjunction with the area component of the survey. Clustering increases the variance relative to a random sample, but this should be compensated by the reduced cost of sampling (Lohr 1999, pp 154).

To implement this approach, we suggest that the list sampling be directly connected to the area sampling, by treating the area sample units (the plots) as clusters. List frame nests within a plot can be defined as a cluster. During the area sample, if a plot is selected for the survey, all list nests in that plot will also be sampled as the cluster. Sampling the list where we sample the area allows us best to assess the coverage of the list and correctly assess nests as occupied or unoccupied. For the rest of this appendix, sampling of the list frame will be done on clusters of list nests within a plot. Plots with list nests will be the list frame sampling unit.

Area Frame

Within strata, we suggest that the sample unit for area sampling be the 10 km x 10 km plots used in the pilot studies. For development of a sampling frame for the contiguous 48 States, we used ArcGIS with a Lambert Equal-Area Projection to generate 10 km x 10 km plots. The plots were then categorized by strata. Non-US and water portions of plots on the coasts or Mexican and Canadian borders were removed. Plots that overlapped two or more strata were assigned to the stratum that had the majority area. Figure 4 is an example of the plot grid from the pilot study in Missouri. Filled blocks represent the selected sample plots; the diamonds indicate location of selected sample list nests.

The 10 km x 10 km grid spanning the contiguous United States was overlain on a map of the list nest locations, associating each nest with a plot, and means and variances of number of nests per plot were calculated for each of the strata. These data form the fundamental information for allocation of samples.

Estimation and Detectability

For estimation and survey design, we follow Haines and Pollock's (1998) methods and add additional components for estimating detection probability. We estimate the total number of occupied nests, N_{Li}, by adding the estimated nests in the list, $\hat{Y}_{Li}$, and the estimated number of occupied nests in the area frame that were not in the list frame, $\hat{Y}_{Ni}$. We use the subscript *N* instead of *A* because the nests are new. The stratum estimates are added up to get the national total,

$$\hat{Y} = \sum_{i}^{I_L} \hat{Y}_{Li} + \sum_{i}^{I_A} \hat{Y}_{Ni}$$

The I_L list or I_{AL} area strata can be different. The list strata effectiveness is determined by the differences in the percent occupied and the area strata effectiveness by the differences in the density of the new nests. The latter is determined by unknown variation in the list coverage along with the occupied nest density itself.

The estimate for occupied nests in the list frame is the sample proportion of occupied nests, $\bar{y}_{Li}$, expanded by the number of nests in the stratum, $\hat{Y}_{Li} = N_{Li}\hat{y}_{Li}$.

The estimate for new occupied nests expands the density of the new nests seen, $\bar{y}_{Ni}$, by the stratum size, N_{Ai}, and the detection probability, $\hat{p}_i$,

$$\hat{Y}_{Ni} = \frac{N_{Ai}\bar{y}_{Ni}}{\hat{p}_i}$$

The *A* stands for the area frame. The higher the density of occupied nests, the larger the stratum area, and the lower the detection probability, the larger the stratum total.

The variances from the list and area frames are independent, so they can be added to get the variance of the total[1],

$$Var(\hat{Y}) = \sum_{i}^{I_L} Var(\hat{Y}_{Li}) + \sum_{i}^{I_A} Var(\hat{Y}_{Ni})$$

If the list is censused, the variance associated with its estimate is 0. If it is sampled, the stratum variances for the list frame only depend on the number of occupied nests, N_{Li}, and the variability of the estimate, $S_{Li}^2 = n_{Li}\bar{y}_{Li}(1-\bar{y}_{Li})/(n_{Li}-1)$, and the sample size, n_{Li},

$$Var(\hat{Y}_{Li}) = \frac{N_{Li}S_{Li}^2}{n_{Li}} - (Fixed\_Part)$$

So the variance decreases as the number of occupied nests and the sample size increases. Components of the formula not needed for this analysis are indicted by the term "Fixed Part," $(Fixed\_Part) = N_{Li}S_{Li}^2$. They represent the parts of the variance that are not affected by the sample size.

Estimation of the stratum area frame variances is complicated by the detection probability.

$$Var(\hat{Y}_{Ni}) = \frac{N_{Ai}S_{Ni}^2}{\hat{p}_i^2 n_{Ai}} + \frac{N_A^2\bar{y}_{Ni}^2(n_p-1)Var(\hat{p}_i)}{\hat{p}_i^4(n_{Ai}-1)} - (Fixed\_Part).$$

The variance decreases as the area (N_{Ai}) density of new nests ($\bar{y}_{Ni}$) the variance of the density of new nests (S_{Ni}^2) and variance of the detection probability $(Var(\hat{p}_i))$ decrease and as the sample size (n_{Ai}) and the detection probability itself ($\hat{p}_i$) increases. Again, the "Fixed_Part"

$$(Fixed\_Part) = \frac{N_{Ai}S_{Ni}^2}{\hat{p}_i^2} + \frac{N_A^2(1-\hat{p}_i)\bar{y}_{Ni}^2}{\hat{p}_i^2}$$

is a part of the variance that is not affected by the sample size. Note that the variance of the new nest density will drop as fewer new nests are found, i.e., if the list is more complete, the variability of the new nests drops. The parts of the variance that change with sample size are used in estimating the required sample size.

Survey Design

To design a survey, we calculate the variances we require given our sampling goals and look at alternative designs to attain those goals by comparing the sample sizes and resulting costs needed. The effect size (in terms of relative change), power, significance level, and variability of the data determine the variance needed from the survey. We use

[1] We use variances when we derive the sample sizes we need because the variances of independent parts of the survey can be added. The standard errors are the square roots of the variance. We use them in the tables and graphs because they are more understandable in that they are used to construct confidence intervals. They are on the same scale as the data.

these components to define the least expensive allocation of samples that meets our variance requirements. We would like to minimize both the costs and the variance,

$$\min\left(\sum Var_{\hat{Y}}(n_{Li}, n_{Ai}) + \lambda \sum Cost(n_{Li}, n_{Ai})\right)$$

The variance, $Var_{\hat{Y}}$, is the variance of the total in the previous section. The variance and cost are written as functions of the list and area sample sizes n_{Li} and n_{Ai}, as both parameters depend on sample size.

Costs also vary by stratum. We approximate the cost of sampling a stratum with a linear function,

$$Cost(n_{Li}, n_{Ai}) = c_0 + \sum_{i}^{L} (c_{Li} n_{Li} + c_{Ai} n_{Ai}) \ ,$$

where the total cost is the sum of c_0, the fixed cost for both the list and area frames, c_{Li}, the cost of adding another nest or nest cluster to the list sample and c_{Ai} is the cost of adding another area sample.

The Lagrangian Multiplier, λ, represents the trade off between cost and variance. When we change the sample sizes we decrease the variance because we are taking a larger sample and also paying the cost of it. Among all the strata there is some consistent tradeoff between reducing the variance and increasing the cost, λ. The solution to the minimization of the cost-variance function, requires more sampling in the strata that for the best price will get the best reduction in variance. The sample is said to be optimally allocated among the strata.

Since we solve the multiplier for the sample size, the stratum nest densities and their variances are input, forming the "data" used in the equations. We use the estimates derived from the nest list and pilot studies (Table 2). Likewise, we also use the nest list data to construct cost functions for sampling. These calculations yield optimal sampling procedures, given the pilot data that are input. Following most sampling texts, we suggest choosing sample sizes 10 percent more than the minimum recommended from the optimal allocation.

We compare four designs:

1. List-only,
2. Area-only,
3. Dual-frame, and
4. Combined dual-frame.

1. List-only**.** The current information comes from the State nest list. A "List-only" design would involve sampling only from these nest lists without any attempt to estimate the number of nests missing from the list. The estimates can be derived by just using the terms in the total and variance equations that have to do with the list. The list estimate is

always biased, as occupied nests always exist that are not on the list. Magnitude of the bias can be expressed as the list coverage, which is the number of nests on the State nest lists as a percentage of the total nests. We include this bias when comparing the sample designs by making the estimate of variability the mean squared error, $\text{mse} = Var\left(\hat{Y}_l\right) + \text{bias}^2$.

2. Area-only**.** The area-only design ignores the State nest lists and estimates the number of occupied nests using just the nests found on a random sample of the plots. The area estimate uses only the terms for the area survey in the total and variance equations. All the nests in the plots are used, not just the new nests. This estimate is unbiased.

3. Dual-frame**.** The dual-frame design includes both the list and the new nests in the area survey. The total and variance equations are shown above.

4. Combined dual-frame. Finally, we include a special case of the dual-frame called the combined dual-frame where the list nests are sampled immediately after sample plots. This could save on flight time. The equations are the same as for the dual-frame, but the size of the list frame sample is the number plots in the area sample times the portion of area plots that also are known to contain list nests plus an extra sample of list cluster plots. We use different cost functions because of the differences in sampling.

<u>Cost Functions for Sampling List-Plot Clusters</u>

The cost functions for sampling the list are determined by simulation, drawing samples and calculating the shortest distance needed to travel among all the sample clusters plus the distances to travel within each cluster. Samples of different sizes are drawn, the distance for the minimum spanning tree is summed for each sample, and a regression is done with flight miles against sample size. A number of samples of different sizes were estimated for each stratum using the contiguous 48 State nest list. Cost functions are derived by a linear regression allowing equations for each stratum to be different. The totals of the distances traveled among given locations are determined from their minimal spanning trees (Paradis 2004, the `mst` function). Minimal spanning trees do not account for flights starting and returning to one or more airports for each flight.

The distances traveled during the pilot surveys can be converted to costs by assuming the planes flew 100 miles per hour and the cost of the plane was a rate of $317 per hour (the Service rate in 2007). Because the conversion factor varies with flight fuel and other costs that will probably increase before implementation, we use flight miles as our measure. Actual costs can be applied post hoc using relevant costs. The relative rates do not change. Only flight miles are accounted for in this analysis. Other costs can be added on to those found here to make more realistic estimates. As cost estimates per list cluster or plot are revised, the analysis should be revised. Figure 5 shows the number of miles needed to fly samples of a given number of list-plot clusters. There is a separate line for each stratum. Some lines do not extend as far as others because of their varying number of clusters. This is especially true for the trace stratum which only has 12 nests in 12 clusters; trace clusters are far apart, hence the line is very steep. The slope affects the proportion of the stratum that is sampled; the steeper the slope, the more expensive the sampling cost and the less it is likely to be sampled. The intercept affects the initial cost of sampling the stratum. Since all strata are sampled to some extent, the initial cost applies to a sample of any size. The other strata have lower, more similar slopes.

Cost Functions for Sampling Plots

The cost functions for the plots in the area frame are similarly determined, see Figure 6. At a range of sample sizes, the minimum distances among the simulated sample plots are added to the within-plot costs for each plot. The within plot costs are determined from the length of the shoreline within each plot. We set a minimum value of 33 miles to scan a plot with little or no habitat. We also set an upper bound, assuming that complete coverage by dividing the plot into transects would be more efficient at some point; the upper bound is never reached.

The linear cost functions are determined as in the list-plot cluster analysis, but here the samples are plots over the whole stratum. The plots occur more regularly than the list nests or plot clusters, so the differences in the stratum cost functions are due to the amount of shoreline in the plots and the size and shape of the stratum. For these cost functions, the cost of sampling the trace stratum is more expensive than sampling the low stratum. Costs of the other strata again are lower and generally similar among strata. The cost functions for the combined dual-frame design are not shown but are slightly higher than those shown in Figure 6.

Proportion of Occupied Nest and List Coverage Simulations

Since we did not have consistent information from all States on the proportion of occupied nests or on list coverages in the High-density strata, we simulated values of occupied nests for each stratum between 0.35 and 0.7, and list coverages from 0.4 to 0.9. For the Low and Trace strata we assumed a much higher proportion of coverage (0.7 to 0.98). We used these values in 100,000 simulations, in which proportions of occupied nests and list coverages were simulated for each stratum and the optimal sample allocation and cost-variance calculations were calculated. The ranges of values provided as results are based on the simulations.

Optimal Stratum Allocation

As mentioned above, the optimal allocation of sampling effort to strata is independent of the overall sample size. Consequently, the allocations presented below represent the relative amount of effort to be allocated to each stratum. The percentages vary because of simulations due to unknown proportions of occupied nests and list coverage. In general, sample sizes increase for strata that are larger, more densely populated, more variable, with a lower detection probability, with a more variable detection estimate, and are less expensive to sample (Table 3). What is striking is the variation allocated to the list frame, 23 to 80 percent. If we knew list coverage to be high we would sample more of the list.

The allocations for the area frame are shown in the second column of Table 3. Notice that trace and low strata are sampled lightly both in relation to proportional sampling and to the large size of those strata. Although large in area, the strata are very lightly sampled because they are not densely populated and are costly to sample. Almost two-thirds of the cost of the survey is due to sampling the Low and Trace strata. (14,000 miles are needed to sample the High-density strata while 26,000 miles are needed to sample the Low and Trace strata.) This highlights the need to sample the low and the trace strata efficiently. During the implementation of the survey, we suggest that the necessity of an area sample in the Low and Trace strata be evaluated. It is unlikely that such a sample will provide much useful information on eagle populations due to the low abundances of nests. In the Low stratum, targeting potential habitat (amount of habitat or shoreline near a given plot) could improve the sampling and estimation. Non-aerial sampling and citizen-science based approaches could greatly enhance the efficiency of the survey, especially in the Low stratum, and we recommend that these approaches be explored.

Survey Sample Design Comparison

With optimally allocated samples for each design, we can compare the three primary alternative designs (list-only samples, dual-frame samples, and combined sampling (sampling list clusters after the plots)) in two ways: (1) *In terms of cost:* what standard error (SE) can we obtain for a given total cost for each of the sampling designs, and (2) *In terms of precision:* what do we have to spend for each design if we require a given overall standard error. Figure 7 answers the first question. The list-only survey is the horizontal line on top. We use the mean squared error (MSE), which reflects both bias and variance. The MSE includes the square of the bias between the list estimate and the actual number of nests. The bias term dominates at the 60 percent list coverage we observed in the pilot studies. No amount of sampling will overcome it - even if all the strata are censused. Dual-frame sampling is more cost effective than area-only sampling in a survey of over 20,000 flight miles (Figure 7). There is not much difference between the dual-frame and the combined dual-frame sampling in terms of the standard error obtained for a given cost.

Table 4 answers the second question: given certain precision requirements (setting differing levels of effect size (relative change), power, and significance level) for the estimates, what cost is needed to obtain such a requirement? The first case is the stated monitoring goals: a 25 percent relative change (effect size) detected 80 percent of the time (power) at a significance level of 10 percent (significance level). These specifications determine a required standard error. The cost is shown in the following columns for the list-only frame (list), plot or area-only frame (plot), dual-frame, and combined-dual-frame. The list-only flight miles are constant but the estimate obtained will always be biased with no way to determine the bias. The dual-frame estimates are an improvement over the area-only frame, with the combined dual-frame design being slightly more efficient. In practice, the economies associated with the combined sampling may be greater.

These costs represent minimum costs. They do not take into account search time for nests, flights to and from airports, weather days and per diem for pilots and observers, differences in flight rates among regions, equipment and preparation costs. Survey planners should add additional funding to accommodate these incidental costs.

Table 5 shows example sample sizes by State for the proposed survey goals. These will change as we work with the States to refine the stratification and sampling methods especially in the Low and Trace strata. Figure 8 shows an example sample selection including area samples in all strata.

<u>Effects of List Coverage</u>

The dual-frame design provides a way to assess the coverage of the list. The area frame is used to estimate the number of new (i.e., not in the list) nests, and hence to estimate the list coverage. The variance of the new nests is the major contribution to the variance of the total. The list coverage (that is, the proportion of actual nests that are in the list) affects the relative efficiency of the designs.

Figure 9 shows how the standard error changes for given list coverage when the survey requirements are the stated survey goals. The dual-frame is better than an area (plot-based) survey only, as list coverage is over 40 percent. The difference improves as the list coverage improves. The list approaches the dual-frame standard errors as the coverage approaches 100 percent. Note that an evaluation based only on the list coverage is problematic without area-based sampling to assess the coverage. That is the value of dual-frame sampling. It allows an assessment of the list coverage, and permits estimation of actual numbers of occupied nests.

The optimal allocation treats the same strata in the list and area frames as different strata, i.e., the Central Florida stratum has a sample of list plots and a sample of area plots. These are treated as if they are in different strata. It then allocates sampling effort to each. Because the variability of the list-frame is so much less than the area frame, most of the sampling effort is allocated to the area-frame. Figure 10 shows the proportion of flight miles allocated to the list as the list coverage improves. We use cost because it is the common denominator between the two frames. The cost allocated to the list increases as the list coverage improved but the costs only vary noticeably when list coverage is greater than 90 percent. As the cost of the plot frame increases or the plot standard deviations improve relative to the list frame, more effort (as cost) is allocated to the list more quickly (red and green lines). The large allocation to the area frame indicates the importance of reducing the variability in the plot sample.

<u>Misclassification of Occupied Nests</u>

We use the definition of occupied nests from this Post-delisting Monitoring Plan for the Bald Eagle (p.15–16). Nests in repair were able to be distinguished by each of the State crews in the pilot study. Fly backs or other methods can be used to verify the nest condition. If an empty nest condition cannot be assessed, the nest is classified as unoccupied. This provides a conservative estimate of occupied nests.

In those cases where the list survey is conducted separately from the area survey, at least two independent observations of occupancy can be obtained. Occupancy should be recorded separately for each visit. The area survey should be run early in the breeding season when the pairs are most tightly bound to the nest. A Lincoln-Peterson estimate can assess the number of nests where occupancy is missed on both visits. If the status of the nest is determined outside the surveys, that better assessment of the status may be used for that observation, but only observations from the list and area surveys should be used in Lincoln-Peterson estimate and in the survey total variance calculations.

Conclusions

The goal of the post-delisting monitoring survey is to estimate the change in occupied bald eagle nests in the contiguous 48 States. To achieve this goal, we use the procedures outlined above for deciding on strata, clustering nests from the contiguous 48 State nest list, optimally allocating samples to strata for both the list and plot surveys, and randomly selecting samples according to that optimal allocation. We estimate sample sizes to obtain estimates with a given power and precision or within given costs. We use the dual-frame procedure with a double observer technique in the plot survey to sample more efficiently, resulting in the reduction of less than half the flight miles. We combine sampling list clusters with the area plots survey to better assess coverage of the list. Finally, we use independent estimates of occupancy to assess the number occupied of nests missed in both the list and area samples.

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Tables

Table 1. Aggregating or merging sequence of adjacent strata. Stratum 1 and 2 are the two strata to be combined. "Edge" is the name the combination strata are given. "SE" is the standard error of the survey total of the combination. The start is the individual State BCRs. Note the SE does not noticeably change until after Edge.156.

Edge	Stratum 1	Stratum 2	SE
All state BCRs			307.93
Edge.001	TX.EdPlat	TX.TamBrl	307.93
Edge.002	NV.SRCOPl	NV.SoMoDs	307.93
Edge.003	TX.ShGrPr	TX.CMxGrP	307.93
Edge.004	Edge.003	OK.ShGrPr	307.93
Edge.005	Edge.004	KS.ShGrPr	307.93
Edge.006	NC.AppMtn	SC.AppMtn	307.93
Edge.007	AZ.SRCOPl	Edge.002	307.93
Edge.008	CA.SoMoDs	Edge.007	307.93
Edge.009	NY.LGLSLP	NY.AtlNFr	307.93
Edge.010	Edge.008	UT.SoMoDs	307.93
Edge.011	Edge.005	TX.ChiDes	307.93
Edge.012	Edge.001	Edge.011	307.93
Edge.013	Edge.009	VT.LGLSLP	307.93
Edge.014	Edge.012	NM.ChiDes	307.93
Edge.015	Edge.010	NM.SRCOPl	307.93
Edge.016	Edge.014	Edge.015	307.93
Edge.017	Edge.016	NV.GrtBas	307.93
Edge.018	Edge.017	TX.OaksPr	307.93
Edge.019	Edge.018	KS.CMxGrP	307.93
Edge.020	Edge.019	NM.ShGrPr	307.93
Edge.021	Edge.013	NY.AppMtn	307.93
Edge.022	Edge.021	NY.NEnMAC	307.93
Edge.023	Edge.020	NM.SMaOcc	307.93
Edge.024	Edge.023	NV.SrNvMt	307.93
Edge.025	Edge.024	UT.GrtBas	307.93
Edge.026	Edge.025	OK.CMxGrP	307.93
Edge.027	Edge.026	TX.GuCoPr	307.93
Edge.028	MD.AppMtn	WV.AppMtn	307.93
Edge.029	Edge.027	UT.SRCOPl	307.93
Edge.030	Edge.029	WY.SRCOPl	307.93
Edge.031	Edge.030	ID.SRCOPl	307.93
Edge.032	Edge.022	VT.AtlNFr	307.93
Edge.033	Edge.031	WY.ShGrPr	307.93
Edge.034	Edge.033	UT.NoRock	307.93
Edge.035	Edge.034	NE.ShGrPr	307.93
Edge.036	Edge.035	SD.ShGrPr	307.93
Edge.037	Edge.036	NE.BdLnPr	307.93
Edge.038	CO.NoRock	Edge.037	307.94
Edge.039	Edge.032	MA.AtlNFr	307.94
Edge.040	Edge.039	MA.AppMtn	307.94
Edge.041	AZ.SoMoDs	Edge.038	307.94
Edge.042	Edge.041	OK.OaksPr	307.94
Edge.043	Edge.042	KS.OaksPr	307.94
Edge.044	Edge.043	OK.ETGrPr	307.94
Edge.045	Edge.040	NJ.AppMtn	307.94
Edge.046	Edge.044	OK.CnHdwd	307.94
Edge.047	Edge.046	KS.CnHdwd	307.94
Edge.048	AR.CnHdwd	Edge.047	307.94
Edge.050	Edge.049	SD.CMxGrP	307.94
Edge.051	Edge.028	KY.AppMtn	307.94
Edge.052	Edge.045	NJ.Pdmont	307.94
Edge.053	Edge.050	ND.BdLnPr	307.94
Edge.054	Edge.053	KS.ETGrPr	307.94
Edge.055	IN.PrHdTr	OH.PrHdTr	307.94
Edge.056	Edge.006	GA.AppMtn	307.94
Edge.057	CO.ShGrPr	Edge.054	307.94
Edge.058	Edge.057	ND.PrPtHo	307.94
Edge.059	Edge.051	VA.AppMtn	307.94
Edge.060	Edge.058	MT.PrPtHo	307.94
Edge.061	VA.SECsPl	VA.NEnMAC	307.93
Edge.062	IL.MSAlVl	KY.MSAlVl	307.93
Edge.063	IL.PrHdTr	WI.PrHdTr	307.93
Edge.064	IA.ETGrPr	MN.ETGrPr	307.93
Edge.065	Edge.064	SD.ETGrPr	307.93
Edge.066	IA.PrPtHo	MN.PrPtHo	307.93
Edge.067	AR.WGCoPl	TX.WGCoPl	307.92
Edge.068	AR.MSAlVl	MO.MSAlVl	307.92
Edge.069	NE.PrPtHo	NE.ETGrPr	307.92
Edge.070	Edge.067	OK.WGCoPl	307.92
Edge.071	KY.CnHdwd	KY.SECsPl	307.92
Edge.072	GA.SECsPl	GA.Pdmont	307.92
Edge.073	Edge.072	SC.Pdmont	307.92
Edge.074	MD.Pdmont	VA.Pdmont	307.92
Edge.075	OH.LGLSLP	PA.LGLSLP	307.92
Edge.076	Edge.075	OH.ETGrPr	307.92
Edge.077	Edge.071	TN.CnHdwd	307.92
Edge.078	AL.AppMtn	AL.Pdmont	307.92
Edge.079	IL.ETGrPr	WI.ETGrPr	307.92
Edge.080	OH.CnHdwd	OH.AppMtn	307.92
Edge.081	Edge.074	PA.Pdmont	307.92
Edge.082	MA.NEnMAC	NH.NEnMAC	307.92
Edge.083	LA.SECsPl	MS.SECsPl	307.92
Edge.084	AL.CnHdwd	AL.SECsPl	307.92
Edge.085	Edge.079	MO.ETGrPr	307.92
Edge.086	DE.Pdmont	DE.NEnMAC	307.92
Edge.087	Edge.083	MS.GuCoPr	307.92
Edge.088	AZ.SMaOcc	AZ.ChiDes	307.92
Edge.089	Edge.087	TN.SECsPl	307.92
Edge.090	CA.NPacRF	CA.SrNvMt	307.92
Edge.091	Edge.080	PA.AppMtn	307.92
Edge.092	CT.NEnMAC	RI.NEnMAC	307.92
Edge.093	Edge.082	Edge.092	307.92
Edge.094	Edge.093	NH.AtlNFr	307.92
Edge.095	Edge.055	IN.ETGrPr	307.92
Edge.096	CT.AppMtn	Edge.094	307.92
Edge.097	CT.AtlNFr	Edge.096	307.92
Edge.098	Edge.097	ME.NEnMAC	307.92

Edge	Stratum 1	Stratum 2	SE
Edge.100	Edge.052	Edge.099	307.92
Edge.101	Edge.056	NC.Pdmont	307.92
Edge.102	Edge.101	TN.AppMtn	307.92
Edge.103	Edge.068	MS.MSAlVl	307.92
Edge.104	Edge.070	Edge.103	307.92
Edge.105	Edge.104	MO.CnHdwd	307.92
Edge.106	Edge.073	Edge.078	307.92
Edge.107	Edge.085	Edge.095	307.92
Edge.108	Edge.100	Edge.102	307.92
Edge.109	Edge.084	Edge.089	307.92
Edge.110	Edge.060	SD.PrPtHo	307.92
Edge.111	CA.CstlCA	Edge.110	307.93
Edge.112	Edge.088	Edge.111	307.93
Edge.113	CO.SRCOPl	Edge.112	307.93
Edge.114	WY.NoRock	WY.BdLnPr	307.93
Edge.115	Edge.062	TN.MSAlVl	307.93
Edge.116	ID.NoRock	OR.NoRock	307.93
Edge.117	Edge.077	IN.CnHdwd	307.93
Edge.118	ID.GrtBas	WA.GrtBas	307.93
Edge.119	Edge.081	Edge.086	307.93
Edge.120	Edge.114	Edge.116	307.93
Edge.121	Edge.118	Edge.120	307.93
Edge.122	CA.GrtBas	Edge.090	307.94
Edge.123	LA.WGCoPl	LA.GuCoPr	307.94
Edge.124	Edge.109	Edge.123	307.94
Edge.125	NJ.NEnMAC	PA.NEnMAC	307.94
Edge.126	Edge.065	Edge.069	307.94
Edge.127	Edge.098	Edge.108	307.94
Edge.128	Edge.063	MN.PrHdTr	307.95
Edge.129	Edge.107	Edge.113	307.95
Edge.130	Edge.124	Edge.129	307.95
Edge.131	Edge.130	NE.CMxGrP	307.96
Edge.132	Edge.117	IL.CnHdwd	307.96

Edge	Stratum 1	Stratum 2	SE
Edge.134	Edge.127	NC.SECsPl	307.97
Edge.135	Edge.119	Edge.125	307.97
Edge.136	Edge.121	MT.BdLnPr	307.98
Edge.137	Edge.066	Edge.126	307.98
Edge.138	MI.ETGrPr	MI.PrHdTr	307.99
Edge.139	Edge.076	Edge.138	307.99
Edge.140	Edge.106	Edge.134	308.01
Edge.141	Edge.131	Edge.140	308.02
Edge.142	Edge.122	Edge.141	308.04
Edge.143	Edge.135	Edge.142	308.06
Edge.144	Edge.136	WA.NoRock	308.09
Edge.145	Edge.115	Edge.133	308.13
Edge.146	Edge.061	MD.NEnMAC	308.18
Edge.147	Edge.143	Edge.144	308.23
Edge.148	Edge.145	Edge.147	308.26
Edge.149	Edge.148	FL.SECsPl	308.32
Edge.150	Edge.139	Edge.149	308.38
Edge.151	Edge.137	Edge.150	308.44
Edge.152	OR.NPacRF	OR.GrtBas	308.51
Edge.153	Edge.151	SC.SECsPl	308.60
Edge.154	Edge.153	MT.NoRock	308.77
Edge.155	Edge.128	IA.PrHdTr	308.94
Edge.156	Edge.154	LA.MSAlVl	309.26
Edge.157	Edge.155	MN.BoHdTr	309.62
Edge.158	Edge.152	Edge.156	310.48
Edge.159	MI.BoHdTr	WI.BoHdTr	312.06
Edge.160	Edge.158	ME.AtlNFr	313.69
Edge.161	Edge.157	Edge.160	315.45
Edge.162	Edge.161	FL.PensFL	318.13
Edge.163	Edge.146	Edge.162	321.03
Edge.164	Edge.163	WA.NPacRF	330.09
Edge.165	Edge.159	Edge.164	339.12

Table 2. Summary statistics of State-BCRs with the number of nests, plot, density per 10 km x 10 km, and standard error of the density. Density is determined from nest list nests. The larger, higher density strata will be sampled much more intensely. It is also encouraging that portions of BCRs in different States have similar plot densities. This suggests that the BCR stratification is effective.

State	Bird Conservation Region	Nests	Plots	Density	SE
Wisconsin	Boreal Hardwood Transition	1635	481	3.40	4.730
Washington	Northern Pacific Rainforest	2002	612	3.27	5.635
Virginia	Southeastern Coastal Plain	473	189	2.50	4.203
Virginia	New England/Mid-Atlantic Coast	159	75	2.12	3.251
Maryland	New England/Mid-Atlantic Coast	363	200	1.82	2.624
Iowa	Prairie Hardwood Transition	129	73	1.77	2.880
Michigan	Boreal Hardwood Transition	1654	1007	1.64	2.806
Illinois	Mississippi Alluvial Valley	6	4	1.50	1.732
Florida	Peninsular Florida	1513	1105	1.37	2.799
Kentucky	Mississippi Alluvial Valley	13	11	1.18	0.982
Minnesota	Boreal Hardwood Transition	1084	937	1.16	2.165
Maine	Atlantic Northern Forest	1055	919	1.15	2.909
Pennsylvania	New England/Mid-Atlantic Coast	2	2	1.00	0.000
Oregon	Northern Pacific Rainforest	657	851	0.77	2.364
Louisiana	Mississippi Alluvial Valley	315	410	0.77	2.333
Tennessee	Mississippi Alluvial Valley	16	21	0.76	1.513
Michigan	Eastern Tallgrass Prairie	31	46	0.67	2.023
Minnesota	Prairie Hardwood Transition	273	497	0.55	1.216
Oregon	Great Basin	529	1156	0.46	2.818
Wisconsin	Prairie Hardwood Transition	446	998	0.45	1.363
Illinois	Prairie Hardwood Transition	13	32	0.41	1.012
Washington	Northern Rockies	93	242	0.38	0.996
South Carolina	Southeastern Coastal Plain	206	543	0.38	1.040
Montana	Northern Rockies	503	1596	0.32	1.012
Florida	Southeastern Coastal Plain	167	584	0.29	0.794
New Jersey	New England/Mid-Atlantic Coast	42	147	0.29	0.672
South Dakota	Eastern Tallgrass Prairie	9	33	0.27	0.944
Nevada	Sierra Nevada	2	8	0.25	0.463
Illinois	Central Hardwoods	42	183	0.23	0.622
Michigan	Prairie Hardwood Transition	139	611	0.23	1.119
Iowa	Eastern Tallgrass Prairie	245	1082	0.23	0.955
Connecticut	Atlantic Northern Forest	2	9	0.22	0.441
Minnesota	Eastern Tallgrass Prairie	22	111	0.20	0.989
Ohio	Eastern Tallgrass Prairie	94	527	0.18	0.742
Pennsylvania	Lower Great Lakes/ St. Lawrence Plain	15	89	0.17	0.482
California	Great Basin	62	400	0.16	0.471
Virginia	Piedmont	65	421	0.15	0.815

State	Bird Conservation Region	Nests	Plots	Density	SE
Nebraska	Eastern Tallgrass Prairie	34	221	0.15	0.480
Missouri	Mississippi Alluvial Valley	15	102	0.15	0.534
Nebraska	Prairie Potholes	23	159	0.14	0.488
New Hampshire	New England/Mid-Atlantic Coast	6	42	0.14	0.417
Ohio	Lower Great Lakes/ St. Lawrence Plain	32	230	0.14	0.416
Indiana	Central Hardwoods	49	355	0.14	0.391
Iowa	Prairie Potholes	42	308	0.14	0.758
Montana	Badlands And Prairies	186	1395	0.13	0.681
Arkansas	Mississippi Alluvial Valley	52	395	0.13	0.573
Kentucky	Southeastern Coastal Plain	5	39	0.13	0.522
Maryland	Piedmont	9	71	0.13	0.412
South Carolina	Piedmont	34	273	0.12	0.492
Minnesota	Prairie Potholes	81	699	0.12	0.472
Idaho	Northern Rockies	122	1059	0.12	0.458
Georgia	Southeastern Coastal Plain	109	949	0.11	0.491
Georgia	Piedmont	48	424	0.11	0.452
Colorado	Northern Rockies	10	92	0.11	0.346
Pennsylvania	Piedmont	13	121	0.11	0.337
Louisiana	Gulf Coastal Prairie	39	367	0.11	0.545
California	Sierra Nevada	55	520	0.11	0.459
Oklahoma	West Gulf Coastal Plain/Ouachitas	29	295	0.10	0.445
Arkansas	West Gulf Coastal Plain/Ouachitas	63	650	0.10	0.435
Texas	West Gulf Coastal Plain/Ouachitas	67	712	0.09	0.676
Missouri	Central Hardwoods	79	871	0.09	0.345
Kentucky	Central Hardwoods	62	699	0.09	0.536
North Carolina	Southeastern Coastal Plain	63	714	0.09	0.308
Alabama	Appalachian Mountains	32	374	0.09	0.363
Washington	Great Basin	86	1006	0.09	0.410
Mississippi	Mississippi Alluvial Valley	17	201	0.08	0.397
Oklahoma	Eastern Tallgrass Prairie	13	154	0.08	0.322
Massachusetts	New England/Mid-Atlantic Coast	16	201	0.08	0.366
New Jersey	Appalachian Mountains	3	38	0.08	0.273
California	Northern Pacific Rainforest	38	485	0.08	0.355
South Dakota	Central Mixed Grass Prairie	1	13	0.08	0.277
Wyoming	Northern Rockies	127	1651	0.08	0.410
New Jersey	Piedmont	3	40	0.08	0.267
Tennessee	Central Hardwoods	30	403	0.07	0.330
Alabama	Piedmont	4	55	0.07	0.262
Utah	Northern Rockies	2	28	0.07	0.378
Oregon	Northern Rockies	38	541	0.07	0.378
Connecticut	New England/Mid-Atlantic Coast	8	118	0.07	0.252
Wisconsin	Eastern Tallgrass Prairie	1	16	0.06	0.250
Nebraska	Central Mixed Grass Prairie	73	1220	0.06	0.247

State	Bird Conservation Region	Nests	Plots	Density	SE
New Hampshire	Atlantic Northern Forest	11	200	0.06	0.287
Illinois	Eastern Tallgrass Prairie	66	1238	0.05	0.288
Alabama	Southeastern Coastal Plain	43	845	0.05	0.250
Ohio	Central Hardwoods	1	20	0.05	0.224
Tennessee	Appalachian Mountains	19	412	0.05	0.221
Idaho	Great Basin	50	1100	0.05	0.269
Missouri	Eastern Tallgrass Prairie	35	825	0.04	0.264
Wyoming	Badlands And Prairies	27	646	0.04	0.249
Oklahoma	Central Hardwoods	3	75	0.04	0.197
North Carolina	Piedmont	17	458	0.04	0.231
Alabama	Central Hardwoods	3	82	0.04	0.189
Ohio	Appalachian Mountains	11	310	0.04	0.202
Massachusetts	Atlantic Northern Forest	2	58	0.03	0.184
South Dakota	Prairie Potholes	28	880	0.03	0.205
Louisiana	West Gulf Coastal Plain/Ouachitas	15	474	0.03	0.175
Oklahoma	Oaks And Prairies	13	418	0.03	0.199
North Dakota	Badlands And Prairies	17	549	0.03	0.265
Arizona	Sierra Madre Occidental	30	972	0.03	0.179
Colorado	Southern Rockies/Colorado Plateau	45	1473	0.03	0.184
Kansas	Eastern Tallgrass Prairie	20	662	0.03	0.180
Arkansas	Central Hardwoods	10	332	0.03	0.256
Indiana	Eastern Tallgrass Prairie	13	448	0.03	0.168
Montana	Prairie Potholes	24	869	0.03	0.248
California	Coastal California	46	1773	0.03	0.263
Mississippi	Southeastern Coastal Plain	27	1047	0.03	0.219
Nebraska	Shortgrass Prairie	9	350	0.03	0.159
Louisiana	Southeastern Coastal Plain	2	78	0.03	0.159
Colorado	Shortgrass Prairie	28	1129	0.02	0.167
Rhode Island	New England/Mid-Atlantic Coast	1	42	0.02	0.154
North Dakota	Prairie Potholes	31	1316	0.02	0.256
Maryland	Appalachian Mountains	1	46	0.02	0.147
Pennsylvania	Appalachian Mountains	20	966	0.02	0.142
South Dakota	Badlands And Prairies	21	1037	0.02	0.148
Nebraska	Badlands And Prairies	1	52	0.02	0.139
Georgia	Appalachian Mountains	3	162	0.02	0.135
Delaware	New England/Mid-Atlantic Coast	1	57	0.02	0.132
Kentucky	Appalachian Mountains	5	302	0.02	0.190
Virginia	Appalachian Mountains	6	401	0.01	0.122
Arizona	Sonoran And Mojave Deserts	15	1060	0.01	0.159
Tennessee	Southeastern Coastal Plain	3	251	0.01	0.109
Texas	Gulf Coastal Prairie	5	521	0.01	0.158
Vermont	Atlantic Northern Forest	2	211	0.01	0.097
Wyoming	Shortgrass Prairie	1	126	0.01	0.089

State	Bird Conservation Region	Nests	Plots	Density	SE
Indiana	Prairie Hardwood Transition	1	133	0.01	0.087
New Mexico	Sierra Madre Occidental	2	285	0.01	0.084
Utah	Southern Rockies/Colorado Plateau	9	1320	0.01	0.113
Oklahoma	Central Mixed Grass Prairie	4	757	0.01	0.073
Utah	Great Basin	3	851	0.00	0.059
New Mexico	Shortgrass Prairie	2	677	0.00	0.054
New York	Appalachian Mountains	1	379	0.00	0.051
Kansas	Central Mixed Grass Prairie	2	1102	0.00	0.043
Texas	Oaks And Prairies	2	1521	0.00	0.036
New Mexico	Chihuahuan Desert	1	878	0.00	0.034
Nevada	Great Basin	2	2466	0.00	0.028
New Mexico	Southern Rockies/Colorado Plateau	1	1326	0.00	0.027
West Virginia	Appalachian Mountains	0	628	0.00	0.000
Delaware	Piedmont	0	1	0.00	0.000
Arizona	Chihuahuan Desert	0	12	0.00	0.000
Texas	Chihuahuan Desert	0	1044	0.00	0.000
Utah	Sonoran And Mojave Deserts	0	4	0.00	0.000
Connecticut	Appalachian Mountains	0	11	0.00	0.000
Texas	Shortgrass Prairie	0	1047	0.00	0.000
Arizona	Southern Rockies/Colorado Plateau	0	937	0.00	0.000
Vermont	Lower Great Lakes/ St. Lawrence Plain	0	45	0.00	0.000
California	Sonoran And Mojave Deserts	0	1056	0.00	0.000
Texas	Tamaulipan Brushlands	0	719	0.00	0.000
Texas	Edwards Plateau	0	588	0.00	0.000
New York	New England/Mid-Atlantic Coast	0	84	0.00	0.000
Mississippi	Gulf Coastal Prairie	0	3	0.00	0.000
Wyoming	Southern Rockies/Colorado Plateau	0	108	0.00	0.000
Massachusetts	Appalachian Mountains	0	7	0.00	0.000
Nevada	Sonoran And Mojave Deserts	0	389	0.00	0.000
Nevada	Southern Rockies/Colorado Plateau	0	3	0.00	0.000
Maine	New England/Mid-Atlantic Coast	0	30	0.00	0.000
New York	Atlantic Northern Forest	0	294	0.00	0.000
Kansas	Shortgrass Prairie	0	372	0.00	0.000
Kansas	Oaks And Prairies	0	3	0.00	0.000
Kansas	Central Hardwoods	0	1	0.00	0.000
Texas	Central Mixed Grass Prairie	0	888	0.00	0.000
North Carolina	Appalachian Mountains	0	213	0.00	0.000
Ohio	Prairie Hardwood Transition	0	1	0.00	0.000
Oklahoma	Shortgrass Prairie	0	113	0.00	0.000
Idaho	Southern Rockies/Colorado Plateau	0	6	0.00	0.000
South Carolina	Appalachian Mountains	0	19	0.00	0.000
South Dakota	Shortgrass Prairie	0	23	0.00	0.000
New York	Lower Great Lakes/ St. Lawrence Plain	0	581	0.00	0.000

Table 3. The range of percent of the total sample allocated to both the list and area frame. The percentages are those within each frame. The first line indicates the allocation of the flight miles (cost) to each frame. The percentages are reversed for the area frame to emphasize that resources are the complements of each other. The variation in list coverage causes a large variation in allocation to each frame. Improved list coverage results in increased allocation to the list frame.

Stratum	**BCR Name**	**List**	**Area**
FL	Peninsular Florida	2.5- 8.8	7.8-2.1
IA	Prairie Hardwood Transition	0.2- 0.6	0.8-0.2
IL	Prairie Hardwood Transition	0.0- 0.1	0.1-0.0
LA	Mississippi Alluvial Valley	0.5- 1.9	3.0-0.8
Low		5.2-18.5	16.1-1.8
MD	New England/Mid-Atlantic Coast	0.6- 2.3	1.7-0.4
ME	Atlantic Northern Forest	1.8- 6.4	7.5-0.9
MI	Boreal Hardwood Transition	2.1- 7.6	7.1-1.8
MN	Boreal Hardwood Transition	1.8- 6.4	5.2-1.3
MN	Prairie Hardwood Transition	0.9- 3.2	2.1-0.5
MT	Northern Rockies	0.9- 3.1	3.5-0.9
OR	Great Basin	0.4- 1.3	4.8-1.3
OR	Northern Pacific Rainforest	0.8- 2.8	3.5-0.9
SC	Southeastern Coastal Plain	0.6- 2.3	2.1-0.6
Trace		0.0- 0.0	0.3-0.1
VA	New England/Mid-Atlantic Coast	0.3- 1.2	0.8-0.2
VA	Southeastern Coastal Plain	0.5- 1.7	2.4-0.6
WA	Northern Pacific Rainforest	1.0- 3.7	5.3-1.4
WI	Boreal Hardwood Transition	1.4- 4.9	5.6-1.4
WI	Prairie Hardwood Transition	1.0- 3.6	4.2-1.1
	Percent allocation to each frame	23-80	77-20

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Table 4. Flight miles (thousands) needed to obtain a sample with given precision requirements for an estimate of the total for the four survey options (DF is dual-frame). The standard errors are those needed to obtain the required effect size, power, and significance level requirements. The list-only survey is not continued beyond the first survey requirements because even censusing the list does not reduce the bias due to incomplete coverage. Thus, a list-only survey cannot meet any of the survey requirements.

Precision	Power	Sig-Lvl	SE	List	Plot	DF	Comb-DF
0.25	0.8	0.10	1,133	16	186	40	39
0.25	0.8	0.05	1,006		230	46	45
0.25	0.8	0.01	825		327	59	58
0.25	0.9	0.10	963		249	48	48
0.25	0.9	0.05	869		298	55	54
0.25	0.9	0.01	731		402	70	69
0.15	0.8	0.10	680		453	78	77
0.15	0.8	0.05	604		550	94	93
0.15	0.8	0.01	495		745	129	127
0.15	0.9	0.10	578		589	101	99
0.15	0.9	0.05	522		689	119	117
0.15	0.9	0.01	438		883	158	155
0.1	0.8	0.10	453		843	149	147
0.1	0.8	0.05	402		989	181	178
0.1	0.8	0.01	330		1,252	251	247
0.1	0.9	0.10	385		1,044	195	191
0.1	0.9	0.05	348		1,180	230	226
0.1	0.9	0.01	292		1,419	305	300

Table 5. The list and area columns show the mean and (range) of the sample sizes for each stratum for the proposed survey goal. Results are based on simulated list coverages and percent occupied nests because we did not have information for each stratum. Note that part of the list sample will be from the area plots that have list nests. List nests in the area plots become part of the list sample.

Stratum	BCR Name	List	Area
FL	Peninsular Florida	14 (8-24)	18 (2-61)
IA	Prairie Hardwood Transition	1 (1- 2)	2 (1- 7)
IL	Prairie Hardwood Transition	1 (1- 1)	1 (1- 2)
LA	Mississippi Alluvial Valley	3 (2- 6)	7 (1-26)
Low		28 (16-49)	29 (2-94)
MD	New England/Mid-Atlantic Coast	4 (2- 6)	4 (1-14)
ME	Atlantic Northern Forest	10 (6-17)	17 (2-62)
MI	Boreal Hardwood Transition	12 (7-20)	16 (2-53)
MN	Boreal Hardwood Transition	10 (6-17)	12 (2-42)
MN	Prairie Hardwood Transition	5 (3- 9)	5 (1-18)
MT	Northern Rockies	5 (3- 9)	8 (1-29)
OR	Great Basin	2 (2- 4)	11 (2-41)
OR	Northern Pacific Rainforest	5 (3- 8)	8 (1-29)
SC	Southeastern Coastal Plain	4 (2- 6)	5 (1-19)
Trace		1 (1- 1)	1 (1- 3)
VA	New England/Mid-Atlantic Coast	2 (1- 4)	2 (1- 7)
VA	Southeastern Coastal Plain	3 (2- 5)	6 (1-20)
WA	Northern Pacific Rainforest	6 (4-10)	12 (2-43)
WI	Boreal Hardwood Transition	8 (5-13)	12 (2-43)
WI	Prairie Hardwood Transition	6 (4-10)	10 (2-37)

Figures

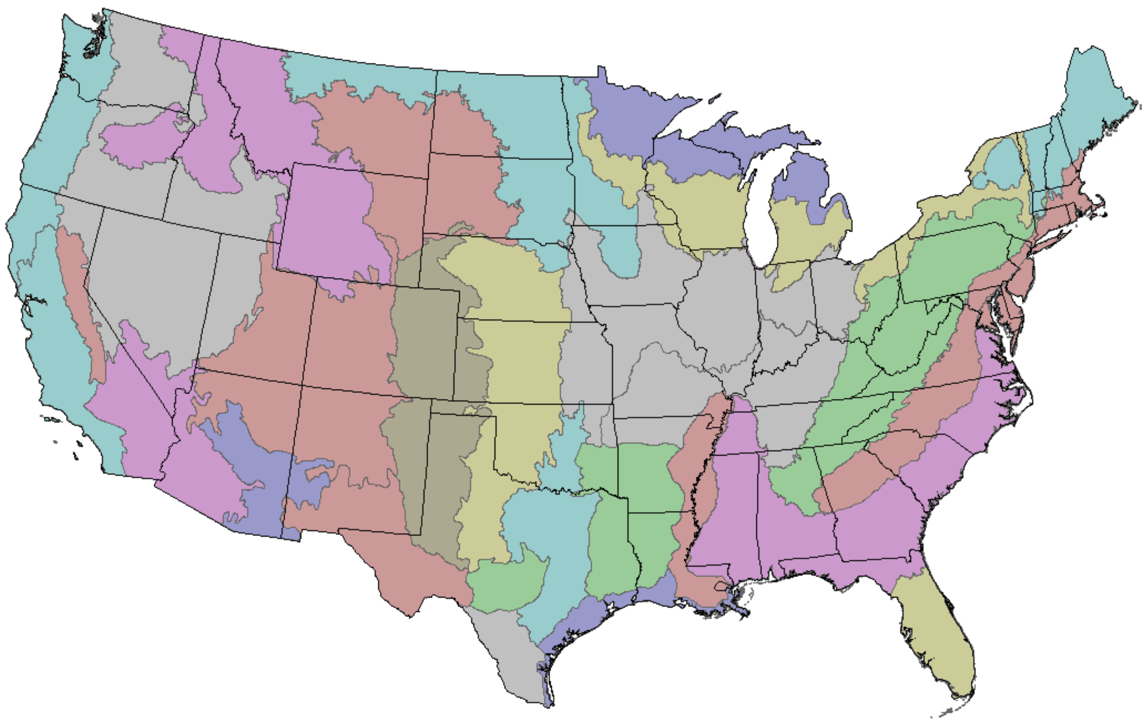


Figure 1: State boundaries and Bird Conservation Regions (BCRs) in the contiguousUnited States

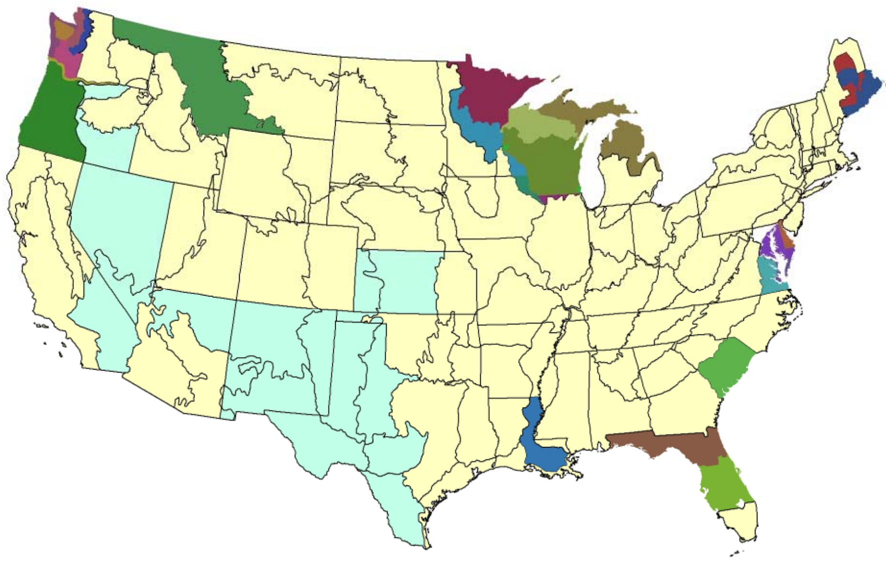


Figure 2: Strata after aggregating adjacent strata with similar nest densities. The aggregate strata are: Trace with only 14 nests in the stratum (light green); Low (the result of aggregating the similar low density strata, yellow); Washington and Oregon Northern Pacific Rainforest; Washington, Idaho, and Montana Northern Rockies; North and Central Florida (South Florida is part of the Low stratum even though it is not adjacent to it); Iowa, Illinois and Wisconsin Prairie Hardwood Transition; Minnesota, Wisconsin, and Michigan Boreal Hardwood Transition; Mississippi Alluvial Valley in Louisiana; South Carolina Southeastern Coastal Plain; Delaware; Virginia and Maryland New England/Mid-Atlantic Coast; Virginia Southeastern Coastal Plain; and two Maine strata.

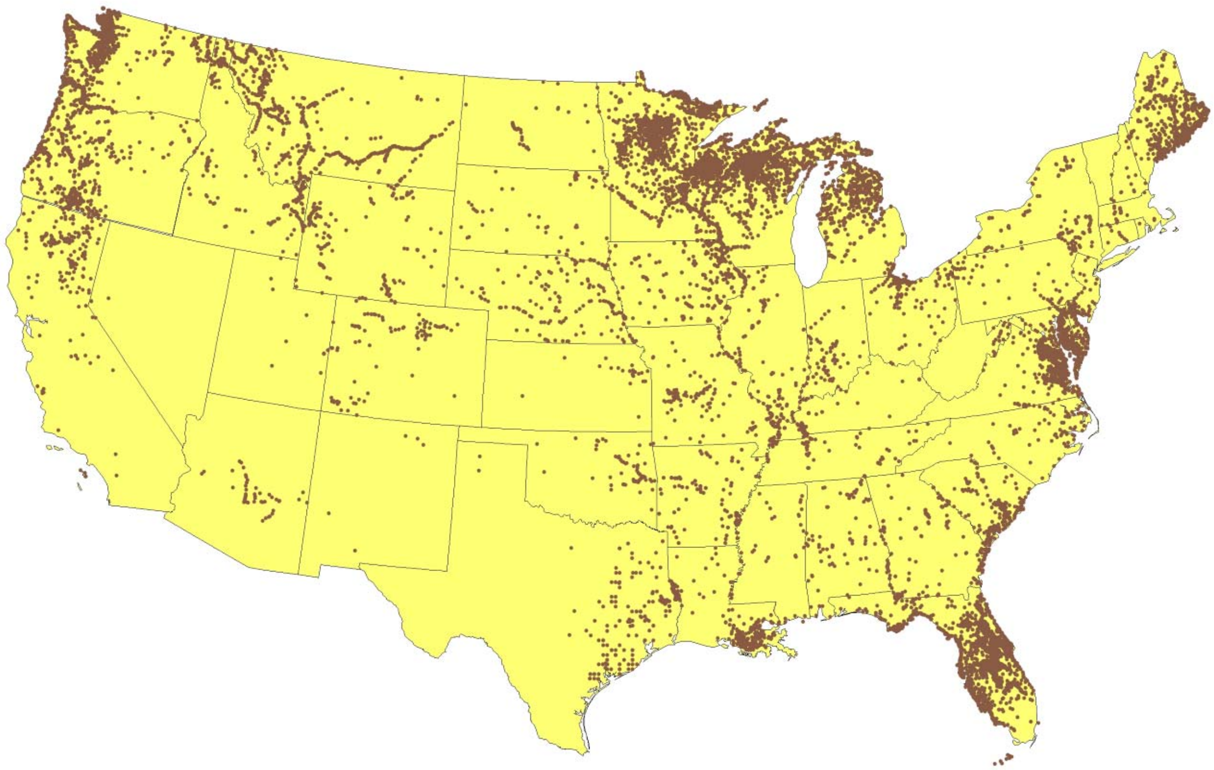


Figure 3: Distribution of bald eagle nests as determined from 2004-2006 State lists.

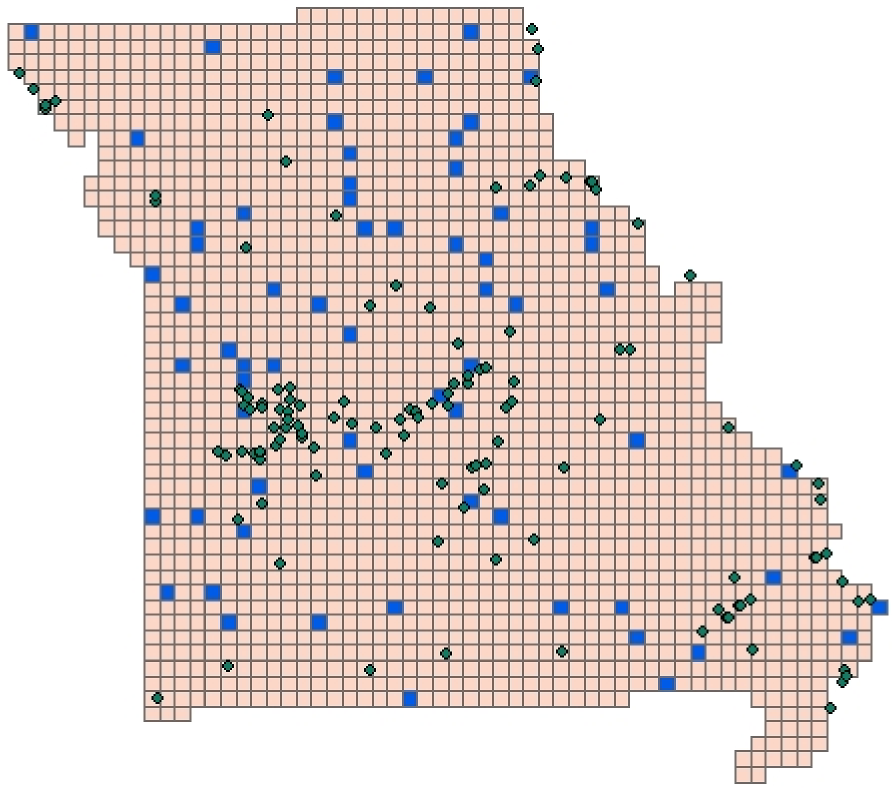


Figure 4: Missouri area frame consisting of 10 km square plots. Shaded squares are the sample plots selected. Diamonds are the list nests selected.

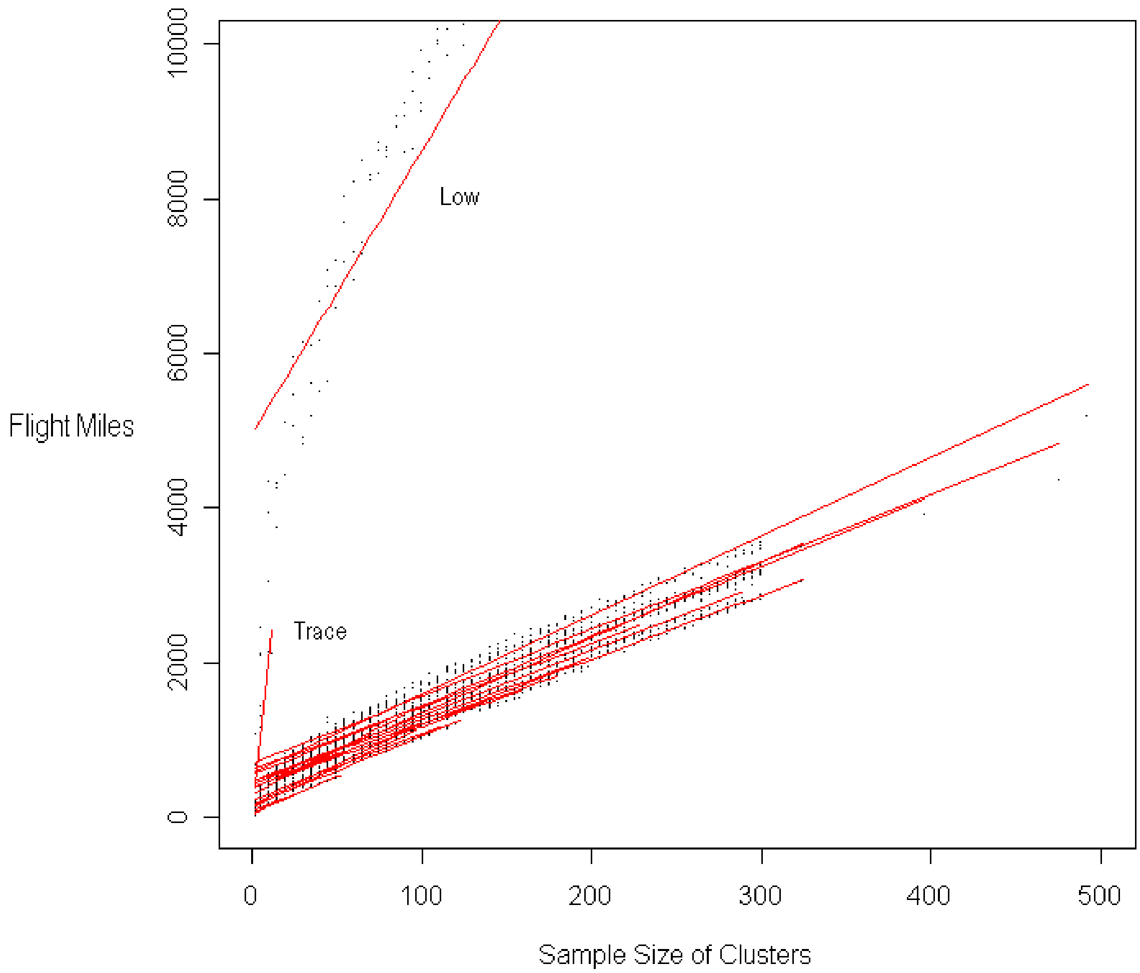


Figure 5: Number of miles needed to fly samples of a given number of list-plot clusters. Each line represents an aggregate stratum. Low and Trace are aggregate strata with low densities of bald eagles.

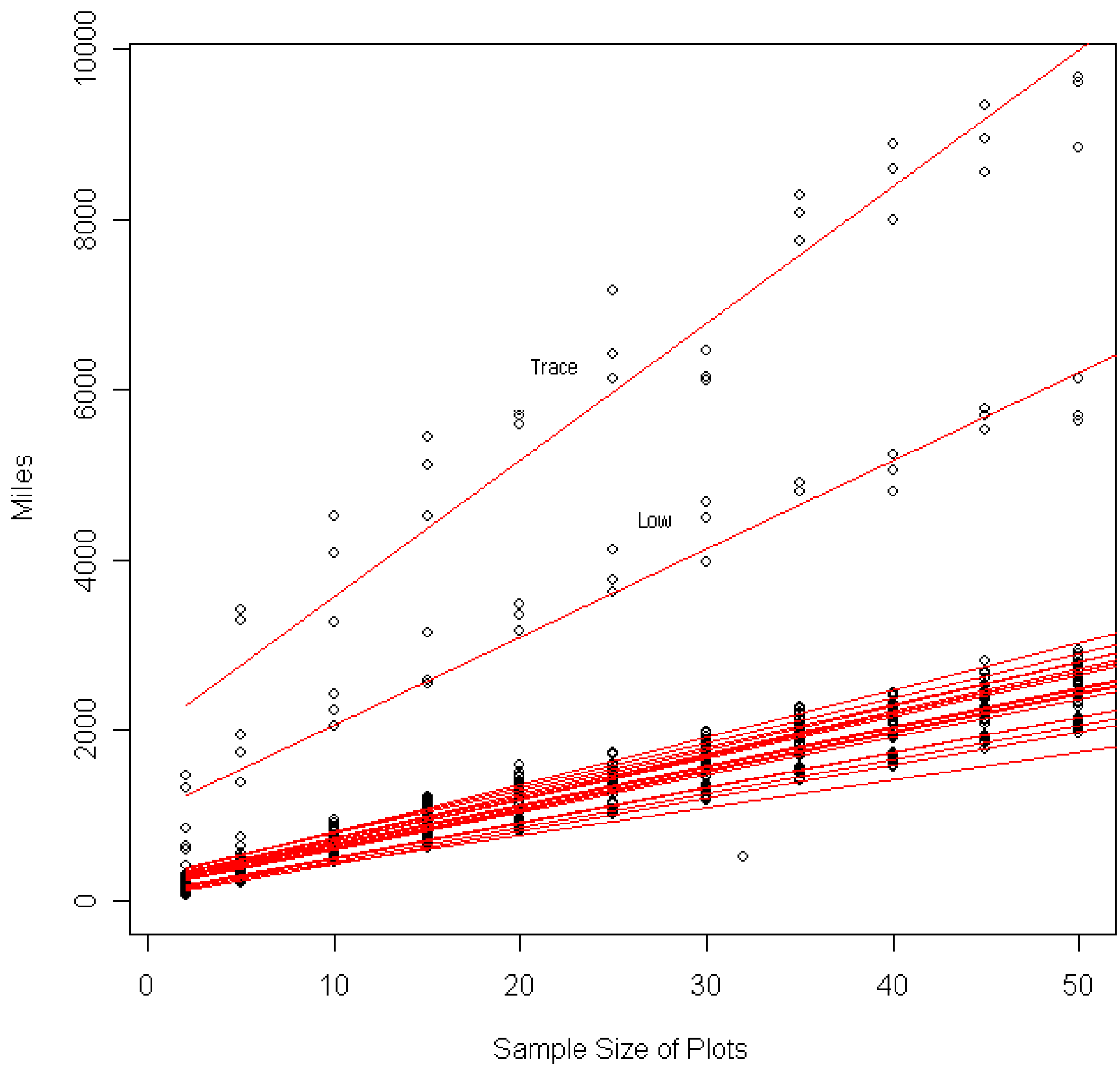


Figure 6: Number of miles needed to fly samples of a given number of plots. Each line represents an aggregate stratum. Low and Trace are aggregate strata with low densities of bald eagles.

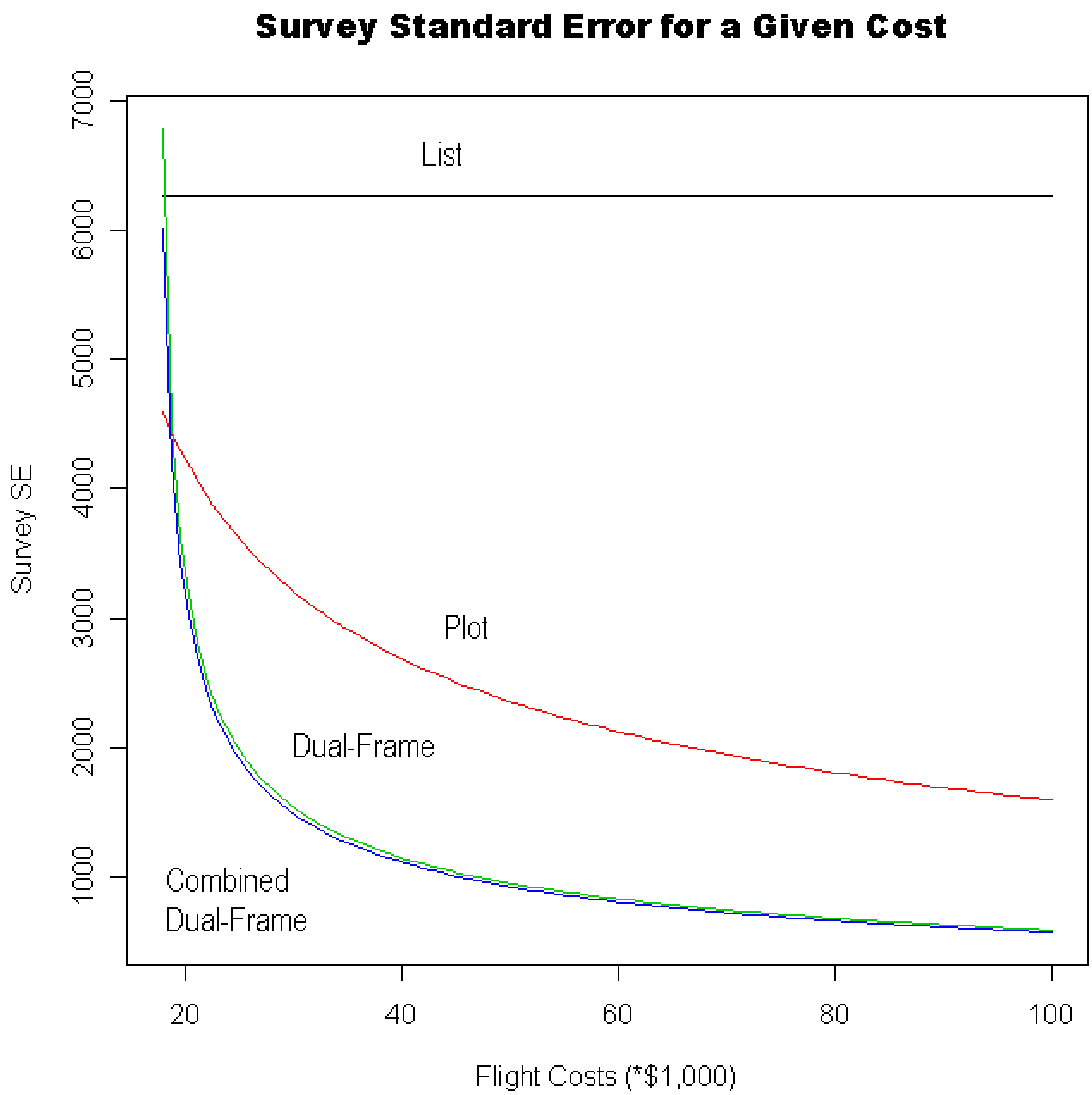


Figure 7: The standard error for a given flight miles for each sample design. The list-only design standard error is a mean square error that includes the bias squared. This bias is the major source of error and cannot be reduced by any amount of sampling, not even a census of the nest list.

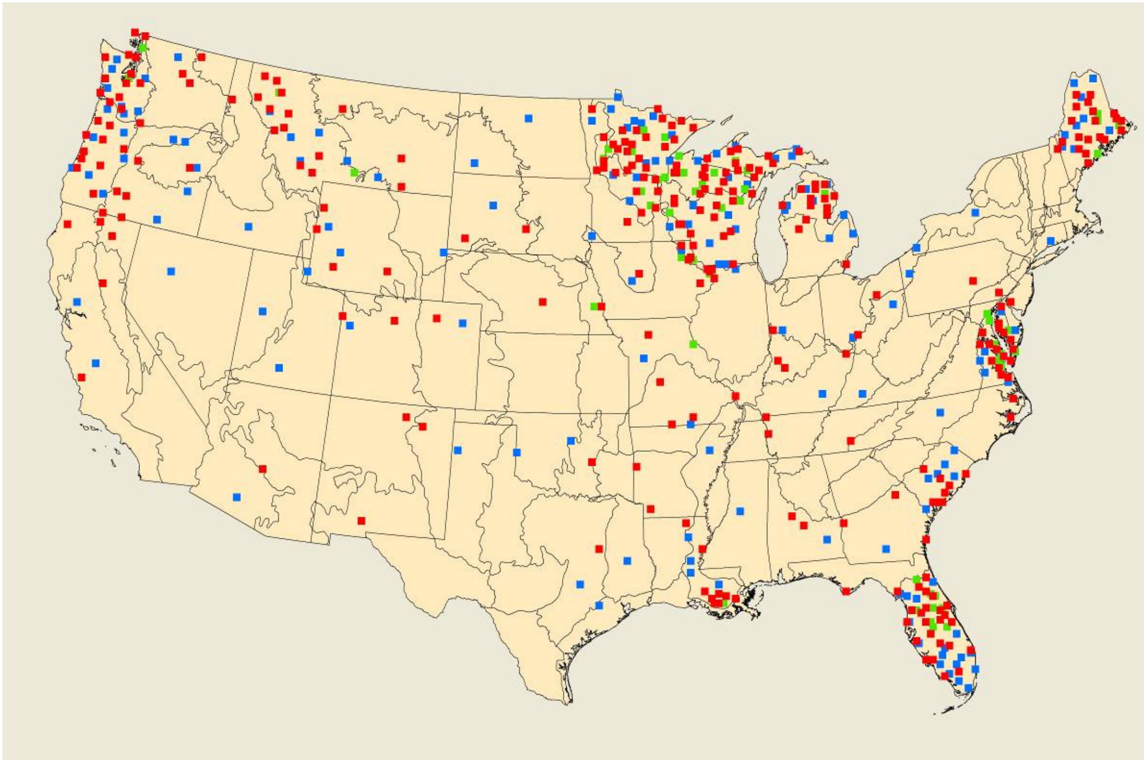


Figure 8: An example sample selection with sample sizes for the proposted survey requirements. The red samples are the list plot clusters, the blue are the area plots, and the green are the area plots also with the list nests. The sample sizes are not fixed for each State, only for the 20 strata. More information on the proportion of occupied nests, list coverage in each stratum and efficient ways to sample the Low and Trace strata will modify the allocation to better target sampling.

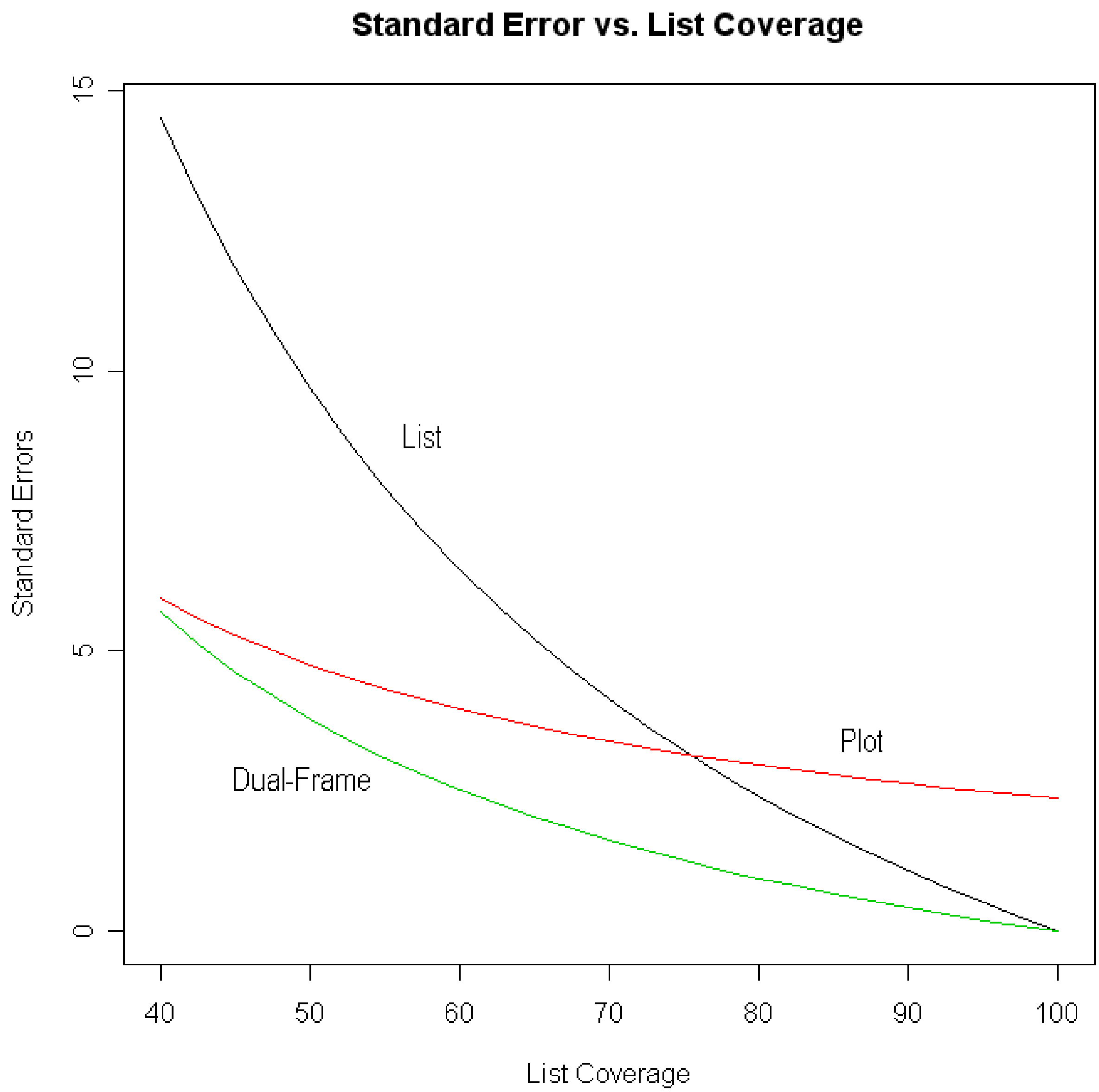


Figure 9: Standard errors for a given list coverage for each of the survey design options. These were calculated given the survey requirements are the stated survey goals. Note that when the list coverage is 40 percent the dual-frame design is equivalent to the plot-only design. The list-only design converges with the dual-frame as the list coverage approaches 100 percent. Unfortunately with the list-only design, there is no measure of actual measure of list coverage.

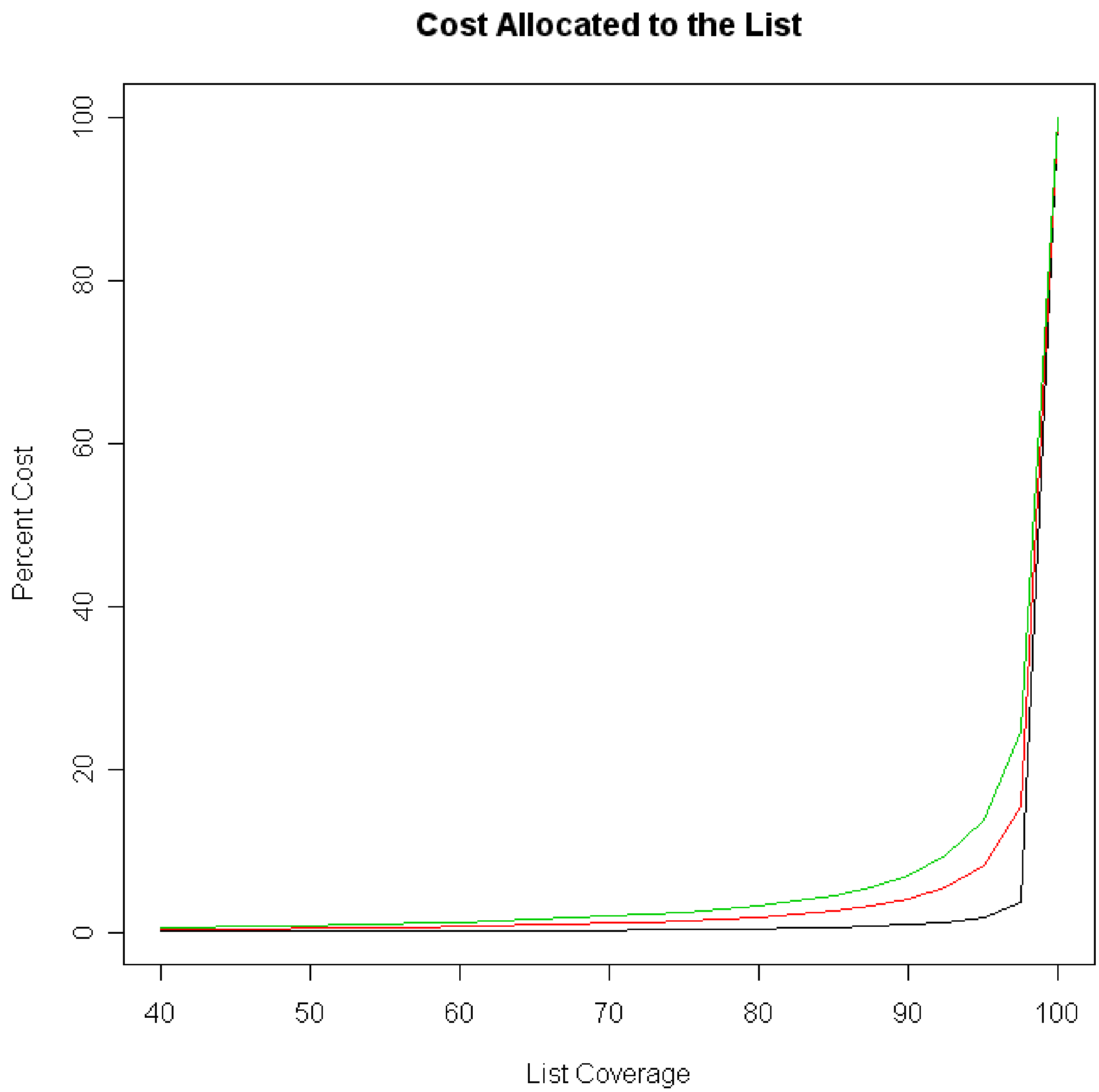


Figure 10: Proportion of the flight miles allocated to the list frame vs. the area frame given different list coverages. As the cost of the area frame increases and/or the variability decreases, more is allocated to list-frame as the two quicker rising curves show.

Appendix 2

Bald Eagle Post-delisting Monitoring Standard Operating Procedures
Based on the Maine Bald Eagle Pilot Project
by John R. Sauer and Mark C. Otto

Introduction

There are three potential types of aerial survey plots for the bald eagle post-delisting monitoring survey: list, area, and combined plots.

List plots will be sampled if the State has not recently updated its nest list. In such cases, the status of all known nests will need to be observed and recorded for selected list plots.

Potential bald eagle habitat in **area plots** will be scanned for any nests and on- or off-the-nest bald eagles. The dual observer protocol described below is used for area plots to assess observer detection.

Combined plots are area plots that also contain known list nests. These plots will first be flown as area plots (i.e. scan habitat for any nests using dual observer protocol), and then subsequently flown as list plots (i.e. return flight through plot to record status of all known nests). To avoid the potential for observers to search for known nests during the area plot portion of the survey, pilots and observers should not know which area plots are actually combined plots until after the area plot portion of the survey is complete (i.e. they complete the area plot survey and then turn over the map to reveal known nest locations).

Area plot sampling requires that observers conduct independent counting in silence. Communication among observers waits until after an observation has been passed by the plane to identify what observers actually saw: the bird or nest. For each observation, information on who saw it and who did not see it should be recorded. If one of the counters is only participating in some of the data collection, they should be recorded as "not counting" for observations that occurred when they were not counting.

This Standard Operating Procedure (SOP) is written assuming the rear seat observer is on the right side of the plane. Sitting behind the pilot is acceptable if needed, but it is preferable that the rear-seat observer be on the right side of the plane and count in tandem with the front-seat observer. In either case, the plane should be oriented, so the observers in tandem (front-back seat) are on the shoreward side or the side with better eagle habitat. Orienting the plane this way will facilitate counting in critical eagle habitat but should only be done when it does not require undue maneuvering or a safety hazard. To maintain independence of counts, the pilot should not orient the plane to make it easier for the rear observer to see eagles that the pilot has seen. If necessary, a screen should be added to prevent observers from seeing each other during counting. Also, front seat observers should not point out sightings as they occur so as to keep the observation independent. The observers sitting in tandem will implement the double observer counting procedure.

Observations will not be noted by either observer until it is clear that the other observer has “missed” the observation. For the front-seat observer, this position should be when their view of the observation becomes obscured, which we define as an angle of 135 degrees behind the observer. For the back-seat observer, this position will be after the observation passes 90 degrees (opposite their position). At this point, the observation will be described by the observer who made the observation, and it will be noted who among the crew (front-seat observer, rear-seat observer, pilot) saw the observation (of a single, pair, nest, juvenile). Note any discrepancies in the identifications of sightings. If needed, the aircraft can bank to verify the observation and collect additional information. For accurate GPS observations it is useful to circle before taking locations.

If possible, the pilot will also be included as a third participant in the observations, although in interior transects the pilot will collect independent data (see below).

Maps of area plots and list plots should be studied before the survey flights to plan potential flight routes. This will minimize potential confusion and maximize observation time during the survey.

Information to be Collected

Information to be collected includes: nest, adult or immature eagle observations; which observers were looking, seeing, or missed the sighting; activity of individual birds (flying, perching, on nest incubating or not incubating); and nest status, (see sample data sheet, p. 61). A “capture history” format will be used to record whether each of the three observers actually saw an observation. The field will have three, single-character values that reflect the status of the observation for each of the three observers: pilot, front-seat observer, and rear-seat observer respectively. Status from an observer will be indicated as a “0” for not seen, a “1” for seen, and an “x” for not observing. For example, the entry "x01" would be entered when the pilot was not observing, the front observer did not see the observation, but it was seen by the rear observer. Observations by the pilot that were recorded on the left side of the aircraft would be coded “1xx.” Observations made by the dual observers when the pilot was not attempting to observe on the right side of the place would be either “x10,” “x01,” or “x11,” where x01 represents pilot not observing, not seen by front observer, but seen by rear-seat observer.

Information to be collected has been coded into the data entry program (Table 1). Eagle ages and nest condition are to be entered as separate species codes: adult, immature, and unknown for off the nest, and empty, incubating, occupied (but not incubating), eggs, or eaglets for a nest sighting. Location off the nest can be flying, perching, or on nest, and the location on the nest identifies the nest tree type to more easily find the nest again. The locations can be tailored to the survey area. Examples are pine, spruce, conifer, deciduous, ground, or not applicable (na). In Florida, we added cell phone tower and stadium lights. Information may be included in the comment field such as approximate height of nest (5 m increments), nest contents (fresh material, egg shell fragments), or whether the nest was seen while cruising or during a secondary search. Eagles on nests should be recorded with the nest record, but eagles observed separately from the nests should be recorded separately. Any ambiguity in recording eagles at nests should be discussed in the comments field of the record.

Table 1. Variables and acceptable values for the data entry files.

Year	2004	Location	fly
Month	4-5	(off nest)	perch
Day	1-31		na
Pilot	*Consistent*		
FObserver	*initials*	Location	pine
RObserver		(on nest)	spruce
Plot	*Number*		conifer
CapHist	001		deciduous
	010		ground
	011		na
	01x		
	0x1		
	100		
	101		
	10x		
	110		
	111		

The `Record` and `Transcribe` programs automatically record time and location (latitude and longitude) from the GPS used. The time and location are recorded both in the track files describing the flight path and in the observation files described above for each observation. The flight path information is important in reconciling area observations with known nests and to determine how effectively the plots were searched. If another method of recording the transcribing is used, these should also be part of the data collected. Instructions on using `Record` and `Transcribe` are in BPManual.pdf special instructions for these surveys are included in FileInstructions.txt.

Survey Notes

Observers and pilots should make a text file of notes about weather, general observations, problems in the protocol, and ideas how to improve the survey. Unusual seating positions (pilot not in the left front seat, etc.) and who is recording the data should also be noted. Observations for each day can be made in the same file. The file should include the time zone used to record the times and the datum the GPS is recording the locations.

Recording Procedures

The front-right observer will reconcile and record observations for all three observers during the flight. Jack Hodges program, or a predetermined alternative, will be used to record and transcribe the sightings. At the beginning of the flight, give the date and weather. When entering and leaving each plot, say "beginning" or "ending list or area plot" and give the plot identification number. For contiguous plots say "leaving [list or area] [number] and entering [list or area] [number]" every time the plot changes (or in Combined plots, when the search changes from searching the habitat to checking status of known nests). The codes recorded will be as follows in Table 2:

Table 2: Codes for Jack Hodges program to record sightings

Code
ADULT
IMMATURE
UNKNOWN
REPAIRED
UNREPAIRED
EMPTY
DESTROYED
NOTFOUND
INCUBATING
OCCUPIED
EGGS
EAGLET
BEGAREA
ENDAREA
BEGLIST
ENDLIST
GPS
COMMENT

The first three codes are for sightings off the nest: ADULT, IMMATURE, UNKNOWN. The next nine are nest condition codes. REPAIRED is a nest with fresh sticks or boughs on top (sign of an occupied nest), UNREPAIRED if not. If the nest condition cannot be determined, use EMPTY. INCUBATING, OCCUPIED, EGGS, EAGLET all are codes of an occupied nest. Put number of adults, eggs or fledglings, nest contents not described by the codes, experienced observer knew location of nest, etc. in the comment field. BEG**[LIST or AREA]** and END**[LIST or AREA]** are recorded when entering and leaving each plot. The number field should have the plot number without leading zeros.

That no observations were seen in a plot can be noted in the comments of an END**[LIST or AREA]** record. This will confirm that no records were missed. From the plot codes, ferrying and time within plots can be determined. GPS is used to record the location of a nest or other geographic feature. CapHist and Location are not used in GPS records. The comment field is used to record what location is recorded. The COMMENT record is used to make a note, such as fog over the coastal part of a plot. The location may or may not be important to the note.

Header variables are Year, Month, Day, Pilot, FObserver, RObserver, and Plot. These are variables that stay constant for the number of observations and are treated differently than the Code, CapHist, Location, Comment variables. In the resulting dataset, the fields should be separated by commas. Any comments should follow after the fields. Commas should not be used in the comments; use slashes or semicolons instead. Acceptable values of the header variables are shown in Table 1 in the format used by the `Transcribe` program.

The time will be set to the local time zone at the start of the survey, for example Eastern Daylight Time and noted in the survey notes. GIS locations must be recorded. Locations of flying eagles will be recorded after the counts have been reconciled understanding that they will be farther down the track from the sighting. Locations of nests should be taken over the nest to reconcile sightings with known nest locations. **When transcribing, remember to save the new header variable values every time the header variables change. The new values will not be recorded unless you do.**

A checklist for the observers to use in the plane is included at the end of this appendix. It is on a separate sheet and may be laminated.

Flight Procedures

Seating Positions: Pilot, front-seat observer, rear-seat observer.

Altitude and speed: Fly at 200-700 feet above ground level at around 100 miles per hour. Make adjustments to give the best visibility to the tandem observers when possible.

Timing and sequence: Time of day should not matter unless the sun is too low and affects visibility. Observers should not continue when overly fatigued. Surveys should be run before the trees leaf out.

Defining flight paths within area plots: The surveys should only include the parts of plots that occur within the defined survey area (i.e. within the contiguous 48 states, excluding areas within large bodies of water, etc.). Because eagles nest within 1 mile of water (i.e., coastlines, islands, inland ponds and lakes of >35 acres, and rivers >330 feet in width or similar definition appropriate for the geographic area), searching should be constrained to these locations. Flight paths should be defined on maps prior to surveys, preferably in consultation with an experienced eagle survey biologist. Transects will be flown along shorelines and interior habitats along shorelines.

Defining flight paths within list plots: Observers should note identifying features and locations of known nests on maps prior to the flights. This will improve the success of nest searches. Record nests that are not found and ones that are destroyed.

Defining flight paths for combined plots: Known nests in the area plots will not be known to the observers prior to the flight. The combined plots will be treated as area plots during the pre-flight planning. Then, after the plot habitat is flown, the front-seat observer will turn to the next map. If there are known nests, the map will contain the locations. The plot will then be treated as a list plot and the status of known nests will be obtained. If the status of the nests was obtained during the preceding area survey, then the nest does not need to be checked again. A non-observer will need to insert the known nest maps after the area plot maps for the combined plots in the order that they will be flown. It is important to the double observer protocol that the observers scan the habitat during the area plot part of the survey and not look for particular known nests.

Shoreline transects: Surveys should be conducted first along edges of water bodies in plots with the right side of the plane (containing front-and and rear-seat observers) on the landward side of the aircraft. The pilot navigates and can act as a third observer for land sightings, or can observe additional land areas (e.g. islands) in the area. The plane should be oriented to facilitate consistent viewing regions for both observers, without tight turns or banking. Single observations by the pilot can be recorded separately from the tandem observers and entered as "1xx," unless the pilot is counting the same field of view as the other front-seat observer. Areas surveyed on the shoreline pass will be one-quarter mile inland from edge of water, and the plane should be located close to shore.

Interior transects: If it appears that the shoreline transect did not cover adjacent eagle habitat, the aircraft should turn and fly a transect with the aircraft approximately one-half mile inland from the shoreline after the shoreline transect is completed. The front and rear-seat observer will conduct the double-observer procedure in the one-quarter mile-wide strip that extends from the edge of the shoreline to the aircraft. The pilot will survey the area on the shore-ward side of the aircraft, from the midline of the aircraft (one-half mile from shore) to one mile from the shoreline.

Islands should be surveyed by shoreline transects and if necessary (e.g., if island is >1/2 mile wide) by interior transects.

Observations: Known nests may be observed outside the plots and recorded, as may new nests within list plots. Information on the locations and status of these nests can be used to update the nest list of the next sample period but will not be used in the statistical estimation. These should be marked as "out of sample" in the comments. Nest searching in conjunction with eagle observations can be conducted, but should be limited to a single additional pass. During these searches, the double observer counting protocol should be maintained (i.e., independent counting until nest is passed).

Eagle and Nest Observation Checklist

1. **Begin [list or area] plot #___**

2a. If an eagle off the nest

a. **Age**: adult, immature, or unknown

b. **Capture history**: [x, 0, 1] codes for left-front, right-front, then right-rear

c. **Location** (off nest): flying, perched

2b. If a nest

a. **Nest condition**: empty, incubating, occupied, eggs, eaglets

b. **Capture history**: [x, 0, 1] codes for left-front, right-front, then right-rear

c. **Location** (on nest): pine, spruce, cypress, (*generic*) conifer, or deciduous

3. **Comment** on nest contents including number of eagles, uncertainty about species' nest, whether observed while cruising or on a secondary nest search, observer knowing nest location. Indicate observation off the sample plots or new nests in list plots

4. **End [list or area] plot #___**

Appendix 3

Bald Eagle Nestlist Website
by Mark Otto

The Service is developing a website for the States to update their bald eagle nest list data and download copies of their data and other coverages needed for the bald eagle post-delisting survey. The survey team will use the nest lists to sample from and to determine the overall survey design. The main purpose of the website is to make it easy for the States to incorporate their nest list data into a national database, to insure consistency and integrity of the data collected from many sources, and to allow the States access to their own data and information they would need for the survey. The website and database would be the single, secure site for this data. Initially, the site will be hidden and protected from unauthorized users. A test version of the site was developed in July 2008.

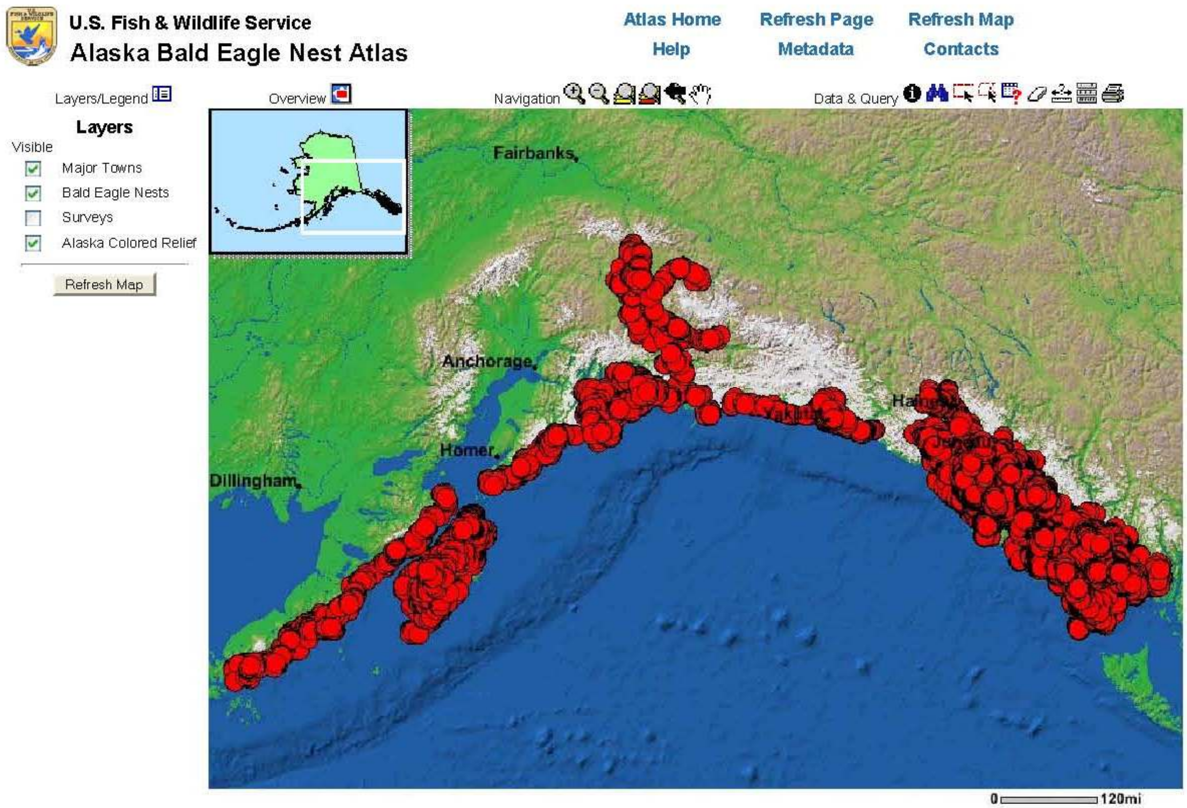
The site will have several secondary uses. Our Service Migratory Birds and Ecological Services programs may access it in the future to assist evaluations of applications for bald eagle permits under the Bald and Golden Eagle Protection Act. Knowing the proximity of bald and golden eagle nests to potential sources of disturbance will facilitate informed permitting decisions. Permit issuers may also be a source of information on new nests. Additionally, the Service's Law Enforcement program will have access to the website in order to use the database information to trace any possible links to depredation on nests.

State biologists would input data using an input form for single or small numbers of new nests. They could also edit past data and upload a text file or other database table. Uploaded data will be scanned for viruses and checked for validity. The user will immediately be informed of any problems with the import, so that the data can be corrected and imported again without undue frustration.

The data would keep information on the locations and the status of the nests over time. There would be two main tables: one to record information on the nest locations, and another to track the sightings/status of the nest within and among breeding seasons. We would use the most current information to develop the survey design. Historical records would be used for research purposes. Since currently abandoned or destroyed nests would remain in the database, we would need to be diligent about recording nest status.

The nest list table would include Nest ID, State, State ID, Site (e.g. Georgetown dump), Position (Latitude, Longitude in decimal degrees), Datum (1927, 1983, …), Status, Observer, Tree or site description (spruce, cell phone tower, ground nest, …), Position in structure, Comment. The sighting table would include Nest ID, year and date, status (adult, destroyed, deteriorated, eaglet, eggs, empty, immature, incubating, not found, occupied, repaired, unknown, unrepaired), territory ID if that is recorded, how the observation was reported, comment, and owner of the record.

Future features might include: (1) an interactive map of nests similar to the Alaska website which allows information on selected nests to be displayed.



(2) Displaying and printing maps of selected 10 km^2 plots with aerial photos or topography identifying bald eagle habitat, with or without list nests. (3) A public part of the website with information showing survey results and a nest map with imprecise or fuzzed nest locations.

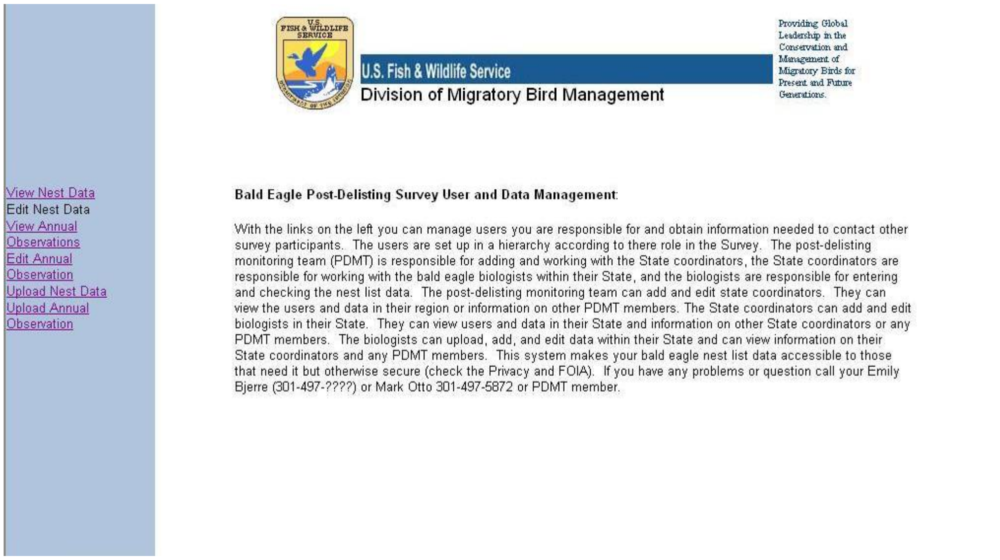
The users of the website would be the administrators, developers, bald eagle management team, State coordinators, State biologists, Service Migratory Birds, Ecological Services, and Law Enforcement programs, USGS and possibly outside researchers. All would access the website and database with a username and password.

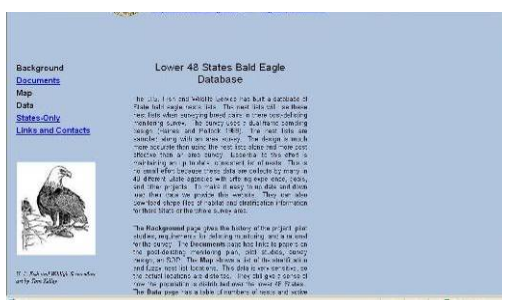
- **Administrators** (1 to 5 people): They would be able to add, modify permissions, and remove users. They could commit data to the database, edit data in the database, modify some web pages and code, and run audits.
- **Developers** (1 to 5 people): They would create, test, and maintain the website, database and code. They would have the same permissions as administrators. (one or two people)
- **FWS Bald Eagle Management Team** (10 to 15 people): They would be able to add, remove, and track (list) State coordinators and State biologists. We would need to keep good contact information for the Team and post that on the site for biologists and State coordinators to get help.
- **State Coordinators** (50 to 100 people): They would be able to add, remove, and track (list) biologists within their State. We would need to keep good contact information for the Coordinators and post that on the site for biologists to get help.

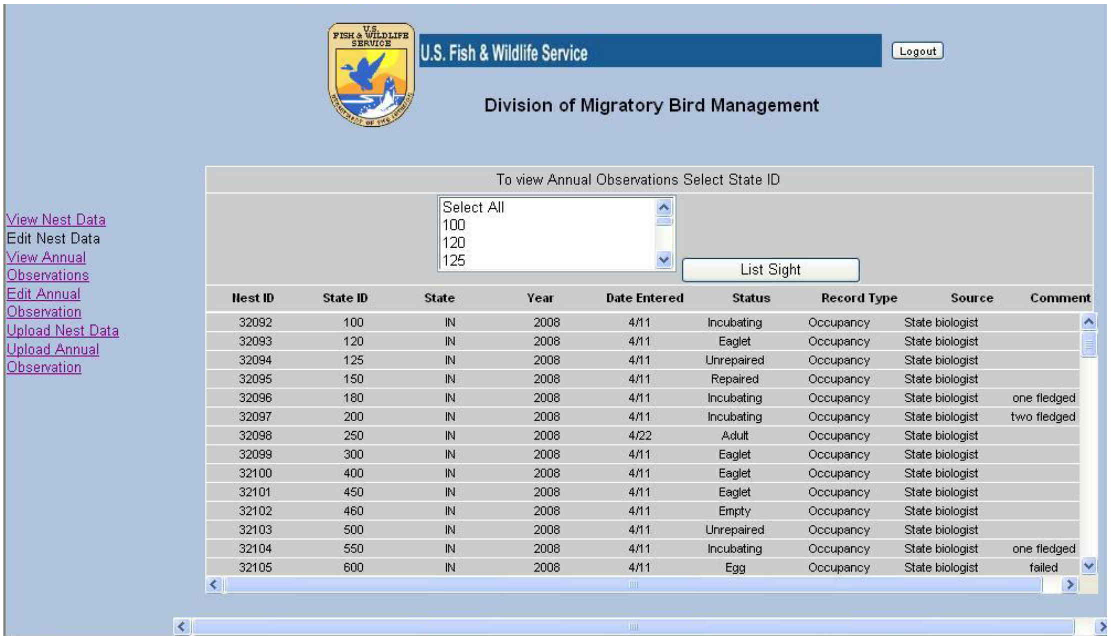
- **State Biologists** (50 to 150 people): They would be able to add, edit, and download information from their State. They will be able to download coverages and other information about the survey.
- **FWS Migratory Birds and Ecological Services** (about 100 people): They would be able to define an area and get the nests possibly affected by a proposed disturbance activity.
- **FWS Law Enforcement** (1 to 10 people): They will need to be able to trace activity by user, view when nest list records were accessed and by whom.

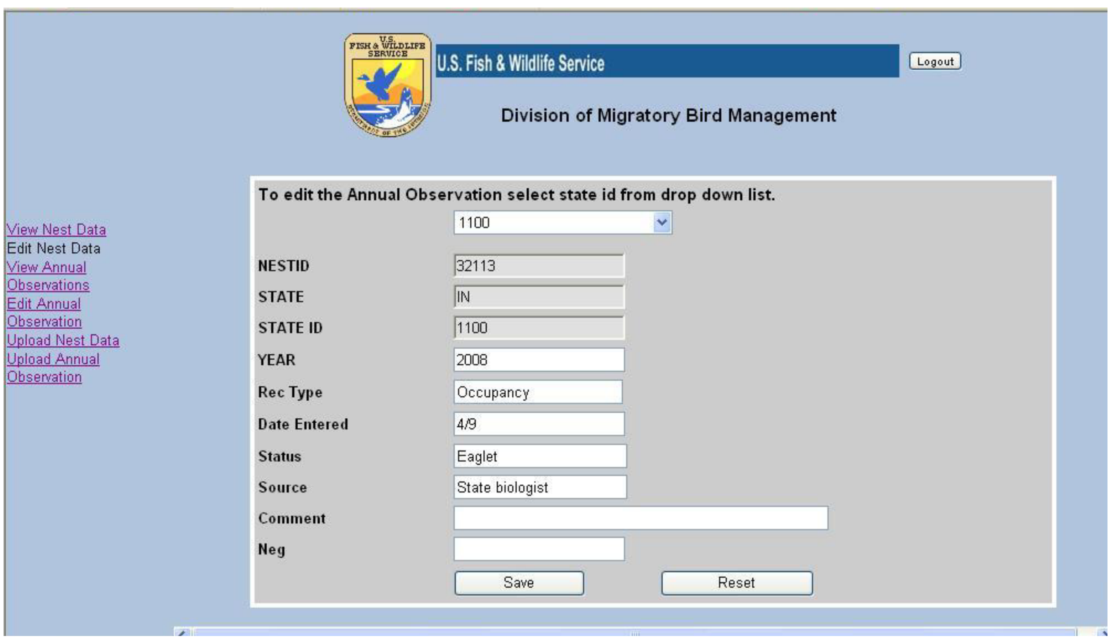
For each survey period each of the States in the contiguous 48 States will be requested to update their list of nests to the extent that data is available. This will include adding any new nests that have been reported and identifying old nests that were destroyed. This data is already collected by many of the States. If no data is available, no changes to the nest list need to be made. To receive consistent information from the States, the website provides two ways to make changes to their nest lists: edit the nest data by nests and annual observations by each observation or upload the changes in a comma delimited text file. The biologists for each state will only be able to view and edit their own data.

Bald eagle database users will log on with user name and password. The website is designed to avoid unintentional traffic as much as possible.









The nests and annual observation on those nests can also be viewed and edited.

Respondents may also upload or e-mail the nest list changes in a comma delimited file with the information described below.

The database contains two main tables: one for nest location and information and another table for the annual observations. Some States may make multiple sightings within each breeding season. Only the summary records for a season will be recorded: one for the occupancy status, and possibly one for the productivity status if the State collects it. The productivity status can stand in for the occupancy if there is not an occupancy record for that year because a productive nest is by definition occupied. The columns for the nest table are:

Column	**Description**
NestID	Unique index among all the States. This we generate to keep track of nests over all States
State	Two letter state abbreviation, using the standard FIPS codes
StateID	Text or number index that the State uses for their nests. Should be unique within the State. This allows the State to identify nests as they do in their own record system.
Lng	Longitude in decimal degrees. We need the locations of the nests to assign nests to plots, our list cluster sampling unit. We also need the location to reconcile the nest with the area observations. If the do not have accurate locations the burden is greater on the States to assign the lists to plots and reconcile the area and list observations. We will display to five decimal places but it depends on the accuracy of the data received. The values will be negative to keep the values within the required -180 to +180 range. We do not use the recommended variable name **long** because Microsoft Access confuses this with the data type **long**.
Lat	Latitude in decimal degrees to 5 decimal places.
LocAcc	Location accuracy: choose the number of meters where less than 10 percent of the locations will be off by more than that distance. Usual GPS accuracy is 200m. Just guess at the distance. Note: National Map Accuracy Guidelines, rockyweb.cr.usgs.gov/nmpstds/nmas.html, use less than a 10 percent error or 1/30" in a 1:20,000 map or within 16.93 meters. (Optional but we need to need to assign the nests to the correct 10 km^2 plot, otherwise the State will need to assign the nests to plots)
Location	Description of the tree (these are not used for vegetation classification), site description, anything to identify the site for reconciliation. (Optional)
Access	Public, Tribal, Federal, State, Local managed, Private, indicate if it is accessible to the public. A citizen observer could legally observe the nest for the survey. (Optional)
Owner	ID of the person responsible for the data (Login name in the website)
DatEntered	Date the data was entered. (Entered automatically when uploaded.)
Comment	Miscellaneous but useful information (Optional). Information about territories may be added here.

We keep multiple annual observations on the same nest, so we can construct the list frame using the annual observation information. For States that collect multiple observations in a breeding season, we can estimate the chances of missing an occupied nest by only visiting the nest one time. The columns for the annual observation table are:

Column	Description
NestID	Unique index among all the States (Assigned by the database)
State	Two letter state abbreviation, using the FIPS codes
StateID	Text or number index that the State uses. Should be unique within the state
Status	Nest status (see below)
NEg	Number of eggs or eaglets, NULL or not used if Status other than egg or eaglet (Optional)
Source	Public call in, State biologist, Confirmed (Optional)
Owner	ID of the person responsible for the data (Login name in the website, user does not enter)
DatEntered	Date the data was entered. (Entered automatically when uploaded.)
Comment	Miscellaneous but useful information (Optional)

Nest status in the Status column of the annual observation table takes on the following values:

Code	Description
destroyed	Nest destroyed or gone
eaglet	1 or more eaglet in nest
egg	1 or more eggs in nest
empty	Empty nest, repair status unknown
immature	Immature on nest
incubating	Eagle or pair on nest displaying incubating
notfound	Not found on previously known location
occupied	Occupied but not incubating
repaired	Repaired nest
unknown	Location known but status unknown
unrepaired	Unrepaired nest

The main information we need to know to set up the list frame sampling is what the status of a current nest is. The important codes are nest destroyed and not found. Nests with other status codes make up the list frame to sample from. After a nest list is sampled or censused during one of the five year sampling periods starting in 2009, we only need to know whether a nest is occupied or not. The incubating, empty (if not able to ascertain repair status), repaired, and unrepaired, and unknown refine the occupied determination. Unknown status nests are considered unoccupied to be conservative but give added information on secondary analyses. If we help measure productivity from a sample or census of nests, we need the eggs, fledgling, and eaglet categories. We will use productivity data that that States are interested in collecting. Keeping and analyzing the productivity data is an opportunity to provide additional information to the States (and to the Service). We put it in our database to make it easy to process surveys for a number of States.

The State nest lists can be updated by making the changes to the web forms above or uploading a table of the updates. The nest table is only updated if the data is different from the current information. The file would have the following information. The State, Owner, and DatTim (date the information was entered) will be entered automatically, using your username, the State that username is associated with, and the computer date and time.

The location accuracy, nest access, source, and nest and annual observation table comments are optional fields. Almost always there are oddities about some observations that are not easily recorded on standard forms, but can save hours of detective work if they are known. It also provides a way to find out what fields should later be added to the formal input. We were not going to collect territory information because we cannot assign territories for new nests or use the information in our estimation. We will also add the State FIPS code, owner ID, and the data and time the owner entered the information. These will be tracked and added automatically using their logon information and the current time. We will work with the States to convert their data to a file that they can upload to our database.

Appendix 4 – Bald Eagle Monitoring Team

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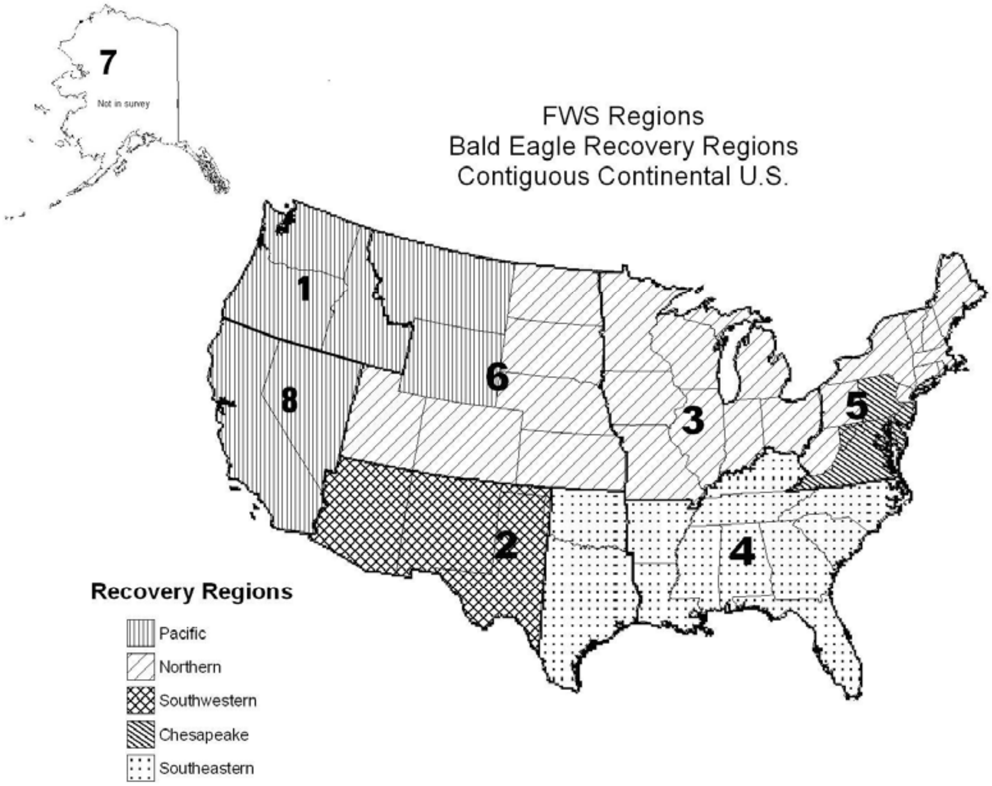
7
Not in survey
FWS Regions
Bald Eagle Recovery Regions
Contiguous Continental U.S.
1
8
6
3
5
2
4
Recovery Regions
Pacific
Northern
Southwestern
Chesapeake
Southeastern

Appendix 5

Glossary

Word	Definition
Allocation	How much of the sample is portioned to each stratum.
Bias	The difference between the true value and the estimate. An estimator is biased if as you increase the sample size the estimates do not approach the true value.
Cluster	A convenient division of the sample into primary and secondary units, so the sample is chosen from the primary units then all or a sample is taken from the secondary units of the primary units selected. This usually increases the variance but makes the sample more cost effective. For example, schools are chosen as clusters because it is difficult to get permission to sample each school. Then, students only within the selected schools are sampled.
Confidence intervals	Interval that we hope the true value of the estimate falls within a given percent of the time.
Detection probability	The probability that an observer or observers will see the object they are counting.
Estimate	The value of a parameter from a statistical model determined from data. The formula is the estimator.
Frame	A list of all possible elements in the population. The list of all known nests or the list of all plots in the contiguous 48 States. We choose the sample from the frame.
Independence	Where one event does not give any information on the chance of another event occurring. For example, having more list nests does not indicate that there will also be more (or less) new nests found.
Lagrange multiplier	Method of optimizing a function when there are constraints, e.g., minimizing the variance given that only so much can be spent sampling, or minimizing the cost given that we obtain a precise enough estimate.
Mean	Characteristic of a population that is the sum over the number of observations; average.
Normalize	Make so that all the values sum to 1. It may also mean to make the values sum to zero and scale the values so the standard deviation sums to 1.
Optimal	The best of all possible choices. Usually choosing the parameter so the value of the function is maximized or minimized.
Population	The aggregate from which the sample is chosen. The target population is what we want to sample: active bald eagle nests. The sampled population is what is actually sampled: may be the active nests in our State nest lists.
Power	The chance of detecting a significant difference when a significant difference exists. Increasing the sample size usually increases the power.
Precision	How much estimates of the same sample size will vary. Technically it is the

Word	Definition
	1/Variance. As the variance of the estimate decreases, the precision increases.
Proportional Allocation	Allocating the sample among strata in proportion to the size the stratum.
Sample	The part of the population that is randomly selected and used to represent and measure the population.
Significance level	The percentage you will accept saying there is a true difference when it only occurred by chance. At a 5 percent significance level, you will get an estimate from a sample that is significant, not because there is a difference, but just by chance. The smaller you make the significance level, the greater sample size you are going to need to detect a significant difference.
Standard error	The standard error is the standard deviation of the estimate, not the population value. As the sample increases the standard error will decrease but the estimate of the standard error will just fluctuate less but remain around the same level.
Stratum	Partition of the population so that the units within each stratum are as similar as possible. You may stratify where sub-estimates are required. We divide the contiguous 48 States into strata where the density of nests differs greatly.
Variance	Measure of the scatter of the population around its mean value. The standard deviation is the square root of the variance. The standard error is the standard deviation divided by the square root of the sample size.