DRAFT POST-DELISTING MONITORING PLAN FOR THE BALD EAGLE, (*Haliaeetus leucocephalus*)

Prepared by
U.S. Fish and Wildlife Service Bald Eagle Monitoring Team
Jody Millar, National Coordinator

Suzanne Audet (Region 1), Greg Beatty (Region 2), Jody Millar (Region 3),
Allan Mueller, Candace Martino, Alfredo Begazo (Region 4),
Craig Koppie (Region 5), Dan Mulhern (Region 6),
Phil Schempf (Region 7), Mary Klee (WO)

Bald eagle pair and nest (photo credit: U.S. FWS)

Table of Contents

/

Summary

The Post-delisting Monitoring Plan (Plan) will monitor the status of the bald eagle over a 20 year period with sampling events held once every 5 years. The Plan will primarily be a continuation of State monitoring activities conducted by the States over the past 20 years. Historically, the States have attempted to census the bald eagle population by anually checking known occupied nests and by adding others found incidentally. For the purposes of this Plan, data from this set of known nest locations will be combined with area plot samples selected from eagle habitat areas across the lower 48 States to provide a dual frame estimate (Appendix 1). Statistically combining the results of these two data sets will provide an estimate 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). In addition, dual observer sampling protocols are recommended to reduce bias (Appendix 2). However, 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 (Arizona, for example).

The Plan recommends that the State natural resource/wildlife conservation agencies continue the nest survey data collection while the Service offers technical assistance on incorporation of the dual frame sampling design. Sampling effort will depend upon the extent of State participation and/or funding available at that time. We will continue our mandated role of reporting the national results while working with the States to collate and analyze the data. This Plan is not intended to replace plans to manage eagles or monitor them more regularly or in a different manner for specific management purposes.

The goal of the Plan is to be able to detect a 25 percent change in occupied bald eagle nests on a national scale at 5 year intervals, with an 80 percent chance of detecting a 25 percent or greater difference between 5 year intervals. This will require updated nest lists and a minimum of about 200 area plots surveyed in States with habitats containing medium to high density of bald eagle nests. If the minimum participation necessary to meet this detection goal is not met, the Team will convene, and with State partners will determine participating States, partners, and funding as feasible to accomplish the Plan goal. If declines are detected, particularly those equal or exceeding the goal, 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, habitat changes or any other significant evidence. The result of the investigation will be to determine if the population of bald eagles in the lower 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the Endangered Species Act. 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 recovery.

Background

Between 1952 and 1957 Charles Broley, an avid eagle watcher, reported that about 80 percent of 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 on March 11, 1967 (32 FR 4001), to list 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 U.S. Fish and Wildlife Service (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 believes 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. The final rule on delisting and the Notice of Availability for this draft monitoring plan were published simultaneously in the Federal Register.

In the years since Charles Broley's discovery of declining eagle numbers in Florida, the States, the 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. Since the

Service's 1999 publication of the proposal to delist the bald eagle, many States have reduced their monitoring efforts.

<u>Post-Delisting Monitoring Requirement of the Endangered Species Act</u>

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.*

This Post-delisting Monitoring Plan for the Bald Eagle (Plan) is intended to track the breeding population status of the bald eagle in the contiguous 48 States after it is delisted under the ESA by estimating the number of occupied nests. **This Plan is not intended to replace plans to manage eagles or monitor them more regularly or in a different manner for specific management purposes.** It is not intended to 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, please refer to the Service's National Bald Eagle Management Guidelines (72FR31156) and regulatory definition of the term "disturb" (72FR31132) which were published in the *Federal Register* on June 5, 2007. Copies of these documents are currently available from our national bald eagle web page located at http://www.fws.gov/migratorybirds/baldeagle.htm.

The successful implementation of this Plan relies on a large number of existing bald eagle monitoring efforts designed and implemented by States, other Federal agencies, non-governmental organizations, and individuals. The Service wants to provide technical assistance and facilitate these existing efforts and to standardize data collection protocols. The result will be a collaborative network of governmental and non-governmental partners contributing to this nationwide effort.

<u>History of Plan Development and Pilot Studies</u>

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 Patuxent Wildlife Research Center, 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, Biological Resources Division, proposed a pilot study. The pilot study, funded by the U.S. Geological Survey for 2004 and 2005, incorporated methods traditionally used by some States to monitor occupied bald eagle territories while adding a statistical design to check the accuracy and assess the variability of those methods.

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 territories (list survey), 41 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 territories, 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 proposed pilot States 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 results of the 2004 and the 2005 pilot studies have been compiled and form the basis for our post-delisting monitoring plan.

We believe this Plan makes the best use of available resources. To do this, we propose to cooperate and provide technical assistance to our State, Federal and non-governmental partners in all aspects of planning and implementing bald eagle monitoring. This includes using methods that allow incorporation of historic and on-going data collections while requiring a minimum level of additional monitoring to detect breeding population level declines. The proposed design will improve the accuracy of data collection and will emphasize areas of greatest eagle abundance. This Plan is not intended to replace plans to manage eagles or monitor them 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 with existing data sets.

Goal

The goal of post-delisting monitoring is to estimate changes in the number of occupied bald eagle nests in the contiguous 48 States on a national scale. Estimates will be calculated at five-year intervals, and the design is based on a goal of an 80 percent chance of detecting a 25 percent or greater change in occupied bald eagle nests between five-year intervals. Achieving this goal depends on how many partners participate in the surveys. We believe an 80 percent chance of detecting a change (as defined above) is a realistic goal based on a moderate level of participation. Strong participation by the States and our other partners will increase the precision while low participation will reduce the precision. If declines are detected, particularly those equal to or exceeding the goal, 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, habitat changes or any other significant evidence. The result of the investigation will be to determine if the population of bald eagles in the lower 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the Endangered Species Act. 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 recovery.

Implementation

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

<u>Service Bald Eagle Monitoring Team</u>

A Service 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 post-delisting monitoring plan. The Midwest Region of the Service has the lead for this effort (Appendix 3).

The role of the Service's national coordinator is to coordinate within the Service as well as with other Federal agencies, States, and non-governmental organizations; provide guidance to the regional coordinators; distribute the draft and final plans to the Service's Director, Regional Directors, Assistant Directors for the Endangered Species and Migratory Birds Programs, State resource agency directors, and cooperators; plan, implement, and analyze the surveys and summarize the monitoring results in cooperation with States and other cooperators; prepare interim and final reports; make recommendations based on survey results; seek partnerships with Tribes, States and other agencies and groups to implement the Plan; and develop partnerships for any needed contaminants studies and analyses.

The role of the Service's regional coordinators is to coordinate Plan development, review, and implementation within the Service's regions and with each State; work with States and other cooperators to ensure that standardized protocols are used in the data collection; participate in working group meetings, assist in the planning and implementation of five-year surveys, and make recommendations based on survey results; coordinate the collection and compilation of regional survey results; provide monitoring results to the national coordinator for inclusion in the interim and final reports; seek partnerships with Tribes, States, government agencies, and non-government organizations to help implement the Plan; and coordinate mortality monitoring (the Service's Region 4 will lead this effort).

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 (BCR) as a means of stratifying high, medium, and low 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.

In addition, if funding is available, Service waterfowl pilots and their aircraft will be requested to participate in the area surveys as a backup for State pilots and aircraft.

State Coordination

The Bald Eagle Monitoring Plan provides for coordination with the States to insure that data collected will be comparable and will permit a good estimate of the breeding population throughout the contiguous States. As indicated previously, many States have been monitoring their nesting bald eagle populations (and in many cases wintering populations as well) for over 25 years. These data represent a valuable source of long term information on bald eagle population trends. The Service's intent is to build on this information source and to use the States' monitoring capabilities and expertise to implement an efficient and effective post-delisting monitoring program.

Early in the Plan development process, Team members made preliminary contact with the States to determine an official contact for each State with whom we could coordinate our efforts. This included summarizing each State's bald eagle monitoring protocol and most recent survey data, and soliciting suggestions regarding the Plan content, methods, and format. Subsequent to this initial contact, the Non-game Technical Committees of the Pacific, Central, Mississippi , and Atlantic Flyway Councils, which are composed primarily of State biologists, were given a presentation on the draft Bald Eagle Post - delisting Monitoring Plan at their biannual meeting and asked to provide peer review. States will be formally requested to provide review and comments during the public review period. *[After comments are received from States, we will describe how they were addressed or incorporated.]*

The national and regional coordinators will work closely with the State contacts (and other cooperators) to provide technical assistance on implementing the Plan and submitting the data after each monitoring period and, in coordination with the States, will propose adjustments to the sampling design, if necessary. This effort will also require the Service biometrician to work closely with the Team and State contacts to select sample areas and maximize sampling efficiency. For those years that fall between the monitoring years outlined in this Plan, the Service will also request and synthesize nest monitoring data, and will have an ongoing request for productivity data and any information regarding major habitat changes or contamination/mortality events collected by States or other partners.

Coordination with Other Partners

Post-delisting monitoring is intended to be a cooperative effort among the Service, States and Tribal governments, other Federal agencies, and non-government partners. Bald eagle monitoring in most States is carried out by a combination of agencies, Tribes, private organizations, and individuals. The continued participation and cooperation of these partners is critical. We anticipate that the combined efforts of all of our partners working together will provide the necessary resources to implement this monitoring 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 have and can continue to assist in evaluating the status of the bald eagle population. Continued efforts to assess productivity of breeding bald eagles can provide additional information on the reproductive performance of eagles. The National Bald Eagle Winter Count has existed for decades and has largely become institutionalized in many States across the country (Steenhof et al. 2002). This effort, while continuing to provide the public and agencies educational value and the opportunity to identify and manage for important eagle wintering areas, provides information on the bald eagle through the bird's distribution, abundance, and age class. There have been migration observation areas that have collected data on eagle abundance that also have become institutionalized over the years. Continuing these efforts post-delisting and providing that information to the Regional and National Bald Eagle Monitoring Team members will improve our ability to evaluate the nationwide and local 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 proposes to work with participating States, Tribes and other Federal agencies to conduct a survey of occupied bald eagle nests that uses information from two sampling strategies. It incorporates samples from a list of known occupied bald eagle nest locations (list frame) and data collected from area-based plots (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 of occupied nests found in the list and the area frames, resulting in an estimate of the total number of occupied nests within the study region that is more accurate than the use of either frame alone.

List Frame

The list frame for this Plan is the current summary of all known occupied bald eagle nests for the contiguous 48 States, which was obtained by collating the most recent nest occupancy data from each State. All States have conducted bald eagle nest monitoring in the past, but at varying levels of effort and at varying time intervals. Thus, the nest list frame will be composed of data collected in different years and of varying quality. As part of the monitoring plan, this list will be maintained by the States. At a minimum, the list may be sampled concurrent with the area frame sample to provide an estimate of nests that are in the list frame.

Area Frame

The area frame is composed of randomly selected plots which will be surveyed via aircraft for occupied bald eagle nests. For this Plan, the area frame is a set of 10 km x 10 km plots to be selected from a grid that overlays the contiguous 48 States. These sample units have been shown in pilot studies to be efficient for sampling bald eagles. The grid matrix for the area frame will be stratified for sampling efficiency based on State boundaries and Bird Conservation Regions (BCRs). The Monitoring Plan will use physiographic regions developed for BCRs (Sauer et al. 2003) 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 propose to divide BCRs into States, and to use these State-BCR units as initial strata. Appendix 2 (Maine Bald Eagle Pilot Project, Standard Operating Procedures) outlines the protocol for collecting area frame data for this Plan. Observations of nests 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 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 Regions and Strata

Because the goal of this Plan is to detect changes in the number of occupied bald eagle nests in the contiguous 48 States, the 48 States as a whole is the study area. It is believed that sampling at this scale will be the most cost-effective approach.

Sampling efforts will be allocated according to different habitat types, which correspond to varying bald eagle nesting densities. (A detailed discussion of sample allocation can be found in Appendix 1). These different habitat types can be segregated into strata, where nesting densities for a defined stratum are generally similar, such as a low, moderate, or high number of nests. To sort the habitats on a broad scale, we will divide the contiguous States into strata based on BCRs and relate those regional habitats to bald eagle nesting density. The BCRs in conjunction with State boundaries will be used to develop an efficient sampling plan.

A GIS-based map has been developed depicting bald eagle nesting density in the contiguous 48 States (see Appendix 1, Figure 1.). The map is based on the most recent nesting data obtained from each State and compiled into one list for the contiguous 48 States (list frame). Sample areas will be established within State/BCR strata that contain low, moderate, or high eagle nest densities. The selected BCR strata will then be divided into 10 km x 10 km grids that will be used to determine the potential sample plots for the area frame. A number of area frame plots (approximately 200 – 600 plots, depending on feasibility) will then be randomly selected from these gridded regions for monitoring. A census of occupied bald eagle nests will be conducted within each selected plot, focusing survey efforts on habitats that have a greater likelihood of having eagle nests as illustrated by this sample of the pilot survey in Minnesota.

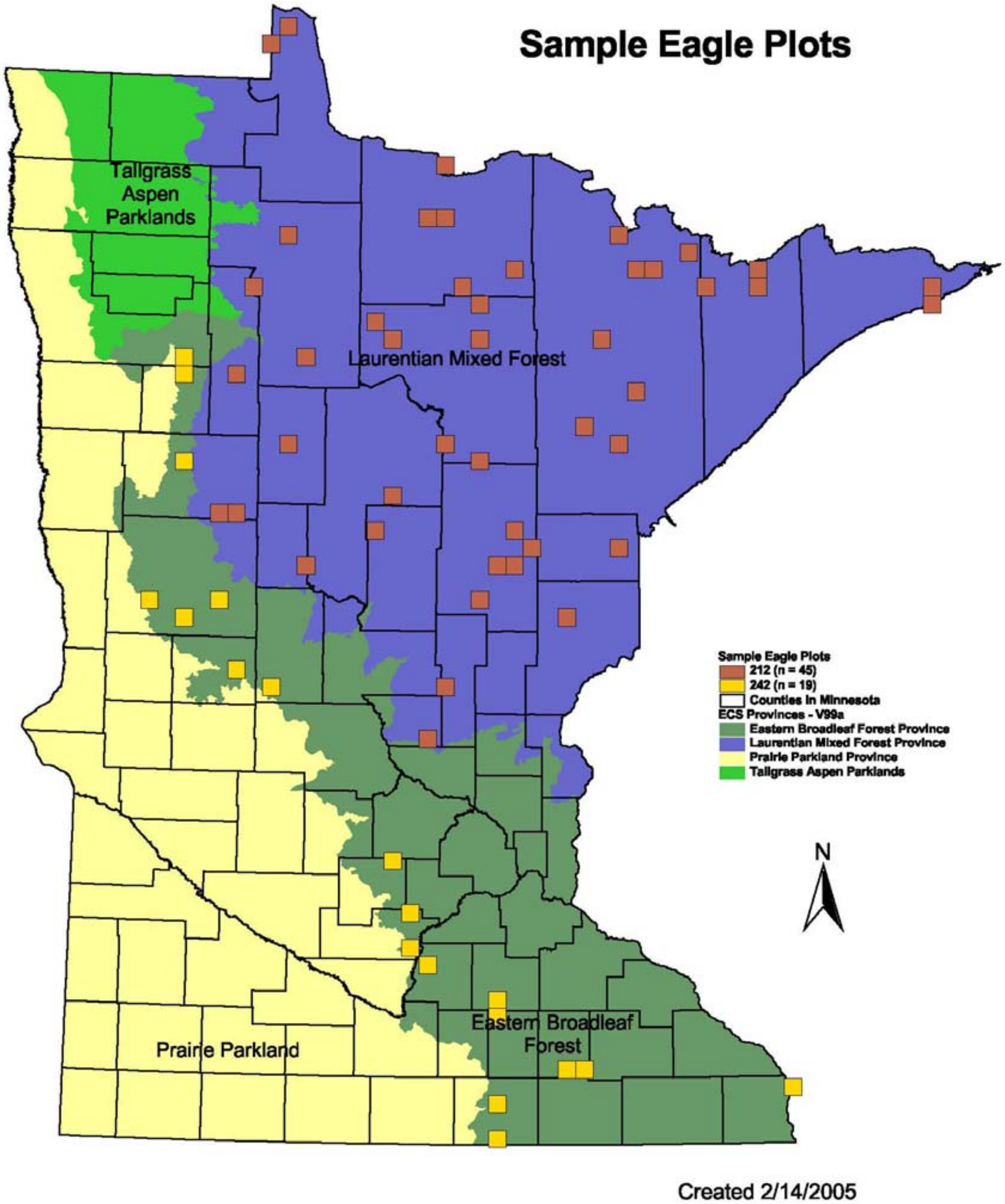


Figure 1. Sample eagle plots for area frame survey, Minnesota Pilot Study 2005

Frequency and Duration of Sampling

The ESA requirement for monitoring a minimum of five years after delisting would barely allow for one breeding cycle for this species. The bald eagle's distinctive white head and tail are not apparent until the bird fully matures at 4 to 5 years of age (Gerrard and Bortolotti 1988). Gerrard and Bortolotti (1988) observed that successful breeding may not occur for two years or more after developing adult plumage. Thus, a breeding cycle is about 6 years (Gerrard and Bortolotti 1988). In order to assess several generations of bald eagles post-delisting, this Plan recommends monitoring bald eagle nesting populations at five-year intervals for a total of 20 years.

Many States conduct monitoring of bald eagle nests on an annual basis. One reason surveys are conducted so frequently is that less time is required to look for nests because their locations are known from the previous year. Secondly, annual surveying provides valuable resource data, including information on whether management techniques are working or if additional measures are necessary to protect nesting eagles.

Due to the long-lived nature of the bald eagle and the abundance and distribution of breeding eagles across the lower 48 States, we would not expect a precipitous decline to occur over a short (i.e.five year) period. Factors that could limit bald eagles in the future such as habitat loss or environmental contamination, are most likely to impact bald eagles over a period of years. Sampling every year is unnecessary for the purposes of this effort and is more costly. Thus, periodic sampling spread over a longer time period is recommended to provide trend information on nest occupancy. However, the Team will review bald eagle information on a continuing basis including productivity, mortality, habitat alterations, and contaminant events. Should this information indicate declines are occurring in between sampling intervals, the Team in conjunction with the States will investigate causes of these declines to determine if the population of bald eagles in the lower 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the Endangered Species Act.

Sampling the List Frame

The Plan suggests States maintain lists of known nest sites within their State. Where lists are not maintained, known nest sites can be sampled as part of the survey. The number of occupied nests in the list can be estimated through either a census of all nests on the list or a stratified random sampling of nests.

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 a 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 that enough data is collected to meet our goals of precision and accuracy (see above). 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 will preclude sampling at one plot. Should all plots be feasible, sampling will cease when the minimum number of plots first selected have been sampled. We note that detectability issues exist when finding bald eagle nests from aircraft. Thus the area frame sampling will implement a double-observer procedure for estimating number of nests missed during sampling.

Protocols

The area frames will be sampled using protocols consistent with those developed during the pilot studies. (A detailed discussion of the 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 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 part 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 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 a few miles away.

Bald eagle habitat: For this study, bald eagle 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, typically a larger sized water body. The pilot States generally defined bald eagle nesting habitat as supercanopy or sturdy-structured trees within one mile of waterbodies greater than 35 acres and rivers greater than 100 meters in width.

Breeding Area (Nesting/Breeding Territory/Site): 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.

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;
- young were raised.

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.

Habitat

The Service will not monitor changes in bald eagle habitat directly. However, the Team, in conjunction with the States, will accept and review data indicating significant changes in habitat across the contiguous States. Some local breeding populations may be affected by changes in the quantity or quality of habitat. Should trends in nest occupancy significantly decline over broad geographic areas, a change in available nesting habitat will be investigated as a possible cause and appropriate actions, as feasible, will be taken.

Contaminants

The Service worked with the Biological Resources Division of the U.S. Geological Survey (USGS) 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 funding from National Biological Information Infrastructure (NBII) to serve the PDF files and abstracts as well as the citations from a separate web site. This contaminants database should be updated every five years in conjunction with the monitoring surveys.

To retrieve references from the contaminants database, enter 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 was listed under the ESA. Data demonstrating reduction in contaminant exposure supported the proposal to delist the bald eagle. 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 electrocution; trauma from collisions with power lines, vehicles, and other obstacles; disease; poisoning; shooting; and other factors (Table 1, Franson et al. undated).

As part of the bald eagle post-delisting monitoring plan, bald eagle mortality will be tracked to alert the monitoring 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; Fish and Wildlife 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. We will contact the bald eagle coordinator with the principle fish and wildlife conservation agency in each State, the Fish and Wildlife Service regional law enforcement agents, the National Wildlife Health Center, and the National Fish and Wildlife Forensic Laboratory requesting them to complete the Bald Eagle Mortality Report Form (Appendix 4) for all dead bald eagles they encounter. Wildlife rehabilitators are required to obtain a permit from the Service to work with raptors and other migratory birds. As part of their annual reporting requirement they will be asked to also complete the Bald Eagle Mortality Report Form. If an unusually large concentration of mortalities occurs, the Service and/or its partners will investigate the causes and determine the potential effect on bald eagle population viability.

Response Trigger

The Team will evaluate the following response trigger after each monitoring period:

> A 25 percent or greater change in occupied bald eagle nests between 5-year intervals (as determined by a power of 80 percent and an error rate of 10 percent).

Reaching the response trigger described above would approach population levels estimated at the time when delisting was first proposed in 1999 based on about 9,000 nesting pairs in 2007. If declines are detected, particularly those equal to or exceeding the goal, the Team in conjunction with the States will investigate causes of these declines, including consideration of natural population cycles, weather, productivity, contaminants, habitat changes or any other significant evidence. The result of the investigation will be to determine if the population of bald eagles in the lower 48 States warrants expanded monitoring, additional research, and/or resumption of Federal protection under the Endangered Species Act. At the end of the 20 year monitoring program, we will conduct a final review. Any relisting decision by the Service will be made by evaluating the status of bald eagles relative to the ESA's five listing factors (ESA § 4(a)(1)). It is the intention of the Service to work with all our partners toward maintaining continued species recovery.

Reporting

The Service will issue a report detailing the results of the first breeding population survey, which will serve as our baseline. This will be available to the public in printed form and on the internet. The report will include a description of the geographic areas surveyed, the survey protocol, and an estimation of the breeding population of bald eagles in the 48 coterminous States.

Every five years the Service will 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 will be available to the public within one year of the completion of the surveys. Reports will also suggest ways to improve sampling protocols or other aspects of the Plan design, if necessary.

Each report will also 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 Team will convene, consult with the States and other partners, and make recommendations for future actions, including an evaluation of the five listing factors, to the Service's Division of Endangered Species.

The Service will 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. In this way, specific causes and/or locations of high eagle mortality can be identified for investigation of patterns and 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 posted on our Web site, or made available to the public in another readily accessible medium. If the bald eagle breeding population is stable in the study area and no significant threats are apparent, monitoring will be terminated. There may be other reasons to continue or establish a different monitoring program with cooperators.

Literature Cited

All documents prepared for notice and comment in the Federal Register must include literature citations for all scientific references used in it. The literature must also be labeled as belonging to one of the following categories: (1) citations of scientific work that are original research based on the collection and analysis of data, peer reviewed and published in the scientific literature; (2) citations of scientific work that are derived from analysis of scientific literature, peer reviewed and published in the scientific literature; (3) citations of scientific work based on the collection and analysis of data but not peer reviewed; (4) citations of scientific work that are based upon analysis of scientific literature but not peer reviewed; and (5) citations of information that are not based directly upon collection, analysis, and publication of data. This includes citations such as personal communications, anecdotes, and newspaper articles.

Carson, R.L. 1962. Silent spring. Houghton Mifflin Co., New York. 368pp. (3)

Franson, J.C., L. Sileo, and N.J. Thomas. Undated. Causes of Eagle Deaths. National Wildlife Health Center, Madison, WI. 1pp. (3)

Fraser, J.D. 1978. Bald eagle reproductive surveys: accuracy, precision, and timing. M.S. Thesis, Univ. Minnesota. St. Paul 82pp. (1)

Gerrard, J.M. and G.R. Bortolotti. 1988. The bald eagle: haunts and habits of a wilderness monarch. Smithsonian Institution Press, Washington and London. 177 pp. (3)

Grier, J.W. and J. E. Guinn. 2003. Bald eagle habitats and responses to human disturbance in Minnesota. Final report. To the Minnesota Department of Natural Resources, Natural Heritage and Nongame Wildlife Program, Division of Ecological Sciences. 44pp. (3)

Haines, D.E. and K.H. Pollock. 1998. Estimating the number of active and successful bald eagle nests: an application of the dual frame method. Environmental and Ecological Statistics 5, 245-256. (1)

Hunt, W. G., D. E. Driscoll, E. W. Bianchi, and R. E. Jackman. 1992. Ecology of bald eagles in Arizona. Report to U.S. Bureau of Reclamation, Contract 6-CS-30-04470. Biosystems Analysis, Inc., Santa Cruz, CA. p. A-149. (2)

Nichols, J. D. J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and H. J. Heglund. 2000. A Double-Observer Approach for Estimating Detection Probability and Abundance from Point Counts. Auk 117(2):393–408. (1)

Postapulsky, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. Pages 21-31 *in* F.N. Hammerstrom, Jr., B.E. Harrell, and R.R. Olendorff, eds. Management of raptors. Raptor Res. Found., Vermillion, S.D. (2)

Schempf, P.F. 1997. Bald eagle longevity record from southeastern Alaska. J. Field Ornithology; 68:1:50-151. (1)

Stalmaster, M.V. 1987. The bald eagle. Universe Books. New York, NY. (1,2)

Steenhof, K. 1987. Assessing raptor reproductive success and productivity. Pages 157-170 *in* B.G.Pendleton, B.A. Milsap, K.W. Cline, D.M. Bird eds. Raptor Techniques Manual. National Wildlife Federation, Institute for Wildlife Research, Scientific and Technical Series. No. 10, Washington, D.C. (2)

Steenhof, K., L. Bond, K. Bates, and L. Leppert. 2002. Trends in Mid-Winter Counts of Bald Eagles Across the Contiguous United States, 1986-2000. Bird Populations 6:21-32. (1)

Steenhof, K. and M.N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. J. Wildl. Manage. 46:885-893. (2)

Appendix 1

Contiguous 48 States Bald Eagle Breeding Pair Survey Design

by Mark C. Otto and John R. Sauer

Introduction

The Endangered Species Act requires that when the U.S. Fish and Wildlife Service (Service) delists a species due to recovery, it continues to be monitored for at least five additional years. If the species declines after delisting, the Service can begin the process to return it to the endangered and threatened species list, and can relist it on an emergency basis, if appropriate. The Plan involves establishing a baseline population estimate and subsequently sampling every five years for twenty years.

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. These efforts form a critical resource for eagle monitoring, and the delisting monitoring plan seeks to maintain these lists of eagle nest sites. However, particularly in areas where eagles are increasing, these lists are not adequate as a monitoring program, as many nests exist that are not in the lists. The delisting program builds on the existing lists, and they form a critical component of the monitoring program. We recommend additional sampling in conjunction with the list sampling to obtain unbiased estimates of eagle nests. A dual-frame approach will provide estimates of 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. The pilot studies assessed the feasibility of the dual-frame sampling design.

Eagle pairs may use one nest of a number of nests in their territories to breed in a given season. We plan to measure the number of occupied nests. Many States collect information on territories along with information on the nests. Because territories are not collected consistently across all States and because we cannot assign territories to new nests found on the area survey, we use nests as our sampling unit.

Bald eagles in the contiguous 48 States generally breed in habitats near water, and portions of States that contain breeding habitats can be delineated on maps. Existing nest sites are also geo-referenced and have been mapped. This geographic information can be used to develop an efficient sample design for the species. We recommend that the sample design (1) stratify by habitat types to permit more intensive samples in areas with a higher density of bald eagle nests, (2) use a dual-frame design that samples known nest sites but also conducts an area-based sample to estimate the total number of nests, and (3) account for nests not observed by estimating detection probabilities using double observer survey methods (Thompson 2004).

Dual-frame sampling uses the list of known nests, in combination with additional sampling, to estimate the total number of nests. For the additional sampling, the study area is divided into plots, and a sample of these plots is randomly selected and censused for eagle nests. This set of plots is known as a sample frame, and the selected plots are the random sample. 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 known list of nests, however, can be incorporated into the estimation. If the nests that are known to be in the sample plots are identified and removed from the sample (a process known as unduplication); then, the remaining data can be used to estimate the total number of nests not in the list. The list and new nests can be added to provide an estimate of the total number of nests.

Additional effort is required during the area surveys to ensure that we account for 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. In 2006, biologists in Missouri volunteered to test the methods. 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.

State biologists were asked to define strata in their States by habitat related to bald eagle densities. 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 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, Sauer and Otto 2004). 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 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, 1481 in Florida (using the 2003 nest list), 1327 in Minnesota and 1939 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 higher than 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 for the entire contiguous 48 States. 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, much 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. The magnitude of change to be detected should be defined in terms of biological parameters and administrative needs. Population sizes naturally vary from year to year, and managers need to distinguish a biologically-significant decline from natural variation. Thus, the magnitude of change the survey is designed to detect must be larger than this natural variation and be sustained (i.e., consistent over more than two survey periods). Because bald eagle populations have been increasing over most of their range, changes in rate of increase may be an important first indicator, but can only be estimated by comparing the result from three or more sample periods. Specification of a reasonable goal is a prerequisite to developing the statistical design. In general, the more stringent the requirements, the larger the sample required to meet them and the greater the cost. Statistical methods and pilot data described here provide a rigorous framework for predicting the number of areas that need to be sampled to meet the goal.

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 two sampling periods 80 percent of the time with a 10 percent chance of getting a significant decline just by chance.

Stratification

Bald eagle nesting density is dependent on the quality and abundance of nesting habitat, including the availability of food (Grier and Guinn, in press). This results in a large variation in distribution both within and among States, variation associated with different amounts of available habitat. The Monitoring Plan uses physiographic regions developed for bird conservation (Bird Conservation Regions, or BCRs; Sauer et al. 2003) 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 MD Coastal Plain as a separate stratum from VA Coastal Plain), and used these States-BCR units as initial strata. 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. For each State-BCR, the eagle nest list data were overlain on a 10km 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 16 contiguous lowest density strata into a "trace" stratum, a region containing only 12 nests in the stratum. The collapsed strata are shown in **Figure 13.**

We view these aggregate strata as reasonable regions for implementing an initial survey design. Collapsing the strata will improve the estimation by avoiding imprecisely estimating numbers of nests in many small strata. (In the future, we could improve the procedure to collapse strata by redoing the cost functions and optimizing the allocation after each stratum merge. We would then look at the improvement in the cost-variance function. This would be very computer intensive.)

The variation of the plot densities in the collapsed 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 should be encouraged to refine these strata using their knowledge of eagle populations and habitat use by the species. Also, we should include amount of habitat or shoreline in the sample selection and analysis. Finally, we can obtain sub-regional or other small area 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. In an area frame, all habitat in the sample plots must be flown.

<u>Cluster Sampling of the List Frame during Area Frame Sampling.</u>

Because sampling the list is likely to be 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 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).

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. List-plot clusters can be further combined with other adjacent plot clusters. This way, more area can be surveyed because the nests are observed by flying directly to their nearby locations. As described later, the sampling for area and list-plot clusters can be done sequentially to save on flight times.

Area Frame

Within strata, we suggest that the sample unit for area sampling be the 10km x 10 km plots as were used in the pilot studies. For development of a sampling frame for the contiguous lower 48 States, we used ARCGIS with a Lambert Equal-Area Projection to generate 10km x 10 km plots. The plots were then categorized by strata. Plots on the coasts or Mexican and Canadian borders had the water and foreign parts of the plots removed. Plots that overlapped two or more strata were assigned to the stratum that had the majority area. Figure 5 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. We did not cluster nests into plots for this pilot survey.

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 (**Table 2**). Because of the inconsistency in how nest status was recorded among the States, in some States we needed to estimate the number of nests that were occupied. We simulated whether a nest was occupied by taking the proportion of occupied nests from similar pilot States. Also, the actual number of nests in a stratum is larger than the estimate from the nest lists, as the list is a biased estimate of total number of occupied nests. We used our pilot data, in which we directly estimated the list coverage (proportion of nests in the list), to estimate list coverage by stratum for sample allocation purposes. 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 nests, N_{Li}, by adding the nests in the list, Y_{Li}, and the estimated number of 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 subscript *i* is for one of the *I* strata. The stratum estimates are added up to get the national total,

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

The estimate for new 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],

$$Var\left(\hat{Y}\right) = \sum_{i}^{I}\left(Var\left(\hat{Y}_{Li}\right) + Var\left(\hat{Y}_{Ni}\right)\right)$$

If the list is censused, the variance is 0. If it is sampled, the stratum variances for the list frame only depend on the number of nests, N_{Li} , and the variability of the estimate, S_{Li}^2 , and the sample size, n_{Li} ,

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

So the variance decreases as the number of nests and the variability decrease and as the sample size increases. The Fixed Part, $\left(Fixed\_Part\right) = N_{Li}S_{Li}^2$, is a part of the variance that is not affected by the sample size.

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

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

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 $\left(Var\left(\hat{p}_i\right)\right)$ decrease and as the sample size (n_{Ai}) and the detection probability itself ($\hat{p}_i$) increases. Again, the

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

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 the estimating the required sample size.

Survey Design

To design a survey, we calculate what 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, level and variability of the data determine the variance needed from the survey.

[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.

We would like the least expensive survey that meets our variance requirements. We would like to minimize both the costs and the variance,

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

The whole expression is a Lagrange multiplier. 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.

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

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

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 λ variable 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. By finding the smallest value of the Lagrange multiplier, we will be sampling more 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, or "data" used in the equations. As these numbers are not known, 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 4 designs:

1. list-only,
2. area-only,
3. dual-frame, and
4. combined dual-frame.

List-only.--The current information comes from the State nest list. We call this the list-only design. 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 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 ($\text{mse} = Var\left(\hat{Y}_l\right) + \text{bias}^2$).

Area-only.--The area-only design ignores the State nest lists and estimates the number of occupied nests just of the nests found on 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. Although the area-only sampling efficiency can be evaluated using the results presented below, we do not separately evaluate the efficiency of this approach in this report.

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.

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 saves on flight time. The equations are the same as for the dual-frame, but we use different cost functions because of the differences in sampling.

Cost Functions for Sampling List-Plot Clusters

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 2006).

The distances traveled during the pilot surveys are converted to costs by assuming the planes flew 100 miles per hour and the cost of the plane was a rate of $235 per hour (the Service rate in 2006). Thus, the conversion factor from miles to cost was 2.35. 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 6 shows how 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 8**. 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 costs 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 slightly higher but similar to those shown in **Figure 8**.

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. 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 less expensive to sample. The sample allocations for the list frame given for an overall list coverage of 60 percent are in

Table 4: Sample allocations for the area frame. The first column is the proportion of all samples that are allocated to the given stratum. The second is the percentage of samples that would be allocated to the stratum if proportional allocation were used (proportional to the size of the stratum). The last column is the first column normalized to the size of **the stratum.**

The first column is the proportion of the total sample that is allocated to a given stratum; the second is the percentage of samples that would be allocated to the stratum if proportional allocation were used (proportional to the size of the list in that stratum). The last column is the first column normalized to the size of the stratum. We show this because large strata may have seemingly large number of samples allocated to it, but not in relation to their size. Note that in the Low Stratum, 38 percent would be sampled using proportional sampling whereas the optimal sampling only calls for less than one percent of the stratum to be sampled. It may seem odd that more of the trace stratum is sampled than would be with proportional sampling, but there are only 12 list-plot clusters in the stratum. The stratum is large in terms of area but not large in numbers of nests or list-plot clusters.

The allocations for the area frame are shown in

Table 5: Costs (based only on flight miles) needed to obtain a sample with given precision requirements for an estimate of the total. The standard errors are those need to obtain the required effect size, power, and significance level

Notice that trace and low strata are sampled lightly both in relation to proportional sampling and to the size of the strata. Although large in area, the strata are very lightly sampled because they are not densely populated and are costly to sample. 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 any useful information on eagle populations due to the low abundances of nests. In the low stratum, potential habitat would have to be used in the selection and analysis.

Survey Sample Design Comparison

Given that samples are allocated optimally 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 8 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-frame sampling if one spends more than $20,000 for flight miles. There is not much difference between the dual-frame and the special dual-frame case of combined sampling.

Regarding 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). Each of these specifications determines a 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 costs 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.**

Effects of List Coverage

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 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.

The optimal allocation treats the same strata in the list and area frames as 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.

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. Finally, we combine sampling list clusters with the sample plots to further reduce the travel times among the sample units.

References

All documents prepared for notice and comment in the Federal Register must include literature citations for all scientific references used in it. The literature must also be labeled as belonging to one of the following categories: (1) citations of scientific work that are original research based on the collection and analysis of data, peer reviewed and published in the scientific literature; (2) citations of scientific work that are derived from analysis of scientific literature, peer reviewed and published in the scientific literature; (3) citations of scientific work based on the collection and analysis of data but not peer reviewed; (4) citations of scientific work that are based upon analysis of scientific literature but not peer reviewed; and (5) citations of information that are not based directly upon collection, analysis, and publication of data. This includes citations such as personal communications, anecdotes, and newspaper articles.

Bowman, T. D., and P. F. Schempf. 1999. Detection of bald eagles during aerial surveys in Prince William Sound, Alaska. J. Raptor Research. 33:299–304. (1)

Grier, J and J. E. Guinn., in Press. Bald eagle nesting habitat use and responses to human presence in Minnesota. Journal of Wildlife Management (1)

Haines, D. E., and K. H. Pollock. 1998. Estimating the number of active and successful bald eagle nests: an application of the dual-frame method. Environmental and Ecological Statistics 5:245-256. (1)

Hartigan, J. A. and Wong, M. A. 1979. A K-Means Clustering Algorithm. Applied Statistics 28, 100–108. (1)

Nichols, J. D. J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and H. J. Heglund. 2000. A Double-Observer Approach for Estimating Detection Probability and Abundance from Point Counts. Auk 117(2):393–408. (1)

Lohr, Sharon L., 1999. Sampling: Design and Analysis. Brooks/Cole Publishing Co., Washington, DC. 494pp. (3)

Paradis, Emmanuel. 2006. "mst: Minimal Spanning Tree," in The Analyses of Phylogenetics and Evolution Manual, http://cran.r-project.org/doc/packages/ape.pdf, p. 85--86. (5)

Sauer, John R. and Mark C. Otto. 2004. Maine Bald Eagle Pilot Project Standard Operating Procedures,Version 8. Unpublished report and Appendix 2 of this document. (2)

Sauer, J. R., J. E. Fallon, and R. Johnson. 2003. Use of North American Breeding Bird Survey data to estimate population change for bird conservation regions. J. Wildlife Management 67:372-389. (1)

Thompson, S. K. 1992. Sampling. John Wiley & Sons, Inc., New York, NY. 343pp. (3)

Thompson, William L. 2004. Sampling Rare or Elusive Species. Island Press., Washington, DC. 429pp. (3)

Tables

Table 1: Collapsing 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.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

State	Bird Conservation Region	Nests	Plots	Density	SE
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
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

State	Bird Conservation Region	Nests	Plots	Density	SE
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
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

State	Bird Conservation Region	Nests	Plots	Density	SE
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
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

State	Bird Conservation Region	Nests	Plots	Density	SE
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: Sample allocations for the list frame given an overall list coverage of 60 percent. The first column is the proportion of all samples that are allocated to the given stratum. The second is the percentage of samples that would be allocated to the stratum if proportional allocation were used (proportional to the size of the stratum). The last column is the first column normalized to the size of the stratum, e.g., a larger stratum with the same number of samples will be shrunk in proportion to its larger area.

Stratum	BCR Name	Of Total	Proportional Allocation	Of Stratum
FL	PENINSULAR FLORIDA	7.98	8.12	2.35
IA	PRAIRIE HARDWOOD TRANSITION	1.70	0.54	7.47
IL	PRAIRIE HARDWOOD TRANSITION	1.11	0.12	23.00
LA	MISSISSIPPI ALLUVIAL VALLEY	3.08	1.55	4.73
Low		12.31	38.93	0.76
MD	NEW ENGLAND/MID-ATLANTIC COAST	4.08	2.03	4.8
ME	ATLANTIC NORTHERN FOREST	6.00	4.77	3.00
MI	BOREAL HARDWOOD TRANSITION	8.18	7.84	2.49
MN	BOREAL HARDWOOD TRANSITION	8.33	6.55	3.03
MN	PRAIRIE HARDWOOD TRANSITION	6.40	2.61	5.86
MT	NORTHERN ROCKIES	7.41	3.76	4.70
OR	GREAT BASIN	2.59	1.68	3.68
OR	NORTHERN PACIFIC RAINFOREST	5.43	3.27	3.97
SC	SOUTHEASTERN COASTAL PLAIN	3.53	1.83	4.60
Trace		0.40	0.20	4.80
VA	NEW ENGLAND/MID-ATLANTIC COAST	2.70	0.86	7.51
VA	SOUTHEASTERN COASTAL PLAIN	2.75	1.60	4.10
WA	NORTHERN PACIFIC RAINFOREST	5.01	5.40	2.21
WI	BOREAL HARDWOOD TRANSITION	5.32	5.35	2.38
WI	PRAIRIE HARDWOOD TRANSITION	5.70	2.97	4.58

Table 4: Sample allocations for the area frame. The first column is the proportion of all samples that are allocated to the given stratum. The second is the percentage of samples that would be allocated to the stratum if proportional allocation were used (proportional to the size of the stratum). The last column is the first column normalized to the size of the stratum.

Stratum	BCR Name	Of Total	Proportional Allocation	Of Stratum
FL	PENINSULAR FLORIDA	6.09	1.39	3.85
IA	PRAIRIE HARDWOOD TRANSITION	1.19	0.09	11.45
IL	PRAIRIE HARDWOOD TRANSITION	0.18	0.04	3.98
LA	MISSISSIPPI ALLUVIAL VALLEY	4.68	0.51	7.99
Low		24.79	65.99	0.33
MD	NEW ENGLAND/MID-ATLANTIC COAST	0.66	0.25	2.30
ME	ATLANTIC NORTHERN FOREST	1.32	1.16	1.00
MI	BOREAL HARDWOOD TRANSITION	10.85	1.28	7.46
MN	BOREAL HARDWOOD TRANSITION	7.98	1.18	5.95
MN	PRAIRIE HARDWOOD TRANSITION	3.2	0.62	4.51

Stratum	BCR Name	Of Total	Proportional Allocation	Of Stratum
MT	NORTHERN ROCKIES	3.68	2.00	1.61
OR	GREAT BASIN	5.02	1.45	3.04
OR	NORTHERN PACIFIC RAINFOREST	3.67	1.07	3.02
SC	SOUTHEASTERN COASTAL PLAIN	2.27	0.68	2.92
Trace		0.43	19.33	0.02
VA	NEW ENGLAND/MID-ATLANTIC COAST	0.86	0.09	8.00
VA	SOUTHEASTERN COASTAL PLAIN	2.54	0.24	9.39
WA	NORTHERN PACIFIC RAINFOREST	5.57	0.77	6.34
WI	BOREAL HARDWOOD TRANSITION	8.50	0.61	12.29
WI	PRAIRIE HARDWOOD TRANSITION	6.52	1.25	4.56

Table 5: Costs (based only on flight miles) needed to obtain a sample with given precision requirements for an estimate of the total. The standard errors are those need to obtain the required effect size, power, and significance level

	Effect Size	Power	Significance Level	Standard Error	List	Plot	Dual-Frame	Combined-Dual-Frame
1	**0.25**	**0.8**	**0.10**	2025.2	74196	65186	24446	24195
2	**0.25**	**0.8**	**0.05**	1651.3	74196	93916	28007	27700
3	**0.25**	**0.8**	**0.01**	1213.4	74196	164268	36996	36546
4	**0.25**	**0.9**	**0.10**	1855.0	74196	76196	25803	25531
5	**0.25**	**0.9**	**0.05**	1536.3	74196	107016	29652	29318
6	**0.25**	**0.9**	**0.01**	1150.1	74196	180984	39190	38705
7	**0.10**	**0.8**	**0.10**	810.1	74196	337176	60853	60024
8	**0.10**	**0.8**	**0.05**	660.5	74196	475674	82011	80845
9	**0.10**	**0.8**	**0.01**	485.4	74196	765745	133586	131601
10	**0.10**	**0.9**	**0.10**	742.0	74196	391826	68968	68009
11	**0.10**	**0.9**	**0.05**	614.5	74196	534615	91640	90321
12	**0.10**	**0.9**	**0.01**	460.1	74196	826112	145791	143612

Figures

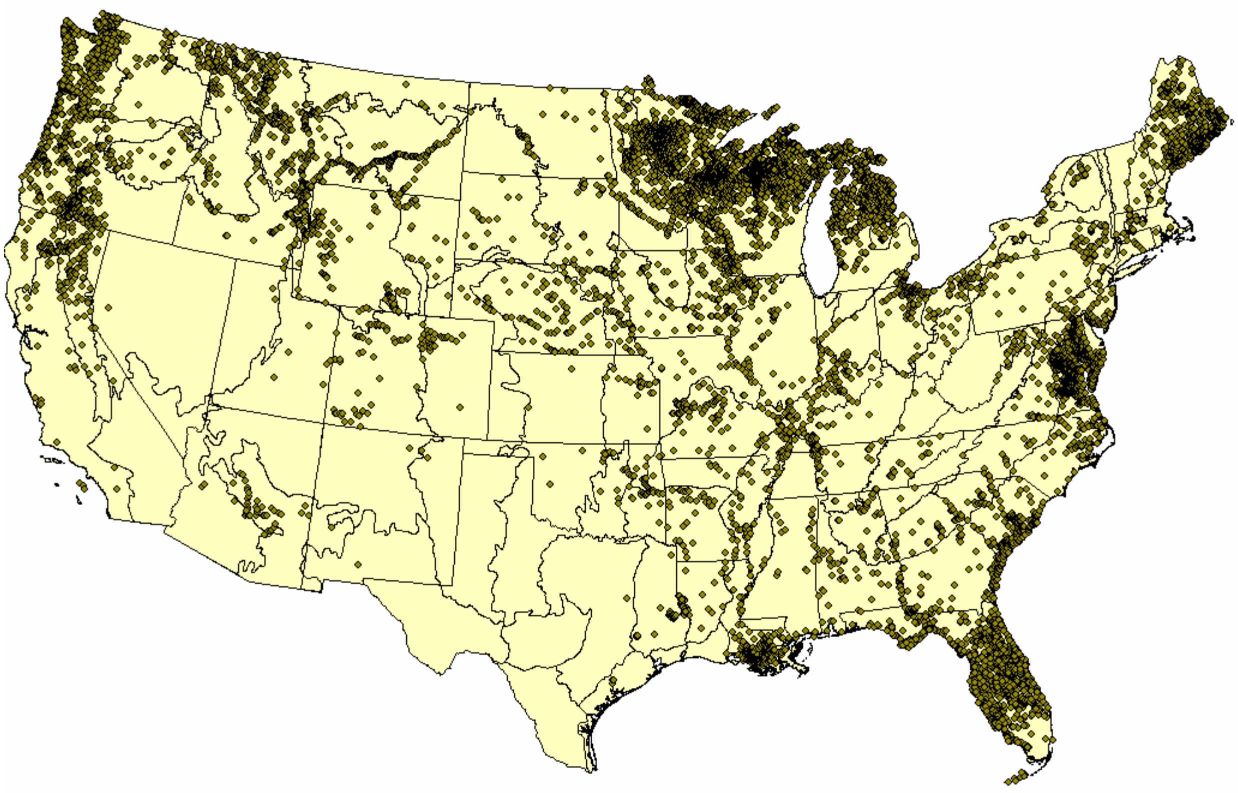


Figure 1: Distribution of bald eagle nests as determined from state lists.
These lists form the basis of one primary element of the sampling program, hereafter called the list frame. As in previous monitoring, these lists should be maintained and updated (by State biologists) throughout the post-delisting monitoring period. This can be done either through a census (observing all nests in the list), or through sampling (e.g., visiting a randomly-selected subset of the nests, or through a cluster sample, as described below).

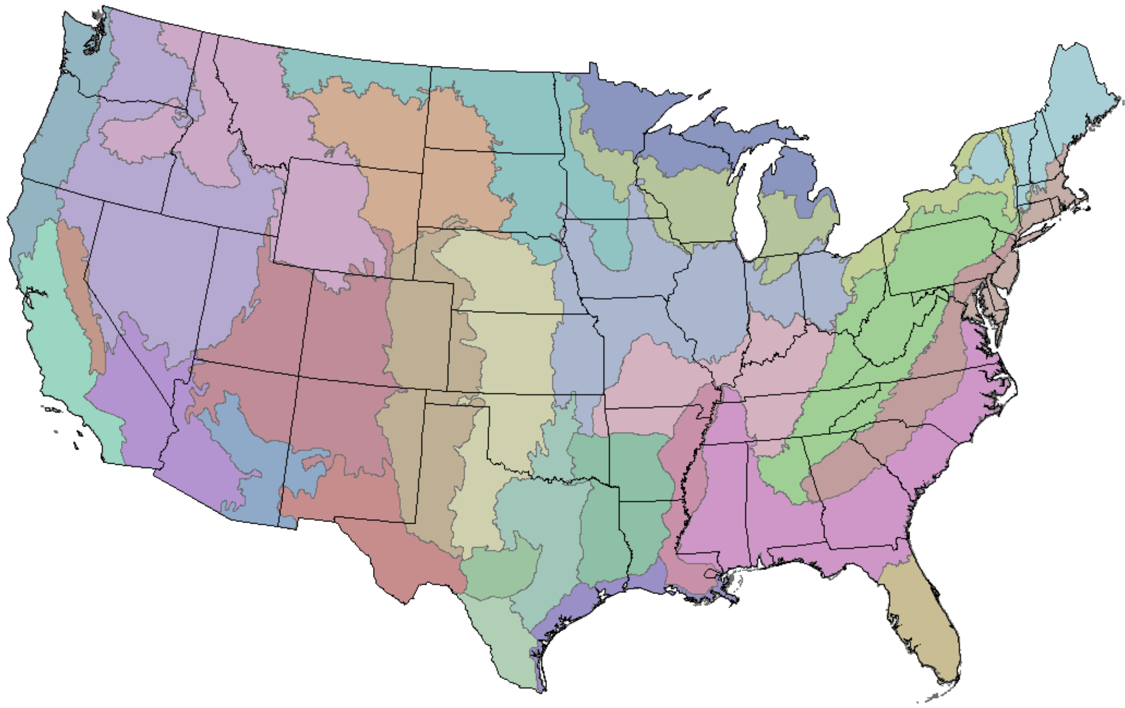


Figure 2: State boundaries and Bird Conservation Regions (BCRs) in the contiguous United States

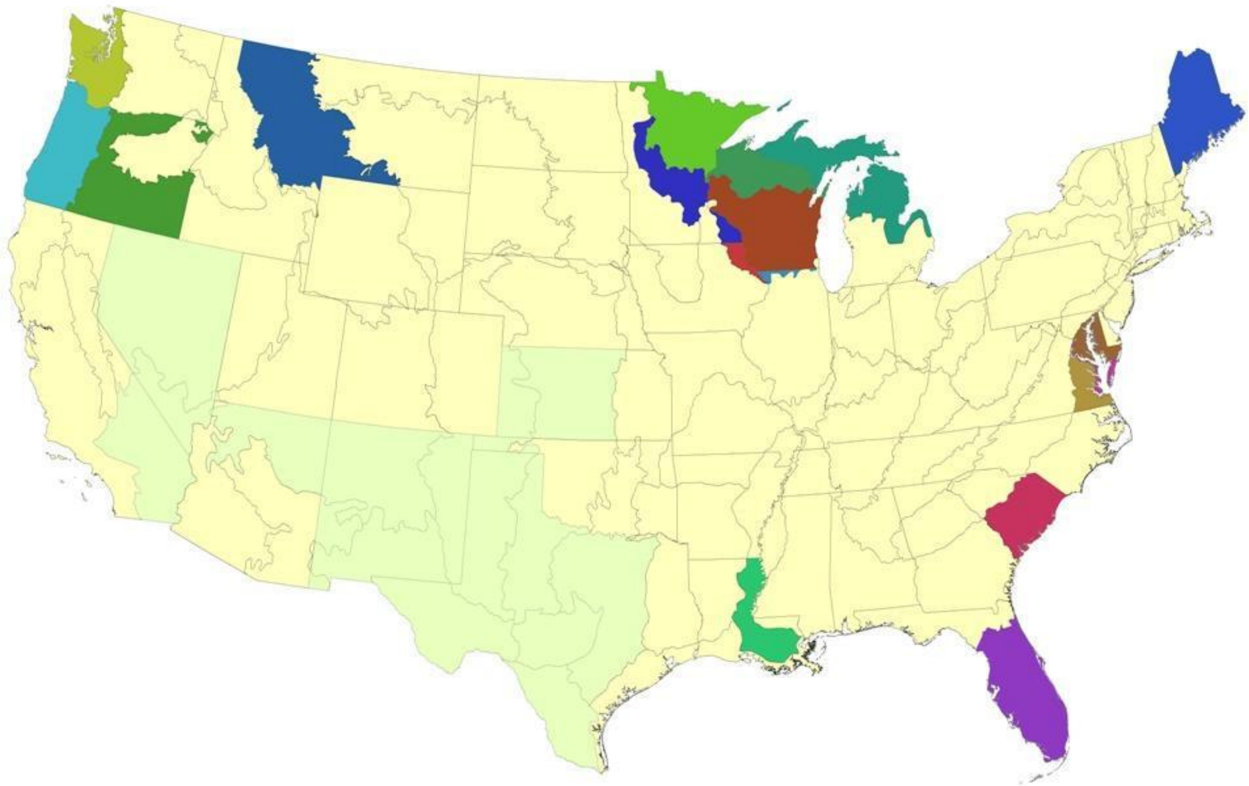


Figure 3: Strata after collapsing adjacent strata with similar nest densities. The collapsed strata are: Trace with only 12 nest in the stratum (light green), Low (the result of collapsing the similar low density strata, yellow), Washington and Oregon Northern Pacific Rainforest, Oregon Great Basin, Montana Northern Rockies, Peninsular Florida, Iowa, Illinois and Wisconsin Prairie Hardwood Transition, Minnesota, Wisconsin, and Michigan Boreal Hardwood Transition, Mississippi Alluvial Valley in Louisiana, South Carolina Southeastern Coastal Plain, Virginia and Maryland New England/Mid-Atlantic Coast, Virginia Southeastern Coastal Plain, and Maine Atlantic Northern Forest.

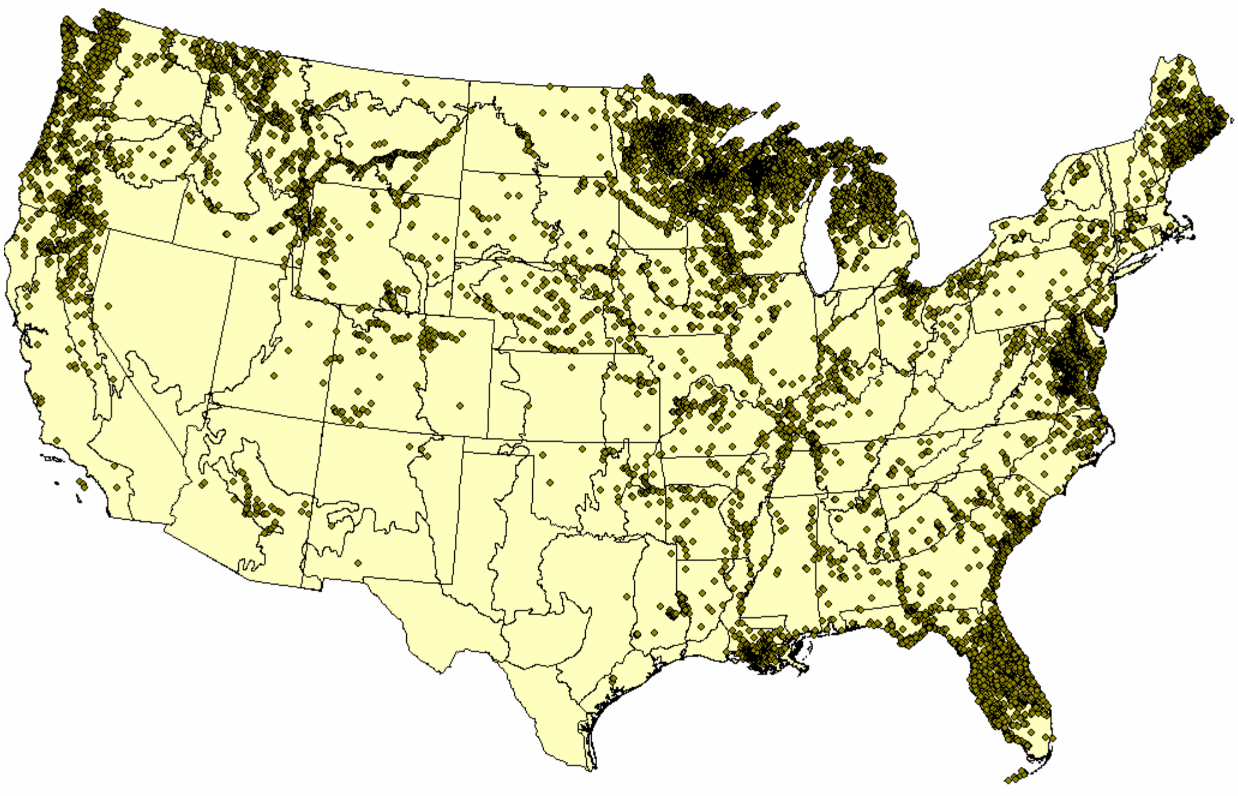


Figure 4: Distribution of bald eagle nests as determined from state lists.

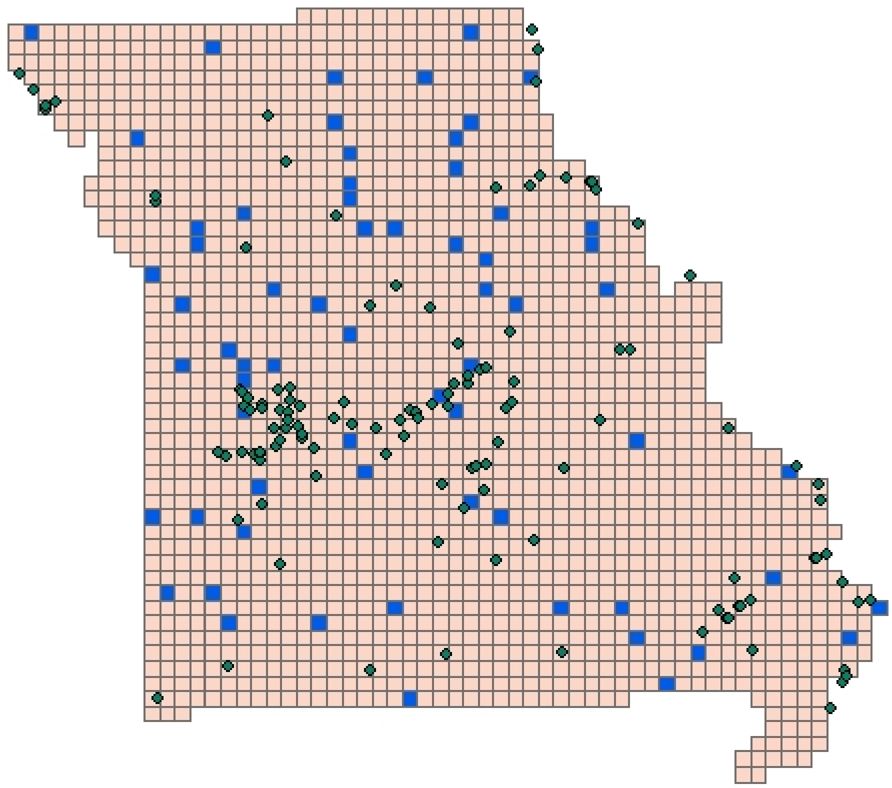


Figure 5: Missouri area frame consisting of 10km square plots. Shaded squares are the sample plots selected. Diamonds are the list nests selected.

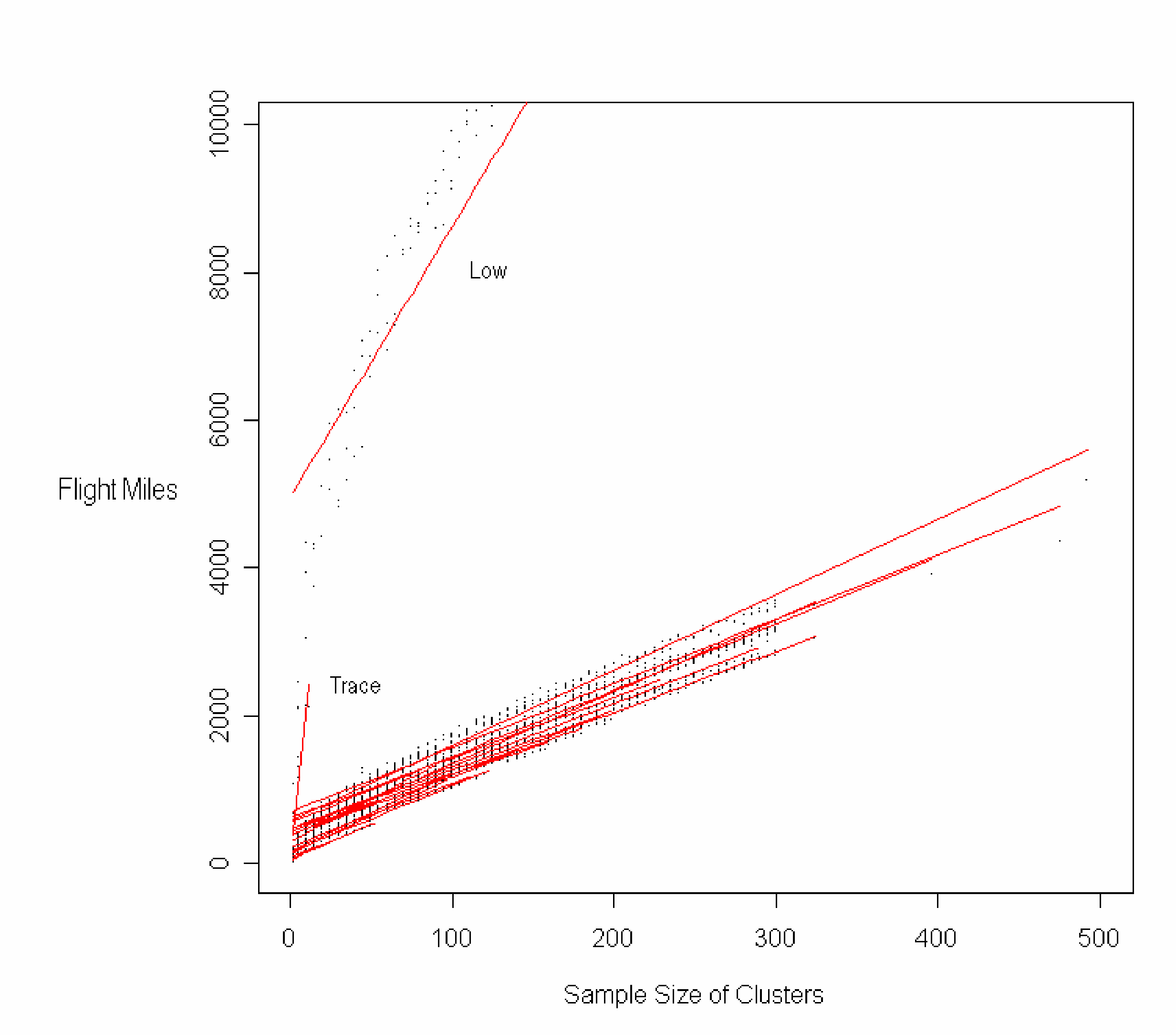


Figure 6: Number of miles needed to fly samples of a given number of list-plot clusters. Each line represents a collapsed stratum. Low and Trace are collapsed strata with low densities of bald eagles.

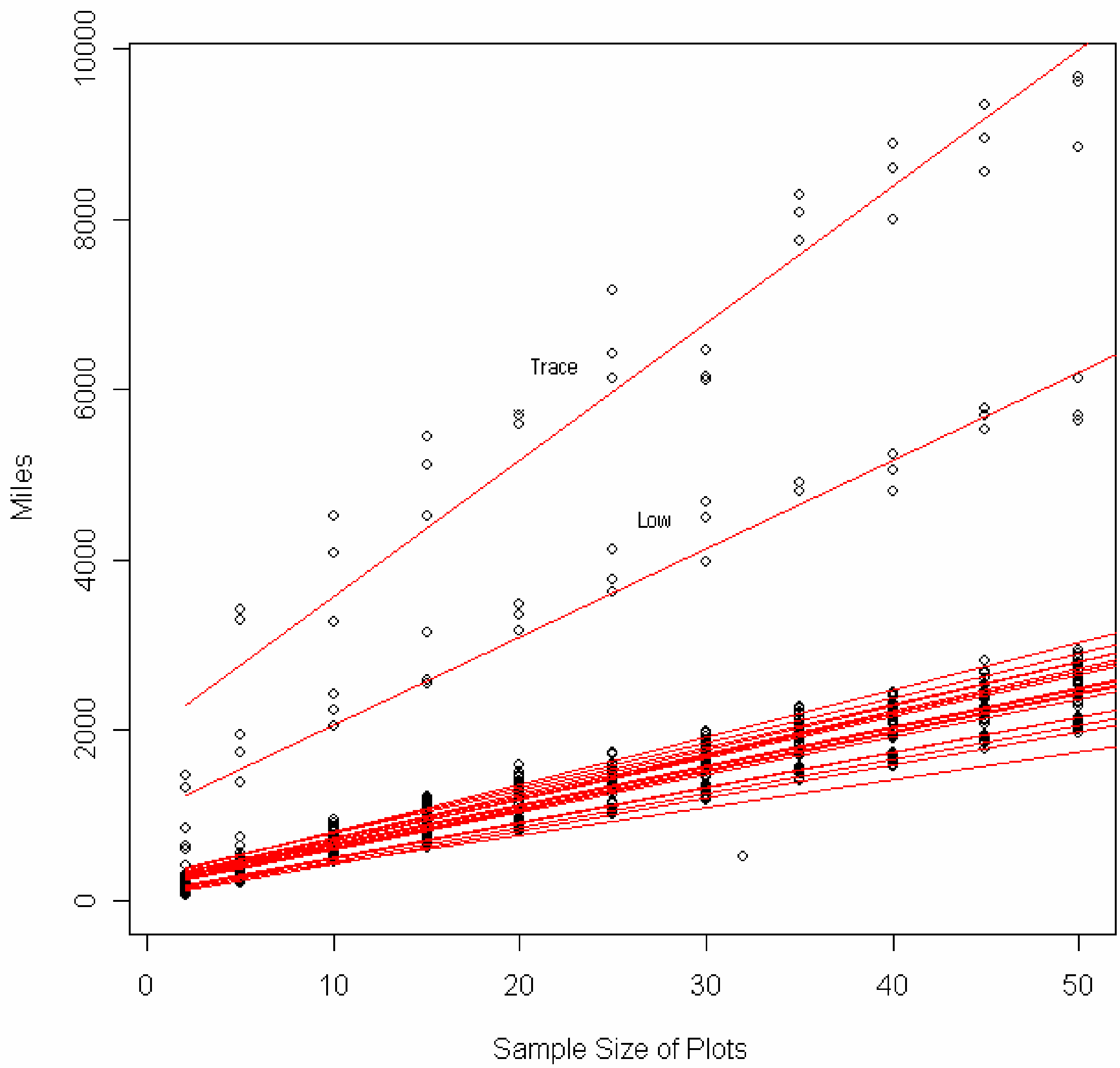


Figure 7: Number of miles needed to fly samples of a given number of plots. Each line represents a collapsed stratum. Low and Trace are collapsed strata with low densities of bald eagles.

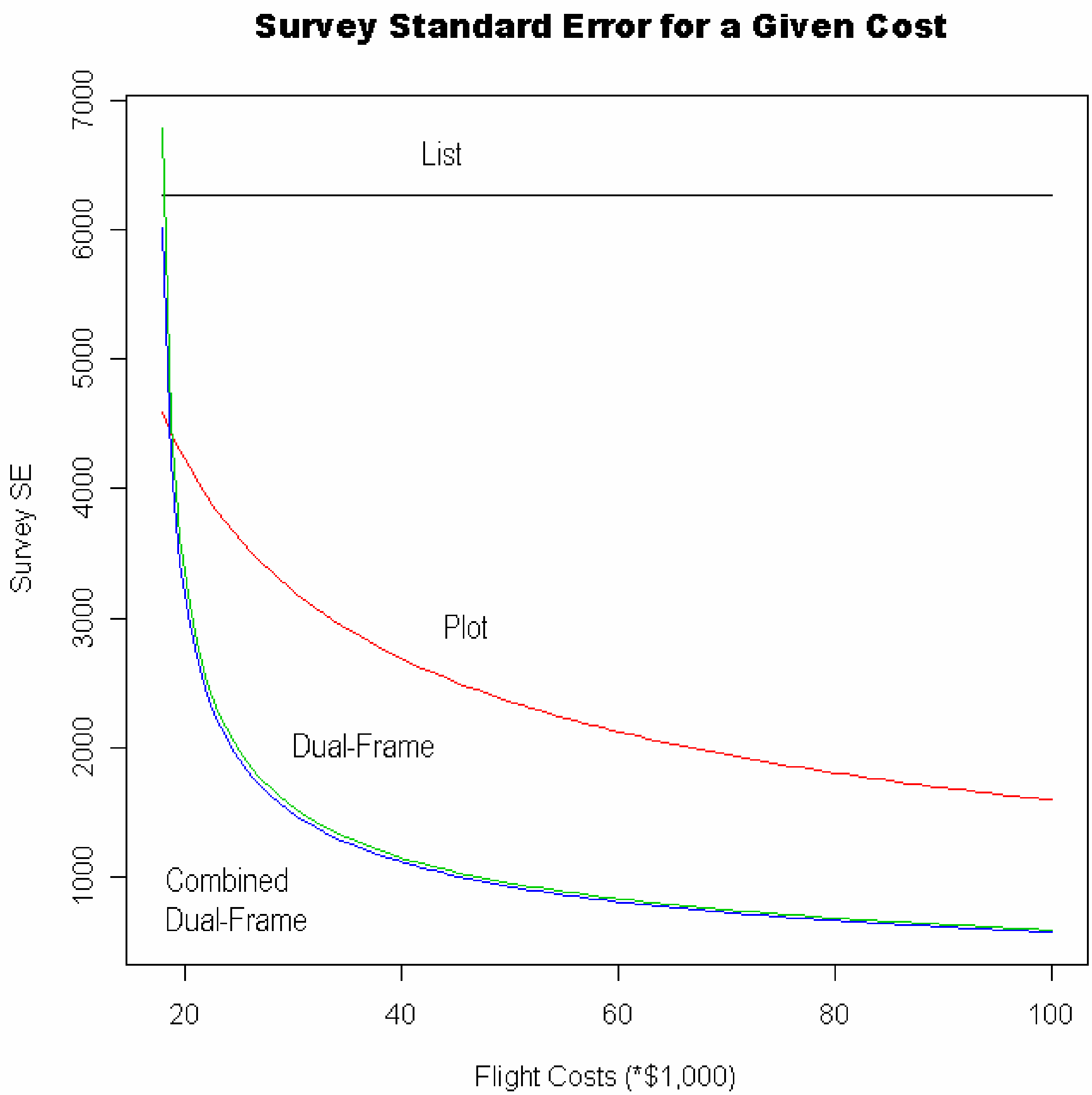


Figure 8: The standard error for a given costs for each sample design. The list-only design standard error is a mean square error that includes the bias squared. This bias is the major source of error and cannot be reduced by any amount of sampling, not even a census of the nest list.

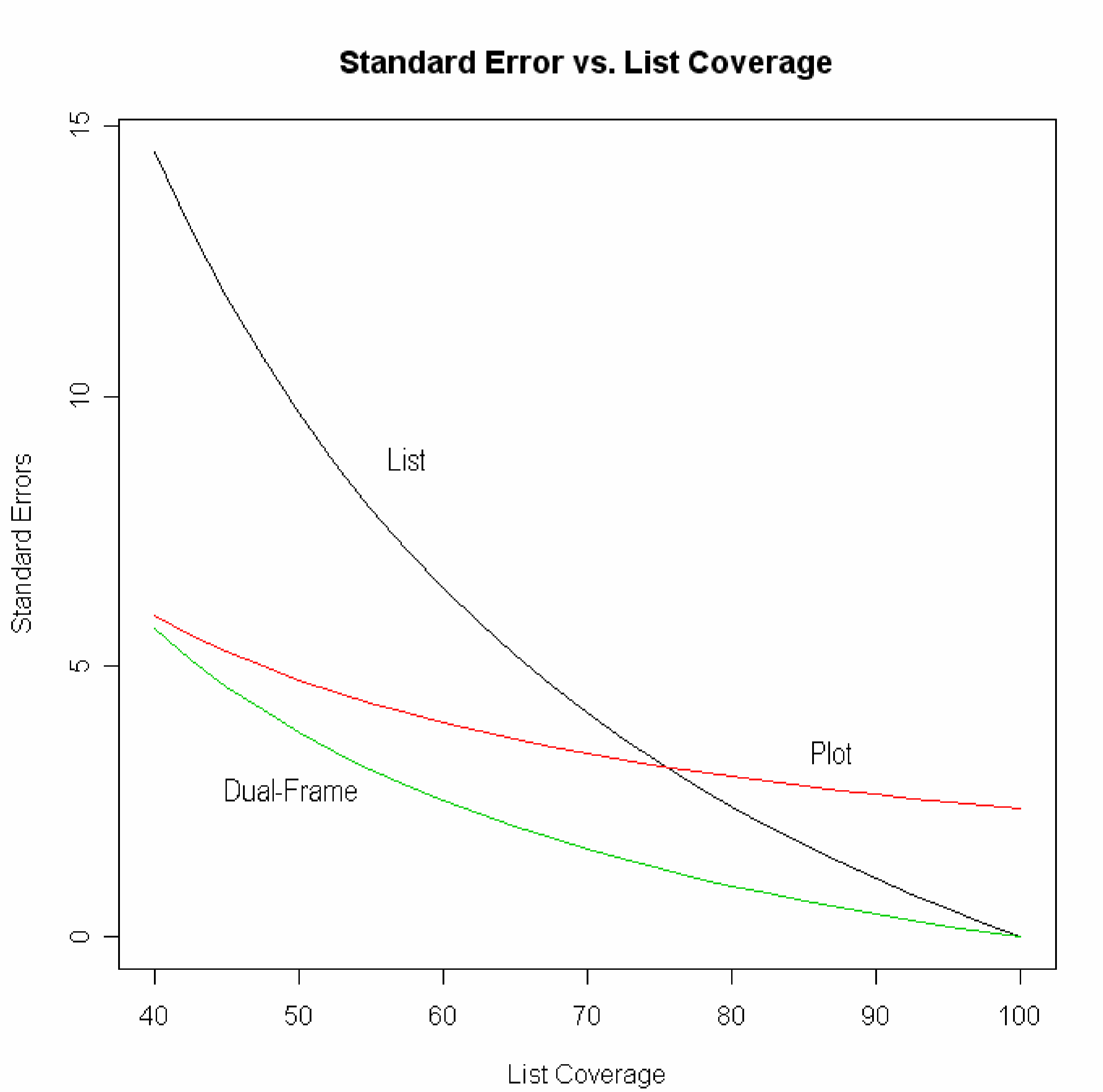


Figure 9: Standard errors for a given list coverage for each of the survey design options. These were calculated given the survey requirements are the stated survey goals. Note that when the list coverage is 40 percent the dual-frame design is equivalent to the plot-only design. The list-only design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

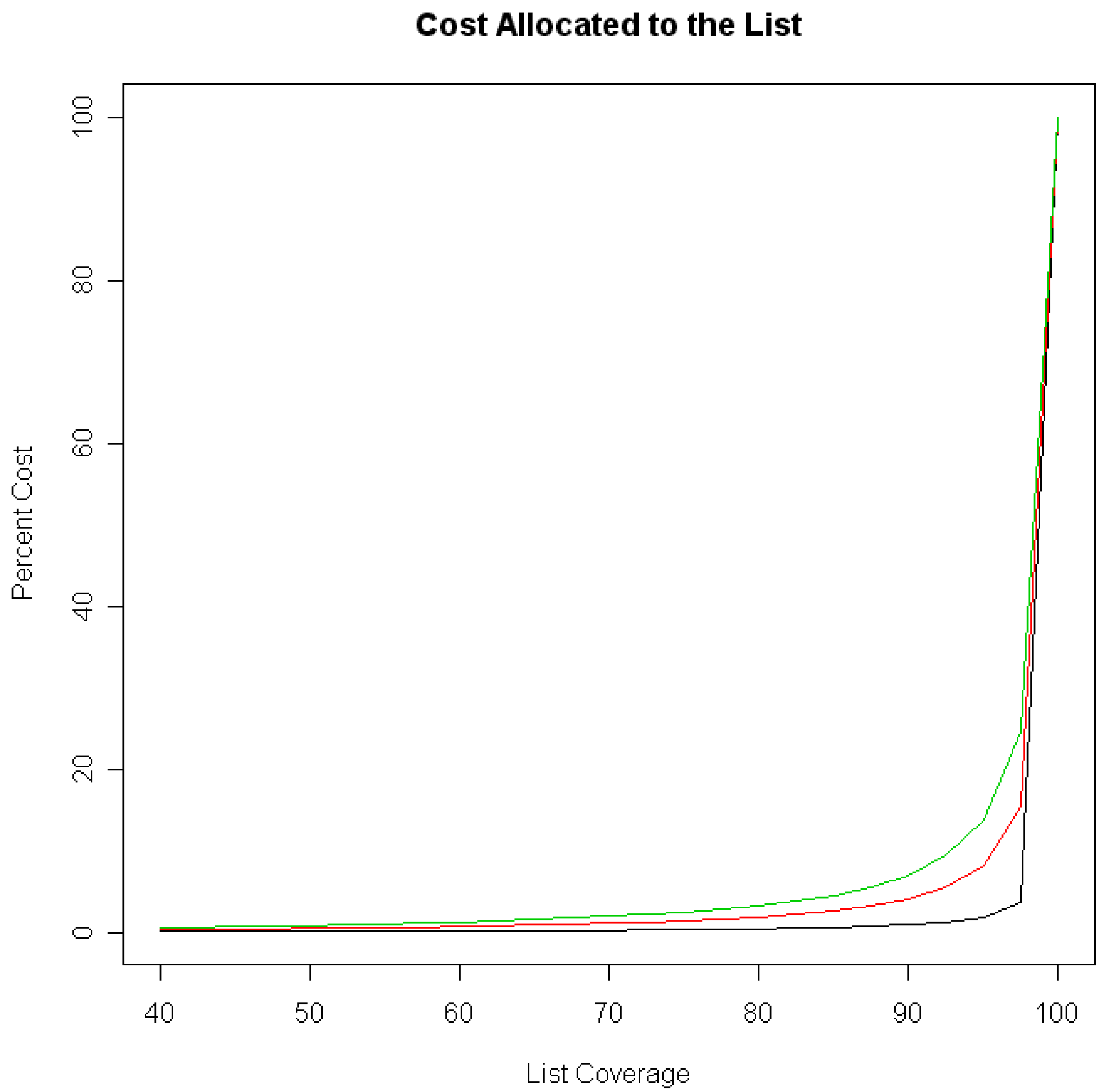


Figure 10: Proportion of the flight miles allocated to the list frame vs. the area frame given different list coverages. As the cost of the area frame increases and/or the variability decreases, more is allocated to list-frame as the two quicker rising curves show.

Appendix 2

Maine Bald Eagle Pilot Project Standard Operating Procedures
by John R. Sauer and Mark C. Otto
23 April 2004, version 8

Introduction

The sampling requires that observers conduct independent counting, but that communication occurs among observers 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.

Due to the need to count a similar area, consistent pairing of the rear seat observer's observations with at least one of the front-seat counters is essential, hence it is necessary to record whether the rear seat counter is on the pilot or passenger side. 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. 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 possible, 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.

This SOP is written as though the rear seat observer is on the right side of the plane. However, if the only seat available is behind the pilot, then the left side could be used for the multiple counting experiment. 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.

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 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).

Information to be collected

Nest, adult or immature eagle observations; which observers were looking, seeing, or missed the sighting; activity of individual birds (flying, perching, on nest (not incubating), incubating); nest status, and approximate distance from the plane will be collected. 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; Approximate perpendicular distance from flight line can be from 20 to 2500 meters; Behavior can be flying, perching, or on nest; and the location or nest tree type can be pine, spruce, (generic) conifer, deciduous, ground, or na. Additional information such as approximate height of nest [5 m increments], nest contents (number of eagles) if more than described by the "species" code, or whether the nest was seen while cruising or a secondary search should be included in the comment field. 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 section of the record.

Survey Notes

Make a text file of notes about weather, general observations, problems in the protocol, and ideas how to better the survey. Observations for each day can be made in the same file.

Recording Procedures

The front-right observer will reconcile and record observations for all three observers during the flight. Jack Hodges programs 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 plot and give the number. For contiguous plots say leaving number and entering number plot every time the plot changes.

The codes recorded will be as follows:

Code	**Hot Key**
ADULT	a
IMMATURE	m
UNKNOWN	u
EMPTY	e
INCUBATING	i
OCCUPIED	o
EGGS	g
EAGLET	l
BEGPLOT	b
ENDPLOT	n

The first three codes are for sightings off the nest: `ADULT`, `IMMATURE`, `UNKNOWN`. The next five are nest condition codes: `EMPTY`, `INCUBATING`, `OCCUPIED`, `EGGS`, `EAGLET`. Put fledglings, nest contents not described by the codes, experienced observer knew location of nest, etc. in the comment field after the number (usually 1) seen and a comma. `BEGPLOT` and `ENDPLOT` are recorded when entering and leaving each plot. The number field should have the plot number without leading zeros. From the plot codes, ferrying and time within plots can be determined.

Header variables are `Year`, `Month`, `Day`, `LFObserver`, `RFObserver`, `RRObserver`, `Plot`, `CapHist`, `AppxDist`, `Behavior`, `Location`. The fields should be separated by commas. Any comments should follow after the fields. Acceptable values of the header variables are shown in Table 1 in the format uses by the trnscrib program.

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

Year	2004	AppxDist	*meters*
Month	4-5	Behavior	fly
Day	1-31		onnest
LFObserver	*Consistent*		perch
RFObserver	*initials*		na
RRObserver		Location	pine
Plot	*Number*		spruce
CapHist	001		conifer
	010		deciduous
	011		ground
	01x		na
	0x1		
	100		
	101		
	10x		
	110		
	111		
	11x		
	1x0		
	1x1		
	1xx		
Plot	*Number*		
	x01		

	x10
CapHist	x11
	x1x
	xx1

The time will be set to the local time zone at the start of the survey, in this case Eastern Daylight Time. 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 State of Maine nest locations. **When transcribing, remember to save the new header variable values after each observation.**

A checklist for the observers to use in the plane is given as an 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 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 affecting visibility. Observers should not continue when overly fatigued. Because of nesting phenology, coastal plots should be flown first in the north-eastern portion of the State. Survey should be run before the trees leaf out.

Defining flight paths within plots: Only survey the parts of plots that occur in Maine. Plots are composed of eagle habitat and habitat in which eagles will not nest. Because eagles nest within 1 mi of water (i.e., coastlines, islands, inland ponds and lakes of >35 acres, and rivers >200m in width), 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 conducted along shorelines and in interior habitats along shorelines.

Shoreline transects: Surveys should be conducted first along edges of water bodies in plot 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. Area 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 transect cover area 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. Collect distance information from the line followed by the plane to the observation.

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

Observations: No notice should be made of observations until it is clear that the aircraft is beyond the observation and other observers would no longer be able to record it. In Alaska eagle surveys, this was determined by only reconciling observations after they passed the wind-tips, and the analogous measure for these surveys are angles relative to the midline of the plane (135 degrees for front-seat observer, 90 degrees for rear-seat observer). At that point, the observer making the observation should communicate with other observers and determine who else saw the observation. 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.

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).

OMB Approval No. _______
Expires __/__/__

Eagle and Nest Observation Checklist

1. **Begin 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. **Distance**: estimate distance in meters of a line parallel to the aircraft track
d. **Behavior**: flying, perched
e. **Location**: if perched on tree or ground

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. **Distance**: estimate distance in meters of a line parallel to the aircraft track
d. **Behavior**: on nest or perched
e. **Nest tree**: pine, spruce, (*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

4. **End plot #___**

****
The public reporting burden for completing this form is estimated to be __XX__ hours, including time for reviewing instructions, gathering and maintaining data, and completing and reviewing the forms. Comments regarding the burden estimate or any other aspect of the reporting requirement(s) should be directed to the Service Information Collection Clearance Officer, MS 222 ARLSQ, Fish and Wildlife Service, Washington, DC 20240.

An agency may not conduct and a person is not required to respond to a collection of information unless a currently valid OMB control number is displayed.
****

(FWS form # 3-2344)

Appendix 3

Fish and Wildlife Service Regional Bald Eagle Monitoring Coordinators

FWS Regions
Region 1: Regional Coordinator – Suzanne Audet *Suzanne Audet* Upper Columbia Fish & Wildlife Office 11103 E. Montgomery Drive Spokane, Washington 99206 *Tel* (509) 893-8002 *Fax* (509) 891-6748 Suzanne_Audet@FWS.gov States - CA, ID, NV, OR, WA, HI, Guam, American Samoa, Commonwealth of the Northern Marianas
Region 2: Regional Coordinator – Greg Beatty ***Greg Beatty*** Arizona Ecological Services Field Office 2321 West Royal Palm Road, Suite 103 Phoenix, Arizona 85021 *Tel* (602) 242-0210 x 247 Greg_Beatty@FWS.gov States -   AZ, NM, OK, TX
Region 3: National Coordinator – Jody Millar *Jody G. Millar* Rock Island Ecological Field Office 1511 47th Ave. Moline, IL 61265 *Tel* (309) 757-5800 x 202 *Fax* (309) 757-5807 Jody_Millar@FWS.gov States -   IL, IN, IA, MI, MN, MO, OH, WI
Region 4: Regional Coordinator – Candace Martino (Jacksonville) and Al Begazo (South Florida) *Candace Martino* Jacksonville Field Office6620 Southpoint Drive South, Suite 310 Jacksonville, FL 32216-0958 Tel: 904-232-2580 x 129 Fax: 904-232-2404 Candace_Martino@FWS.gov *Alfredo Begazo* South Florida Ecological Services Office

1339 20th Street
Vero Beach, FL 32960
Phone:(772) 562-3909
Fax: (772) 562-4288
Alfredo_Begazo@FWS.gov

States - AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, PR,VI

Region 5: Regional Coordinator – Craig Koppie
Craig Koppie
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401
Tel (410) 573-4534
Fax (410) 269-0832
Craig_Koppie@FWS.gov

States -   CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT, VA, WV, and Washington, D.C.

Region 6: Regional Coordinator – Dan Mulhern
Dan Mulhern
Kansas Ecological Services Field Office
2609 Anderson Avenue
Manhattan, Kansas   66502
Tel (785) 539-3474 ext 109
Fax: 785 539-8567
Dan_Mulhern@FWS.gov

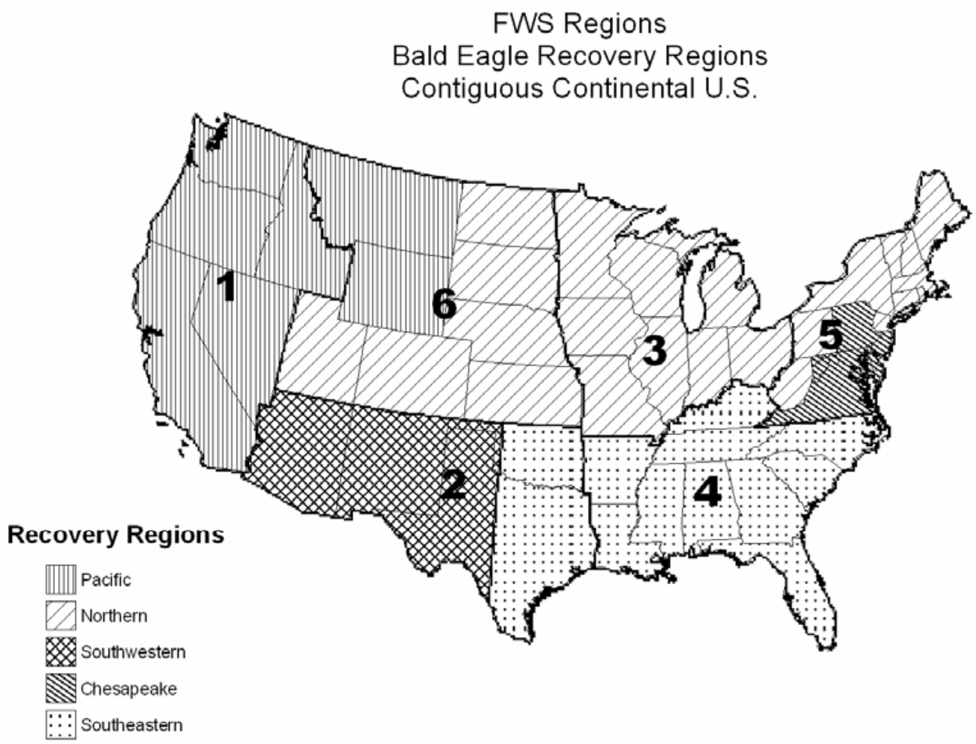
States: CO, KS, MT, ND, NE, SD, UT, WY

Region 7: Regional Coordinator – Phil Schempf
Phil Schempf
Migratory Bird Management-Raptors
3000 Vintage Blvd., Suite 240
Juneau, Alaska 99801
Tel (907) 586-7331 or 7243
Fax (907) 586-7378
Phil_Schempf@FWS.gov

State - AK

Region 9: Washington, DC Endangered Species
Mary Klee
USFWS, 4401 N. Fairfax Drive
Mail stop 420 ARLSQ
Arlington, VA 22203
Tel *(703) 358-2061*
Fax: 785 539-8567
Mary_Klee@FWS.gov

Michelle Morgan, Chief – Branch of Recovery & Delisting
USFWS, 4401 N. Fairfax Drive
Mail stop 420 ARLSQ
Arlington, VA 22203
Tel (703) 358- 2061
Fax: 785 539-8567
Michelle_Morgan@FWS.gov



Appendix 4:

OMB Approval No. _______
Expires __/__/__

Bald Eagle Mortality Report Form

With the assistance of State agencies and non-governmental organizations, the U.S. Fish and Wildlife Service is monitoring the status of the bald eagle. Tracking deaths of adult and immature bald eagles is an important component of that monitoring. These forms are being distributed to State conservation agencies, wildlife rehabilitators, and Fish and Wildlife Service law enforcement personnel. Please complete this form if a bald eagle dies while in your possession or if you collect a bald eagle that is already dead. Send the completed form to:

U.S. Fish and Wildlife Service

Your Name: ____________________________________

Organization: ____________________________________

Address: ____

E-mail: ____

Phone: ____

Date Bald Eagle Died or was Collected Dead: _________________________________

Location where Bald Eagle was collected, alive or dead:
____

Fate of Bald Eagle Carcass: Locations where it was analyzed and where was it disposed (i.e. Eagle espository)____
____

Cause of Death:
- Road Kill: _____
- Electrocution: ______
- Shooting: _______
- Collision with Building: ______
  - Wires: _____
  - Other (indicate what): ______________________
- Avian Vacuolar Myelinopathy: ________________________
- West Nile Virus: ____________________________
- Other Disease (indicate what): ____________________________
- Unknown: _________
- Poisoning:__________________________
- Other (indicate what): ______________________

****
The public reporting burden for completing this form is estimated to be __XX__ hours, including time for reviewing instructions, gathering and maintaining data, and completing and reviewing the forms. Comments regarding the burden estimate or any other aspect of the reporting requirement(s) should be directed to the Service Information Collection Clearance Officer, MS 222 ARLSQ, Fish and Wildlife Service, Washington, DC 20240.

An agency may not conduct and a person is not required to respond to a collection of information unless a currently valid OMB control number is displayed.
****

(FWS form # 3-2343)

Appendix 5: Glossary

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. Many times schools are chosen as clusters because it is difficult to get permission to sample each school. Then, students within only 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 lower 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, and 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 according to given criteria. Usually choosing the parameter so the value of some 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 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: Is the percentage you will allow your estimates to be significant just by chance when there is really not significant difference. 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 5 percent of the time. 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. For example, the standard error of the mean is the standard deviation divided by the square root of the sample size.

Stratum: Partition of the population so that the units within each stratum are as similar as possible and as different as possible among the partitions. You may also stratify where sub-estimates are required. We divide the lower 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.