

Recommended Methods for Inventorying and Monitoring Landbirds in National Parks

Steven G. Fancy, National Park Service Inventory and Monitoring Program, 1201 Oak Ridge Dr., Suite 200, Fort Collins, CO 80525.

John R. Sauer, USGS/BRD Patuxent Wildlife Research Center, 11510 American Holly Dr., Laurel, MD 20708.

Key points in this document:

- Dozens of different approaches are used to sample birds in North America, and there is no single method that can be used to sample all species. Survey methods tend to be developed to sample groups of species that share common habitats (e.g., waterfowl, shorebirds), although some surveys are aimed at single species (e.g., piping plovers). Here, we focus on methods that sample bird in terrestrial habitats such as forests, grasslands and deserts, and provide references to sampling methods for other groups such as shorebirds and seabirds.
- As in all biological surveys, there are 2 general principles to consider:
 - All areas for which you want information must have a chance of getting sampled by the survey, and survey results do not apply to areas that are not sampled.
 - Biological survey methods tend to miss animals during the actual counts, as individuals and species are not detected by a simple count. Some sampling methods (such as distance sampling) allow for estimation of the detection rates, and others (such as simple point counts) do not. For most objectives, it is necessary to use methods that allow for estimation of the detection rates.
- The recommended method depends on the objective of the survey.
 - If the purpose is simply to generate a checklist of birds in a park, the best approach is to have qualified observers go to all of the interesting areas in the park and record what they find using a “microatlas” approach.
 - If the purpose is to get some idea of distribution by species and a qualitative assessment of relative abundance such as “abundant”, “common”, or “rare”, then point counts or strip counts or some sort of index method are suitable.
 - If the manager is interested in comparing bird abundance among species, habitats, or sites, or in determining trends in population size, then it is critical to implement additional procedures to ensure consistency over time and space, primarily by adding some measure of detectability, and we recommend distance sampling (line transect or variable circular plot [VCP] sampling) or double-observer (DO) methods.
 - If the objective is to obtain information on primary demographic parameters or vital rates (productivity and survivorship) to help determine causes of bird population trends, we recommend constant-effort mist netting and banding such as used by the MAPS (Monitoring Avian Productivity and Survival) program.
- We do not recommend use of traditional (or unadjusted) point counts for estimation of abundance.
 - In point counts, a single observer stands at a sampling point and records the number of individuals of each species heard or seen during a specified time period without any attempt to estimate detectability.
 - Although this method is used in the North American Breeding Bird Survey (BBS), point counts cannot be reliably used to compare bird abundance among species, different habitat types, or among observers. Because surveys are done in many habitats by many

observers in National Parks, point counts will not provide acceptable information for the GIS applications and other likely uses of bird data.

- We recommend that point count protocols can be modified using VCP or double-observer methods to allow estimates of detectability for many species and yet still allow comparisons to historical data obtained with unadjusted point counts.
- Use of methods that allow for estimation of detectability are recommended for projects funded by the NPS Inventory and Monitoring Program. We think that the improvement in the quality and credibility of data compared to that obtained by unadjusted point counts more than justifies the increase in cost and effort required to incorporate an estimate of detectability.
- Distance sampling or the double-observer approach are the default methods. Any proposal to use unadjusted point counts or some other index method when the objective is to compare differences among species or provide population trend information must provide good justification for why the better methods cannot be used.
- Although distance sampling requires additional training and is not a panacea for all species, it can and is being done throughout the country in many types of habitats.

Introduction

Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Moreover, birds have a tremendous following among the public, and many parks provide information on the status and trends of birds in the park through their interpretive program. More than 650 species of birds breed in North America. Most common survey methods allow simultaneous collection of information about species that share a common life history or habitat, but no single method will adequately sample the diversity of either habitats that birds occupy or life history groups such as seabirds, songbirds, raptors, and shorebirds all bird species. Hundreds of different sampling approaches have been used to quantify status or trend of bird populations, and dozens of different monitoring programs are currently in place throughout North America to determine local, regional, or national trends in bird numbers. The website <http://www.mp1-pwrc.usgs.gov/birds.html> has information on 20 different bird monitoring programs used in North America.

The purpose of this document is to help busy natural resource managers in national parks (and their contractors and cooperators) find the most appropriate methods for inventorying and monitoring bird populations in the hopes of developing some consistency in bird sampling approaches among parks and regional efforts. The appendix lists some recommended methods and sources of additional information for surveys of raptors, shorebirds, marsh birds, and colonial-nesting birds, but our focus is on methods that are appropriate for simultaneously sampling a large number of terrestrial bird species in a variety of habitats such as forests, deserts and grasslands. We identify some of the problems with existing programs that should be avoided, and highlight some of the promising, recent developments in the art and science of bird counting that people may not be aware of.

We think that it is especially important to use consistent methods to sample birds so that data can be compared among parks and to samples taken outside of parks. Sample sizes for bird surveys in parks will usually be small because of limitations of personnel and funding, and comparison with other sites will help put the park's data in context and may help to interpret the results. Because of the annual variability in most biological indicators, it may require 10 or more

years of data to identify population trends. By adding the spatial dimension (comparisons to other locations) to the temporal dimension (repeated surveys over time), it may be possible to identify patterns sooner, and to develop partnerships to respond to problems that are identified.

In the next sections, we identify 4 general objectives, and discuss approaches to meeting the objectives. In our view, any survey must be reviewed in light of 3 primary concepts: (1) **Objectives** – to adequately develop a survey, some goal must be clearly stated so that the design can be specified and a clear product will be produced that can be evaluated by predefined criteria; (2) **Sampling Frame** – to conduct a statistically valid survey, you have to randomly select samples from a list of all possible samples. The list is called the sampling frame. This sampling frame defines the area to which your survey actually applies, and must be defined as part of the survey development; and (3) **Detectability** – we miss birds during counting, and to conduct a credible survey we either have to assume that the number missed does not vary over space and time or we have to incorporate some method of figuring out how many birds are missed. For each objective, we briefly note some of the issues associated with sampling frames and detectability.

Objective 1: The goal of the survey is to simply document which species occur in the park.

The recommended approach here is to have qualified birders go to different areas of the park and record which species they find there to produce a checklist. A good inventory usually requires multiple visits and methods at different times of the year in order to document the rare species that are often of greatest interest. A fairly complete inventory may require considerable effort to survey all habitats and different seasons to increase the chance of detecting most species that occur in the park.

The park must provide some structure to this effort to ensure that the information will be credible. The following should be kept in mind as you plan the inventory: (1) **Evaluate and document the skill level of each observer** - Observers should be able to identify all birds that might be seen in the park; the success and credibility of the survey will depend on using well-trained, experienced observers; (2) **Record keeping** – survey data including species encountered, locations, dates, evidence of breeding status, and other relevant information must be appropriately stored in computer files; (3) **Taxa and habitats of interest must be adequately surveyed** - as in all surveys, if some areas (or species groups) are not sampled, we cannot claim to have surveyed them.

To ensure adequate and extensive coverage, we recommend that a “sampling framework” such as a grid or some other map-based areas be developed, and that sampling be encouraged in all areas. A grid (such as UTM cells) could be placed over the park, and observers asked to keep separate lists for each cell in the grid. In that way, information can be integrated with other park data using the park GIS at the scale of the grid cells. Other possibilities for collecting information at more local scales include defining areas (strata) for surveying based on permanent features such as roads, trails, rivers, or other features. We also suggest that particular habitats and species groups be targeted for special counting effort.

Estimating Total (and Relative) number of Species - Of course, no one will count all species, and it is difficult to figure out how much sampling is sufficient to get a good species list. One approach is to use statistical procedures with checklist data to estimate the number of species missed (i.e., the detectability of species) during counting. These procedures, which have been applied to bird count data (e.g. Boulinier et al. 1998), are based on capture-recapture

methods, in which a “capture” is a species seen by a birder and the total number is estimated from the pattern of species’ occurrences among birders. Using these procedures, it is possible to calculate species richness for the park, or for different strata within the park (e.g., different vegetation types or elevation zones; see the paper by Nichols and Conroy 1996). The programs CAPTURE and SPECRICH, available at <http://www.mbr-pwrc.usgs.gov/software.html>, allow you to enter data from one or more surveys and calculate species richness online. These procedures do not identify species that are not seen, but they do provide an estimate of the number of species that have not yet been encountered but are likely to be present. This allows an assessment of the adequacy of the sampling that has been conducted (e.g., have you recorded 90% of the species that occur in the park?)

To estimate species richness for the entire park or for different strata within the park, you should have people with similar skill in detecting birds visit each of the areas of interest and generate a checklist using some standardized approach that will ensure that they could encounter all the targeted species. Each observer must be capable of identifying each species, and each species must have some chance of being detected. Hence, to survey a subset of species such as nocturnal birds or marsh birds (that only call at night or when stimulated by playback of recordings), all checklist participants must maintain a protocol that would allow them to encounter the species. Generally, 5 replicate checklists are needed for each sample site to apply the statistical estimation procedures (Nichols and Conroy 1996).

Objective 2: The goal of the survey is to determine distribution and get a qualitative measure of relative abundance (“abundant”, “common”, “rare”) of each species in the park.

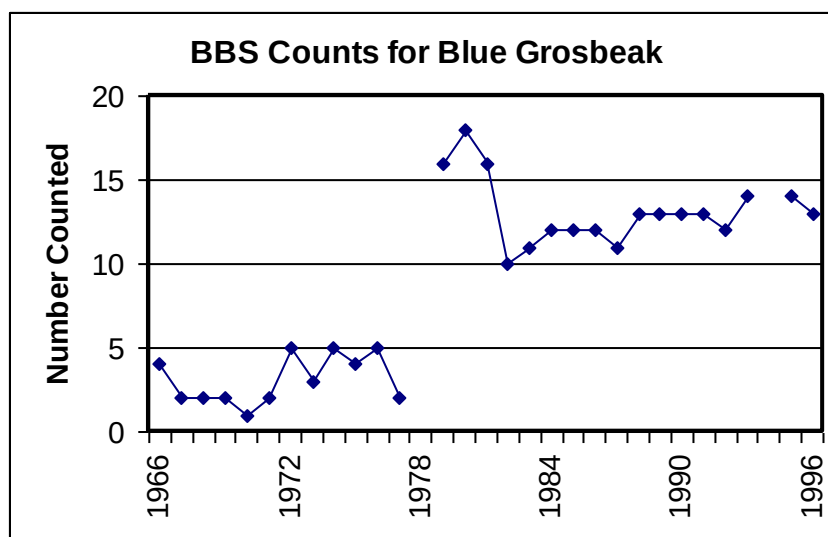
There are many different ways to generate distribution maps using either direct sampling or modeling approaches, but in each case it is important to develop a statistical sampling design that allows inferences to be made beyond the areas actually sampled. The document “Guidance for the design of sampling schemes for inventory and monitoring biological resources in national parks” available at <http://science.nature.nps.gov/im/monitor> gives some examples of how to select sample sites such that data from those sites can be used to make inferences to specific strata or the entire park.

One method appropriate for this objective is the standard (or “unadjusted”) Point Count, in which an observer stands at a predefined location and counts birds with a specific protocol. The Point Count method is currently the most common method of monitoring birds, and is used in the BBS, National Wildlife Refuge monitoring programs, National Forest monitoring programs (e.g. Manley et al. 1995), and to assist management efforts associated with Partners in Flight (Ralph et al. 1995). Counts are usually most effective during the breeding season, when singing rates are higher. Details of the method and field data forms are available in Ralph et al. (1995).

Point counts provide a great deal of information, and are generally easy to implement. They can be used to estimate species richness by strata, and the results can be used to classify the relative abundance of each species into categories such as “abundant”, “common”, “uncommon”, and “rare”. Standardization of methods and observer training is essential in ensuring some level of comparability of results. The difficulty with point counts is that people often use the results as a measure of differences in bird population size over time or among locations. Unfortunately, the number of birds that are counted at a sampling station is actually a combination of the

number of birds that are actually there, and the proportion of them that you detect. Many people interpret differences between two point counts as the difference in number of birds, when in fact the difference may be caused entirely by differences in detectability. Without a measure of detectability, counts of birds are an unreliable measure of differences in the actual number of birds present. Burnham (1981) wrote that “Without estimating detection probabilities, the use of counts as indices of abundance is scientifically unsound and unreliable”. Barker and Sauer (1995) found that the incomplete counts obtained by point counts “can bias estimators and testing procedures, leading to inappropriate conclusions. A large portion of the variability in point counts is caused by the incomplete counting, and this within-count variation can be confounded with ecologically meaningful variation”. Nichols et al. (2000) wrote that “We believe that most questions meriting the effort required to carry out point counts also merit serious attempts to estimate detection probabilities associated with the counts”. We concur.

An example of the problem is shown in the following count data for Blue Grosbeak along a Breeding Bird Survey route:



The counts of Blue Grosbeak obtained on this BBS route suggest that the population has increased during the 30-year period of 1966-1996, with a major population increase between 1978 and 1982. However, based on data from other BBS routes and various studies, there is no indication that the Blue Grosbeak population has actually increased. The pattern of counts shown above may have resulted entirely from changes in observers that ran this particular BBS route. The counts between 1966 and 1977 were obtained by one observer, then another observer ran the route in 1979 and in 1981-1984, a third observer did the 1980 count, a fourth observer did the 1986 count, and a fifth observer did the 1995-1996 counts. The apparent quadrupling of the population between the 1960s and 1980s was apparently due to the observer change, which numerous studies have shown is a major problem with bird surveys. Observer effects such as this are accommodated in the BBS analysis of population change through use of covariates (i.e., change is only estimated within an observer's data), but even in a survey as consistently run as the BBS there are important unresolved issues associated with our inability to distinguish real population change from changes associated with observers, weather, and other factors that have nothing to do with the population.

Differences in detectability can lead to misleading results even when the same observer conducts all of the point counts. To give a simple example, let us say that the average count for Species X in spruce forests is 2.0 birds/count compared to 4.0 birds/count in open shrublands, suggesting that the species is twice as abundant in the shrublands. However, if the probability of detecting the species in spruce forest is lower because you can't see as far and can't hear as far, then the true difference in abundance between the two habitat types may be very different, and the raw counts are a misleading measure of relative abundance. The same is true when comparing one species to another: some species are more showy and vocal than others, resulting in higher counts, and yet the more cryptic or quiet species may actually be more abundant. Unfortunately, remarkably small differences in detectability (e.g., < 9%) can lead to statistically significant differences in counts (Sauer and Link, in press). Without a measure of detectability, point counts can always be criticized when used to compare differences in abundance among species, habitats, different time periods, or places. The counts can, however, be used to obtain information on distribution and to assign qualitative measures of abundance to a species such as "lots of them" or "very few of them".

Note: These comments just begin to touch on an important controversy in biological sampling. Estimation of detection rates is considered by statisticians to be essential in any sampling that is not a "census." As biologists with field experience, we are sympathetic to the need to develop feasible methods. However, it is essential that the information be scientifically credible and defensible so that it can be relied upon to make resource management decisions. In our view, point counts that do not incorporate some procedure for estimating detectability do not meet this standard.

One common modification of point counts is to play recorded calls to increase probability of detecting rare or secretive species such as marsh-breeding or nocturnal species. Sample protocols for these species are referenced in the Appendix. Because the number of species encountered in these surveys is usually quite small, it is difficult to apply the statistical methods for estimating species richness, and the counts of both species and relative abundance of species are used as the dependent variables. It may be practical to include the playback procedures at a subset of points in habitats appropriate to the targeted species. Broadcasting the taped calls after the standard count period could increase the chance of detecting the targeted species.

Objective 3: The goal of the survey is to compare relative abundance among species, habitats or areas, or to detect trends in population size.

As indicated in #2 above, the number of birds you count at a sampling station is a combination of the number that is actually there and the proportion of them that you detect during the count. Very rarely do you count all of the birds that are actually present, and to meet the objectives stated in #3 you need to estimate the proportion of birds that you miss. We recommend that you use one of two methods to meet this objective: either Distance Sampling or the Double Observer Approach. Each is explained below, with greater emphasis on Distance Sampling because it is the most established of the two and can be conducted by only one person.

Distance Sampling.

Distance sampling, which includes both line transect sampling and variable circular plot (VCP) counts, has been used for more than 30 years to estimate animal abundance and for most sampling situations is the best method currently available for determining relative abundance or

trends for most bird species. In practice, the method is basically the same as unlimited distance point counts, except that for each bird heard or seen during the count, its horizontal distance from the observer is estimated. In the case of line transect sampling, the observer walks down a transect and records either the perpendicular distance to each bird heard or seen, or else records the sighting angle and sighting distance instead of the perpendicular distance. Variable circular plots are a type of distance sampling where the observer stands at a sampling station and records the horizontal distances between the observer and each bird. Line transects are usually more efficient than VCP counts where they can be conducted because you continually collect data as you walk down the transect, whereas during VCP counts you count birds only from stations located every 250 m or some interval along the transect. However, VCP counts are the preferred approach in patchy habitats if you want to associate bird data with vegetation or other habitat information, and in dense, rugged or hazardous terrain where you need to watch your footing as you walk down the transect. Another advantage of VCP counts is that the data can be directly compared to historical point count data such as from BBS counts and can contribute to ongoing programs such as the National Point Count Database.

Distance sampling is currently being used to sample birds in various national park settings throughout the country. VCP counts have been used to sample birds in parks in Hawaii for more than 20 years, and several field tests have been conducted in Hawaii that validate the method (e.g., Fancy 1997, Nelson and Fancy 1999). Channel Islands NP has been conducting line transect sampling and VCP counts to monitor landbirds since 1993, and VCP counts are currently being used for bird inventories in Yukon-Charley NPP and Great Smoky Mountains NP. We need to emphasize, however, that although distance sampling generally does improve estimates of abundance and population trends for many species, it is not a panacea and there are a number of limitations of the method even with the best trained and most highly skilled observers. For example, in many surveys, the majority of birds are heard but not seen, and the observer estimates the distance to a tree or bush or other object where they think the bird is hiding. Distances cannot be estimated accurately in many situations because of habitat complexity or ventriloquial bird voices or other reasons. Also, more than 100 detections may be required to develop a good detection function for each species, such that multiple surveys of the same area will be required for all but the most common species in order to get adequate sample sizes.

Occasionally, there are detectability issues in bird sampling that VCP and other estimation procedures cannot address. For example, there may be unobservable portions of the population (such as females) that are not detected at all during counting. Or, it may be impossible to estimate detectability at the appropriate scale, for example when habitat-specific detectability exists in a rare species. Thus, even with a measure of detectability factored into estimates derived from counts of birds, such estimates may still be an unreliable measure of differences in the actual number of birds present in some situations. Interpretation of survey data requires a sensitivity to these extra-statistical limitations of the estimation procedures.

Nevertheless, we recommend distance sampling as the best method currently available for meeting this objective of collecting abundance or trend information. There have been a number of recent developments with distance sampling that now make it easier to implement both in the field and with data analysis:

- The book “Distance sampling: estimating abundance of biological populations” by Buckland et al. (1993) provides a good background of the theory and specific details of distance sampling.

- Distances do not have to be estimated exactly in the field as some earlier reports suggested. Distances that are recorded as accurately as possible in the field can then be placed into distance intervals and analyzed as grouped data, such as 0-16 m, 17-32 m, 33-48 m, etc. When data are analyzed in distance intervals, there is no error as long as the estimated distance to the bird is placed in the correct interval. Laser rangefinders are now available in the \$200 to \$300 range that can measure the distance to a rock or tree within 1% accuracy, and these can be used in certain situations for training and to improve distance estimates during counts (distances to various reference points around each sampling station can be estimated prior to the start of the count).
- Data from repeated surveys of the same area or areas with similar habitat characteristics can be combined to increase sample sizes. By combining surveys, it is possible to estimate densities of many rare species, even in situations where only 1 or 2 birds are detected while sampling 30-40 stations.
- It is possible to adjust for different covariates such as the observer effect, and effects of dense vegetation or weather on detection distances. Version 4 of the DISTANCE program will allow you to model covariates directly in the software.
- It is still possible to use historical count data collected using unadjusted point counts if a park switches to VCP counts but records the number of birds detected during the same duration of sampling. For example, if you have been running a BBS route in the park for 20 years, you can still make direct comparisons between the new data if you conduct VCP counts and record detections made during the first 3 minutes with the old data for each sample location and species. To compare with historical 5-minute point counts as well as BBS data, you could record those birds detected during the first 3 minutes, and then indicate those detected in the next 2 minutes of a 5-minute count.
- Version 4 of the DISTANCE software, due out in Fall 2000, will have a number of features specifically designed to make it easier to analyze bird count data. It will be possible to program a data entry form that matches your field form to make it easier to enter data into the program. The software will allow you to combine data from multiple surveys, and covariates such as different observers can be modeled directly in the program. The software will be free, and a number of people in the National Park Service or partner agencies will be trained to analyze data – you do not need to be able to analyze your data to use this method.
- The NPS I&M program is in the process of developing materials to help parks implement distance estimation in parks, including data forms, training materials, and assistance with data management and analysis. Check the website <http://science.nature.nps.gov/im/monitor>.

Double-observer Counting

Double-observer counting provides an alternative method of modifying point counts to incorporate detectability information. In this procedure, two observers count at each point. One observer is the “primary,” who counts all birds they see or hear. A “secondary” observer records the birds detected by the primary observer, but also notes any birds missed during counting by the primary observer. The two observers alternate roles between points, so that for any area of interest the data will have replicate points at which each observer was primary. Using these data, the proportion of birds missed by each counter can be estimated (Cook and Jacobson 1979, Nichols et al. 2000). This procedure has only recently been implemented for point counts, but it appears to provide reasonable results (Nichols et al. 2000). A few comments:

- General protocols for point counts, such as standardized criteria for duration and conditions for counting, can be followed for both double-observer and VCP counts. However, both procedures greatly enhance the quality of the information from the counts, by allowing for estimation of detectability. Double-observer counts also have intrinsically-higher detection rates than unadjusted point counts, simply because two observers are counting.
- Double-observer methods require that birds be counted within a fixed radius to allow a rigorously-defined area for estimation of density. The fixed radius also eliminates the possibility that differences in detectability between observers represents differences in area counted by observers.
- Detectability can only be estimated when both observers have counted as primary observers. Consequently, if habitat-specific detection rates are needed (and they generally are needed), it must be ensured that sufficient replicates exist within each habitat type to allow each observer to be primary at more than one point.
- Sample field sheets and specific protocols for a double-observer study are available on request from the USGS Patuxent Wildlife Research Center.
- Computer programs exist for estimation of detection rates from double-observer surveys (J. E. Hines, USGS Patuxent Wildlife Research Center, Laurel, MD).

General Comment on Detectability Estimation

Bird surveys tend to be omnibus, in that the survey is designed to count many species at the same point. Unfortunately, this limits our ability to modify the surveys to increase the efficiency for any particular species. Consequently, most surveys collect good information for a few species, and relatively poor information for many species. This is not a reflection of the quality of the estimation procedure, but instead reflects the lower quality of all information for these low abundance species. This should be a warning sign for **any** use of the data for those species, not just for the estimation of detectability.

Objective 4: The goals of the monitoring effort are to aid in determining the causes of population trends and differences in abundance among species, habitats, and areas; and to identify and evaluate management actions to reverse declining trends and increase low population sizes.

The use of point counts that include measures of detectability can provide estimates of abundance or density of landbirds, and can facilitate analyses to determine population trends and differences in abundance among species, habitats, and geographic areas. These methods, however, fail to provide data on the primary demographic parameters or vital rates (productivity and survivorship) of landbirds. Without data on vital rates, it is difficult to test competing hypotheses to account for observed population changes, or even to determine the stage(s) in the life cycle at which population change is taking place; that is, whether the change is being driven by causal agents that affect birth rates or death rates or both. This information is critical for most landbird species, especially those for which death rates are driven primarily by factors operating on their wintering grounds, often thousands of kilometers removed from their breeding grounds.

Monitoring the vital rates of landbirds allows the construction of demographic models to assess the viability of populations, aids efforts to identify management actions to reverse

population declines, and facilitates evaluating the effectiveness of those remedial management actions. This is because environmental stressors and management actions affect vital rates directly and usually without the buffering or time lags that often occur with population trends. Moreover, habitat- and landscape-specific data on vital rates provide a clear index of habitat and landscape quality, and can identify population sources and sinks.

The technique of constant-effort mist netting and banding is a tested and proven method for collecting information on vital rates of landbirds. Annual indices of productivity and adult population size are obtained from analyses of data on the numbers of young and adult birds captured; annual estimates of adult survival rate, adult population size, proportion of residents in the adult population, and recruitment into the adult population are obtained from modified Cormack-Jolly-Seber analyses of mark-recapture data. The technique has been in standardized use since 1982 in the British Constant Effort Sites Scheme, and since 1992 in North America in the Monitoring Avian Productivity and Survivorship (MAPS) Program. MAPS protocol is currently used in both Denali and Shenandoah National Parks as part of their Long-Term Ecological Monitoring (LTEM) efforts, and 37 MAPS stations are currently being operated in 17 NPS units nationwide. The standardized nature of MAPS data and the continental scope of the program, with over 500 stations operated annually, means that data on vital rates of landbirds from NPS units can be directly compared to each other and to data from >100 stations on national forests, >100 stations on DoD military installations, and >270 stations on other federal, state, and private landholdings.

A MAPS station includes a permanent array of about ten mist nets located in the core eight hectares of a 20-ha study area. MAPS protocol includes the standardized operation of these nets for about six morning hours during one day per 10-day period, for six to ten (depending on latitude) consecutive 10-day periods between May or early June and early August. All birds captured are identified to species, age, and sex and, if unbanded, are banded with USGS/BRD numbered bands. Additionally, the apparent breeding status of each species encountered at the station is determined each year, and habitat structure within and surrounding the station is assessed according to a standardized protocol. These combined protocols allow landscape-level demographic data for a whole suite of landbirds species to be collected in a cost-effective, nationally standardized manner.

An integrated approach to monitoring both vital rates and population trends of landbirds, and relating them to habitat characteristics across the landscape, is critical for determining causes of population changes and for identifying, as well as testing, management actions and conservation strategies to reverse population declines. The most effective and useful avian monitoring programs will be those that incorporate multiple, complementary approaches — population distribution and trend monitoring through VCP point counts, and determination of vital rates through constant-effort mist netting. Finally, avian monitoring efforts should be conducted in conjunction with assessments of the habitats on which targeted bird communities depend, to provide insights into the ecological correlates of declining or increasing populations. Ideally, appropriate habitat assessments should be coordinated with other park monitoring programs, so that effort is not repeated, and data on a variety of taxa and ecological processes throughout the park can be readily integrated.

Acknowledgments: Helpful reviews and comments on earlier drafts of this document were made by Deanna Dawson, David DeSante, Colleen Handel, Bruce Peterjohn, Ken Pollock, C. J. Ralph, Rodney Siegel, Ted Simons, and Keith Watson. We appreciate their help in developing these guidelines.

Literature Cited

- Barker, R. J., and J. R. Sauer. 1995. Statistical aspects of point count sampling. Pages 125-130 in C. J. Ralph, J. R. Sauer, and S. Droege, eds. *Monitoring Bird Populations by Point Counts*, USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.
- Boulinier, T, J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Pollock. 1998. Estimating species richness to make inference in community ecology: The importance of heterogeneity in species detectability as shown from capture-recapture analyses of North American Breeding Bird Survey Data. *Ecology* 79:1018-1028.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. *Distance sampling: Estimating abundance of biological populations*. Chapman and Hall, New York. 446pp.
- Burnham, K. P. 1981. Summarizing remarks: environmental influences. *Studies in Avian Biology* 6:324-325.
- Cook, R. D., and J. O. Jacobson. 1979. A design for estimating visibility bias from aerial surveys. *Biometrics* 35:735-742.
- Fancy, S. G. 1997. A new approach for analyzing bird densities from variable circular-plot counts. *Pacific Science* 51:107-114.
- Gibbs, J. P., and S. M. Melvin. 1993. Call-response surveys for monitoring breeding waterbirds. *Journal of Wildlife Management* 57: 27-34.
- Kennedy, P. L., and D. W. Stahlecker. 1993. Responsiveness of nesting northern goshawks to taped broadcasts of 3 conspecific calls. *J. Wildl. Manage.* 57:249-257.
- Long Point Bird Observatory. 1996. *Marsh Monitoring Program Training Kit and Instructions*. Long Point Bird Observatory and Environment Canada, Long Point, Ontario.
- Manley, P. N. et al. 1995. *Monitoring Task Force Group Report: guidelines for monitoring populations of neotropical migratory birds on National Forest System Lands*. U. S. Forest Service, Unpublished Memo.
- Nelson, J. T. and S. G. Fancy. 1999. A test of the variable circular-plot method when exact density of a bird population was known. *Pacific Conservation Biology* 5:139-143.

- Nichols, J. D., and M. J. Conroy. 1996. Estimation of species richness. Pages 226-234 *in* D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster. Measuring and monitoring biological diversity: Standard methods for mammals. Smithsonian Institution Press, Washington.
- Nichols, J. D., J. E. Hines, J. R. Sauer, F. Fallon, J. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability. *The Auk*. In Press.
- Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. Pages 161-168 *in* C. J. Ralph, J. R. Sauer, and S. Droege, eds. Monitoring Bird Populations by Point Counts, USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.
- Sauer, J. R., and W. A. Link. Some consequences of using counts of birds banded as indices to populations. *in* C. J. Ralph and W. Peach, eds. Monitoring Bird Populations with Mist Nets, USDA Forest Service, Pacific Southwest Research Station, General Technical Report, (In Press).

Appendix – Sources of information for monitoring other bird groups

Many regional and national monitoring programs exist for taxa of management interest. Here, we provide references for some of the techniques and protocols used for these programs. It is important to recognize that these procedures often do not conform to the principles of survey design stated in this document, especially when local managers take the information and attempt to implement the methods for local areas. Instead of providing sampling frames useful at local scales, they tend more often to provide information that can be aggregated at regional scales. Detectability is often not estimated as part of these surveys, a reflection of the emphasis on estimation of temporal change rather than spatial pattern. We suggest that the protocols used for these taxa be reviewed before use to ensure that they will provide information relevant at the scale of a National Park.

Hawks: Fuller and Moster (1987, Raptor survey techniques. Pages 37-65 in Raptor management techniques manual, National Wildlife Federation, Washington DC). The tape playback method works fairly well for breeding woodland hawks, but is rather labor intensive. Their methods for non-breeding surveys are the current "standards", but undoubtedly have problems with detectability issues. A "Report of a Workshop to Develop a North American Raptor Monitoring Strategy" is available at <http://www.mpl-pwrc.usgs.gov/raptor/raptor.html>.

Shorebirds: A standardized monitoring protocol to collect, compile, analyze, and disseminate information about shorebird population trends, distribution, and abundance is being developed. The report "A Comprehensive Monitoring Program for North American Shorebirds" can be downloaded from <http://www.manomet.org/USSCP/files.htm>

Marsh Birds: Secretive marsh birds are difficult to detect and inhabit areas that are often not readily accessible. Therefore, they are poorly surveyed by the Breeding Bird Survey and other existing monitoring programs. A number of efforts have been made to standardize marsh bird surveys using taped playback response. Notable among these is the work by Gibbs and Melvin (1993, J. Wildl. Manage. 57: 27-34) and the Long Point Bird Observatory's (LPBO) Marsh Monitoring Program (1996, Marsh Monitoring Program Training Kit and Instructions). See <http://www.mpl-pwrc.usgs.gov/marshbird/> to download copies of workshop reports and obtain information on efforts to develop consistent methods for monitoring marsh birds.

Colonial Waterbirds: The USFWS, USGS, and state agencies are collaborating to create a system of periodic inventories of colonial waterbirds in the United States. See <http://www.im.nbs.gov/cwb/cwb.html>