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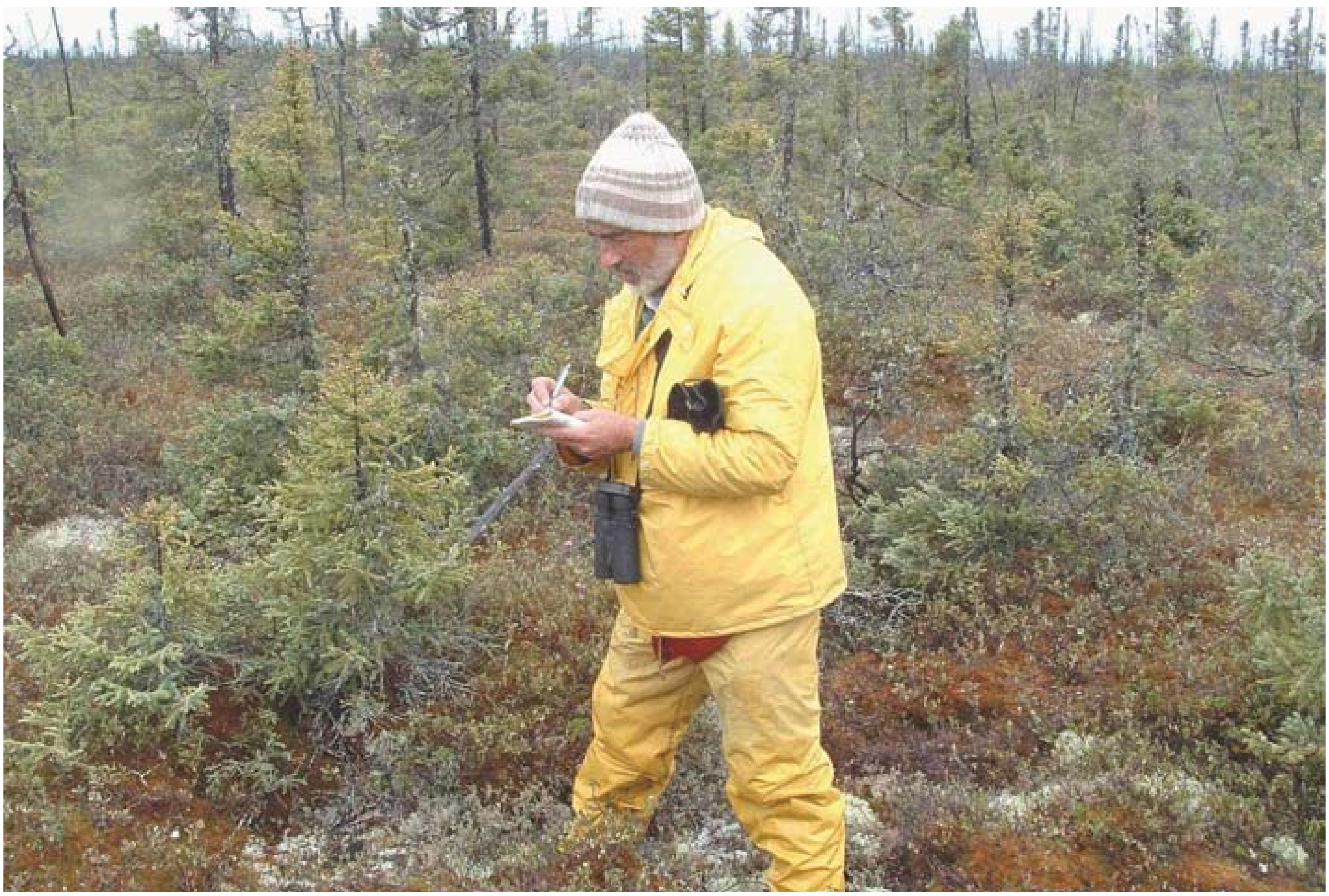
Monitoring bird populations in small geographic areas

Special Publication
Canadian Wildlife Service
March 2006



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Abstract

Numerous methods exist for monitoring bird populations, and there is a large literature describing them. There are few resources, however, that provide comprehensive advice on every step of organizing and carrying out a survey, from the early stages of planning to final use of the data. Even fewer resources are designed to meet the needs of a wide variety of potential users, from amateurs interested in change of bird life in a local study preserve to professionals testing hypotheses on the response of birds to habitat management, although much of the advice should be the same for every monitoring program. Whether survey objectives are very modest or rigorously scientific, samples must be sufficiently numerous and well distributed to provide meaningful results, and the survey should be well designed to ensure that the money and effort going into it are not wasted.

This document is intended to be a complete resource for anyone planning to organize monitoring of noncolonial landbirds within a relatively small geographic area (e.g., from the size of a woodlot to a large park). The first of its two parts provides background explaining the importance of good study design and gives specific advice on all aspects of project planning and execution of high-quality data collection for the purpose of hypothesis testing. The second part is self-contained and nontechnical and describes complete plans for a site-specific checklist survey, suitable for addressing monitoring questions frequently asked by amateurs and for involvement of volunteers in data collection. Throughout are references to additional resources, from background literature to sources of existing survey protocols, analysis software, and tools for archiving data.

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Contents

Introduction

A question frequently asked of population monitoring biologists is: “What can I do to monitor birds at …?,” where the location of interest is a specific, relatively small geographic area such as a nature reserve or a park. All too often the question is answered only casually, because a complete answer is far more complicated and lengthy than first meets the eye. The purpose of this document is to address the topic of site-focused monitoring in detail, to meet the needs of a variety of users, from amateur to professional.

Monitoring, in the conventional sense of detecting change in population parameters over both short and long periods, can help identify bird communities or species undergoing important population change, can contribute to the setting of habitat objectives, and serves as a tool for evaluating conservation and management actions. Bird population monitoring at a specific site is usually motivated by a desire either to contribute data to monitoring at a broader geographic scale (e.g., a national program) or to investigate population change within the selected site itself, often to provide guidance for site management.

While it is sometimes possible to contribute to monitoring at both local and broad scales simultaneously, there are some significant challenges to doing so. One of the basic tenets of monitoring, regardless of the geographic scale, is that all portions of the geographic area of interest must have a chance of being sampled. This requires that sample locations be selected according to a specified sampling design. If sample points are selected because they are “good for birds,” are easily accessible, or contain a particular habitat (e.g., protected forest), they are unlikely to be representative of the region as a whole. Therefore, valid inferences cannot be made about birds away from the sample points themselves. In most cases, user-selected small areas (such as parks) are unlikely to have been selected as sampling locations within the sampling frame of a statistically rigorous, broad-scale monitoring program, and data from those sites cannot be incorporated directly into such a broad-scale program without skewing results.

Nevertheless, there are a number of cooperative programs that make use of data from nonrandomly selected sites. Although less powerful than programs with rigorous sampling designs, these programs can produce results that—with careful analysis and appropriate interpretation—are useful for a variety of scientific and conservation purposes. Participation in this type of program allows the double benefit of providing information on a particular site that may be of interest to the survey participant as well as providing comparative information from other sites to put those results into context. Readers interested in this type of cooperative monitoring program should refer to Appendix 2, which gives information on broad-scale monitoring projects that invite participation from sample locations of the volunteer’s choice.

In this document, we provide detailed advice on project planning and data collection techniques that are most suited to monitoring the status of populations within relatively small geographic areas, including options that can accommodate both professional and amateur interests. In some cases, the methodology may be compatible with one of the above-mentioned broad-scale projects, but this is not the main criterion we have considered. While advice on good monitoring practice will be similar for any geographic scale, monitoring objectives often differ according to the size of the study area. At broad geographic scales (regional or across a species' range), the most common objective is to document long-term population change. While this is frequently an objective at smaller geographic scales as well, small-area studies are particularly suited to hypothesis testing, such as determining the response of bird populations to management activities or habitat variation or conducting tests of alternative survey techniques. Such studies will be greatly improved by using methods that allow estimation of detection rates and subsequent adjustment of raw counts. Another common objective for monitoring in smaller areas is to determine what species are present (e.g., to compile a species inventory for a park) and to track changes in bird community composition over time. The methods we discuss in this paper are the ones most appropriate for the monitoring objectives commonly articulated for relatively small areas.

The document is divided into two parts. Part 1 contains general advice on planning a new monitoring program, including setting objectives, developing a sampling plan, selecting a count protocol, preparing for field operations, and planning for data analysis. Information in Part 1 can be used to design a wide variety of monitoring programs, tailored to the specific needs of the user, and will be most relevant to biologists who want to develop plans for high-quality monitoring and/or hypothesis testing. Part 2 contains detailed guidelines and options for organizing a site-specific checklist survey, a program that is well suited to the involvement of volunteers and can meet outreach and education objectives while also generating useful data on bird populations. Part 1 will be valuable for users of Part 2 as well, because it explains the reasoning behind the recommendations in Part 2.

The methods we discuss for monitoring abundance are particularly appropriate for landbirds with dispersed distribution in the breeding season or in winter. For recommendations on monitoring abundance of landbirds during migration, see Hussell and Ralph (1998). Although we mention some of the challenges that colonial species pose for sampling design, we do not cover the special methods that are often used to count these species or others requiring specialized count methods (see Bibby et al. 1992 for a good introduction and Fancy and Sauer 2000 for more specific techniques). Nevertheless, many of the concepts in Part 1, particularly regarding the definition of appropriate objectives, are relevant for all species.

Box I.1 highlights the chief topics that should be considered before a monitoring project is implemented. Part 1 treats each issue in greater detail. No single document, however, can provide all the advice needed for sound study design under every circumstance. Additional information can be found on the U.S. National Park Service Inventory and Monitoring Program website (see Appendix 1), while selected key literature and web resources are cited in the text. Despite the availability of many written resources, we strongly recommend that anyone planning a new monitoring program should consult a statistical expert during the design phase of the program.

Box I.1. Issues to be considered when designing a bird monitoring program

- Program objectives
- Parameters to be estimated
- Field methods
- Statistical quality of the data
- Survey design: spatial and temporal sampling
- Training of personnel, and planning for data management and analysis

Part 1
Designing a monitoring program

1.1 Program objectives

Box 1.1. Factors to consider in setting objectives

- Question(s) to be answered
- Survey precision targets
- Plans for using results
- Most appropriate geographic scale
- Most appropriate time scale
- Target species
- Costs

The crucial first steps in designing a monitoring program are to define the objectives, laying out clearly what question(s) the study is intended to answer; articulating targets for quality of results (survey precision); and planning for use of results. Nearly every aspect of survey design will be affected by the selected objectives, including decisions on which species to study, what parameters to estimate, what field methods to use, and where and how often to sample. A great deal of time, effort, and money can be wasted on population studies that are inadequately designed to answer the question being addressed. The wastage can be just as great if the data, no matter how high the quality, are not analyzed and used for the purpose for which they were collected. Even surveys with very modest objectives of involving volunteers for outreach and educational purposes should be well designed in order to make the best use of the time being contributed and to increase the volunteers' satisfaction with their participation.

Objectives should be defined as specifically as possible, considering not only "What do I want to know?," but also "Why do I want to know it?" and "Will this be worth the effort?" For example, the goal may be to detect change in bird populations in a park over a period of years. Why, however, do you want to know? For what purpose will the results be used? The methods of choice will differ depending on whether the aim is public education or personal interest or whether the results will be used as a basis for habitat or species management, for influencing public policy, or for publication of hypothesis tests in a journal.

Included in setting objectives is the need for a decision on the most appropriate geographic scale. Is the desired end product information on a single study area (e.g., a park), comparison of populations among habitats or study areas (e.g., a group of parks), or comparison of populations between a study site and the surrounding region (e.g., comparing population characteristics within a park with those outside park boundaries)?

The desired time scale also needs to be considered. While it is often tempting to think of monitoring as indefinite and long-term, it is important to define a time frame over which different objectives will be met and products produced. This is usually required by funders and also provides motivation for participants and a basis for evaluating whether the program is meeting its objectives. If the major objective is long-term, then consideration should be given to incorporating additional objectives, such as short-term hypothesis testing, which will greatly enhance the value of long-term monitoring (Nichols 2000).

Objective setting should also define target species, since the best techniques to use will vary depending on the species. While it is almost never possible to monitor all species in a study area using a single survey, it is wasteful of resources to focus on a single species when additional species could easily be monitored at the same time.

Finally, the initial definition of objectives must consider expense. Cost estimation should include realistic expenses for personnel, training, field costs, and data handling. A rule of thumb is that 25–30% of the total project cost is needed for data storage, data analysis, and preparation of reports to disseminate results to target audiences. Monitoring plans can often be adjusted to reduce expense, but if the study objectives cannot be met as a result of those adjustments, then the survey should not be started at all.

1.2 Parameters to be estimated

The objectives of the study determine the parameters to be estimated and the measurements to record in the field. A few examples are listed in Box 1.2. Parameters should be rigorously defined, because differences in definition can affect the choice of field methods and study design.

Box 1.2. Examples of study objectives and parameters

Objectives	Parameters
▸ Detect long-term trends in species abundance within a park	▸ Number of birds singing in June, as an indicator of numbers attempting to breed
▸ Determine habitat where target species are most abundant in winter	▸ Mean density of birds in each habitat during winter months
▸ Determine how much nest success varies over time or among treatment blocks	▸ Proportion of nests in each period or treatment that fledge one or more young

1.2.1 Species lists

Lists of species present or breeding in an area are often used to compare species composition between time periods or among locations, to document the occurrence of unusual species, and to determine seasonal occurrence of species at particular locations. Species lists have considerable public relations and educational value, especially when volunteers are involved in data collection. (See Part 2 for guidelines on a volunteer survey involving species lists.)

The parameter of interest in preparing species lists is often not well defined. Frequently, the objective is to compile a reasonably complete tally of all species that have been recorded in the study area, based on fairly thorough observation throughout the area and at all times of year. In this case, rigorous evaluation of completeness of coverage may not be necessary. For more scientific purposes (e.g., to document change in species composition over time), the sampling scheme should be more stringent and should allow estimation of the proportion of total species likely to be present that have actually been detected. In this case, abundance monitoring might be undertaken simultaneously in order to maximize the value of the survey effort. Indeed, species lists are often secondary products of surveys that are designed primarily for other purposes.

1.2.2 Abundance monitoring

The most common objective of bird monitoring studies is to detect changes in abundance. Population trends are useful in assessing a species' status, helping to determine conservation priorities, and detecting whether species are responding to management activities. In most cases, however, population trends alone do not provide conclusive information on the causes of population change. It is therefore valuable to design the study so that the samples taken in each time period can also be used to test hypotheses comparing abundance among sites or habitats or to evaluate birds' response to management action (e.g., last example in Box 1.2). This allows ongoing evaluation of the importance of factors suspected to cause population change, so that when worrisome trends are detected, there will already be information available on the best means of management.

During the breeding season, "abundance" is usually defined as the number of birds that attempt breeding (i.e., defend territories) within the study area. This definition allows the number of singing birds to be used as the variable measured on surveys. In some cases, especially with waterbirds, it may be preferable to use count methods that include nonterritorial, nonbreeding birds. Defining "abundance" for the nonbreeding season can be challenging, especially for species that vary in flocking tendency and movement throughout the winter. Depending on the study objectives, the most appropriate abundance parameter for the nonbreeding season may be the mean number of birds present during the study period or the maximum number present at any one time.

1.2.3 Demographic monitoring

Knowledge of demographic processes—productivity and survival—is key to modelling a species' population dynamics, and information on demography can often elucidate causes of observed changes in abundance.

In general, productivity is easier to monitor than survival, because estimation of survival rate requires long-term study and frequently larger sample sizes than can be achieved at a single site. We focus here on productivity monitoring, but note that protocols exist (e.g., the Monitoring Avian Productivity and Survivorship [MAPS] Program; see Appendix 1) that could conceivably be used to monitor survival of selected species within a single study area.

Productivity monitoring is usually aimed at detecting spatial or annual differences in reproductive success and elucidating the causes of these fluctuations, with detection of long-term trends a secondary objective. With appropriate study design, demographic monitoring can be used to detect differences in reproductive success in relation to habitat, predation levels, weather, and other factors.

Parameters related to productivity include nest success (number of young that leave the nest per nesting attempt), proportion of adults displaying parental behaviour (e.g., feeding young), and proportion of young birds in the post-breeding season population. The first two parameters are indicators of breeding success in the study area, while the latter (age ratios) may include birds that have moved into the study site from elsewhere (Nur and Geupel 1993), making it difficult to define the population being monitored.

1.3 Field methods

Here we describe the field methods recommended for measuring the parameters described in section 1.2 and outline the strengths and weaknesses of each approach. Using one of these common methods ensures that the results will be comparable to the results of many other studies. Moreover, for many of these methods, instructions for data collection, data forms, and analysis programs are readily available. Some common approaches to meeting study objectives are summarized in Box 1.3.

Box 1.3. Common approaches to meeting particular study objectives

- If the aim is to offer opportunities for participation in fieldwork without having to design or organize a survey, consider recruiting volunteers to set up a sample site within the study area for one of the existing volunteer surveys described in Appendix 2.
- For documenting the presence and distribution of species in a study area, the simplest approach is to have qualified observers visit all parts of the area repeatedly, throughout the season(s) of interest, and record the species detected and where and when they were seen (see Part 2).
- Using the same methods as above, but also recording the number of birds detected on each visit, will generate information on relative abundance of species. If the sampling design permits replication of effort at a future time, results can reflect change in detectable bird populations at the sample sites (see Part 2).
- With careful attention to sampling design and with sufficient sample size, “index counts” (counts that are unadjusted for difference in detection ratios) can provide quantitative estimates of spatial or temporal trends in abundance that, as a minimum, can be used to guide further, more rigorous investigation into potential causes of changes.
- Bias reduction methods are available that can generate more robust and interpretable results from bird counts, and these should be used whenever feasible—particularly when the objective is to compare abundance of birds among habitats, species, or years with a target level of statistical precision suitable for hypothesis testing and supporting management action. The methods we discuss for adjusting index counts are distance sampling, double-observer methods, removal sampling approaches, and double sampling.
- The MAPS (see Appendix 1) protocol (constant-effort mist netting) can be used to get indices of annual variation in regional productivity and survival.
- The Breeding Biology Research and Monitoring Database (BBIRD) (intensive nest monitoring) (see Appendix 1) is a useful approach for obtaining relatively unbiased, area-specific information on reproductive success.

Regardless of the field technique selected, producing useful results requires using the method consistently, distributing sample points appropriately, and gathering a sufficient quantity of data. These issues apply to every technique, study question, and degree of desired precision, so we treat them separately in later sections of the document.

1.3.1 Species lists

For generating a species list, visual/aural surveys are the preferred method if only one field method is to be used (Dunn and Ralph 2004). Certain groups of species will be underrepresented in visual/aural counts compared with mist netting (e.g., secretive species that inhabit dense understorey vegetation or that rarely sing), but most species will eventually be detected with sufficient survey effort. We describe the main visual/aural survey techniques below.

1.3.1.1 Visual/aural survey techniques

1.3.1.1.1 Area search

Area search consists of moving through all parts of a predefined area and recording all species detected. The advantages of area search for species surveys, compared with point counts and transect counts (see section 1.3.1.1.2 below), are that observers can concentrate their efforts in parts of the plot where birds are most abundant and can track down elusive individuals to make certain of identification. Area search is less practical, however, in very densely vegetated areas where observer movement is difficult or causes a commotion that could scare birds into silence or into moving off the sample plot. In some areas, observer movement may be restricted by a need to avoid damaging vegetation or to stay off private property.

There are two main approaches to using area search for the purposes of species inventory, differing primarily in the size of the area to be searched. The first is used in most "atlas" projects (detailed mapping of bird distributions), in which the study area is divided into equal-sized units that are usually too large to be well sampled in a single day (often 5- or 10-km squares). Each square or a sample of squares chosen to be representative (see section 1.5.1) is thoroughly searched over many visits, usually within a limited time frame of several years (see Smith 1990 for more information on atlases). Division into equal-sized units ensures that all portions of the study area will be visited and makes the survey more replicable in the future. In most cases, these squares are too large, complex, or inaccessible for complete coverage, and observers are able to survey only portions of the block. In this case, it is important to ensure that at least some portions of all habitats within the block are sampled.

The second approach to using area search is to select a representative group of relatively small sample plots (e.g., 1–2 ha up to 1 km^2, depending on habitat), so that all areas of the plot can be searched on a single visit (see Part 2 for more detail on this approach). Given a sufficient number of visits, a reasonably complete species list can be accumulated (Dieni and Jones 2002). The advantage of this second approach is that it can be combined with counting birds during a specified time period (e.g., 20 min) to provide an index of abundance. Indeed, it makes little sense to record only the presence of a species under these circumstances, as numbers add so much value to the data set.

1.3.1.1.2 Point counts and transect counts

Point counts require the observer to stand at a preselected spot for a specified period of time (usually 3, 5, or 10 min) and to record all species detected by sight or sound (Ralph et al. 1995a; Hamel et al. 1996). Transect counts involve an observer moving slowly along a specified path, recording all species detected on either side of the path during the time it takes to get from start to end. These techniques may not generate as complete a list of species as an area search, but they have the added advantage that they can also be used for abundance monitoring (see section 1.3.2). For dual-purpose surveys, observers can be asked to record all species detected while moving between the point count or transect locations being used for abundance monitoring, in order to bolster the overall species list. Point counts may be better than transect counts for detecting birds in densely vegetated habitat, because the observer stands quietly in one spot rather than causing a constant disturbance while making observations. Time spent per unit area is more easily standardized in point counts. Finally, point counts and transect counts may be preferred over area search when permission for access is required from landowners, who might be more willing to let observers onto their land if only specific sampling points are to be visited.

1.3.1.2 Mist netting

In building a species list, it can sometimes be useful to combine visual/aural surveys with a capture program such as mist netting. This technique increases detection probabilities for some cryptic species relative to visual/aural surveys (Pagen et al. 2002; Ralph and Dunn 2004), especially during the nonbreeding season, when birds may not be very vocal. However, mist netting requires intensive effort by trained personnel who have obtained federal permits to capture birds (see North American Banding Council 2001a,b), and it is less efficient than visual/aural counts in detecting as many species as possible in a given period.

1.3.2 Abundance

1.3.2.1 Visual/aural survey techniques

The same techniques described for documenting presence–absence of species can also be used to obtain counts of birds: area search (using small plots), point counts, and transect counts (as well as mist netting). Instead of simply recording which species are detected, the observer also records the number of birds seen or heard during a specified count period (e.g., 20 min for a 2-ha area search or 5 min for a point count).

All else being equal, transect counts are preferable to point counts for abundance sampling when distance sampling techniques are used (see section 1.3.2.2.1), because they can yield more reliable estimates of abundance and density (Rosenstock et al. 2002). However, especially for forest birds, the required assumptions for transect counts may not be met. Furthermore, point counts may be preferred when conditions make it difficult to walk a straight line, when noise of observer movement reduces aural detections, when multiple species are being studied in an area of patchy habitat, or when bird data are going to be related to habitat variables (Fancy and Sauer 2000). It is also easier to standardize the time spent by observers on point counts compared with transect counts. A combination of transect counts and point counts can be used in the same study to make best use of both techniques.

Point counts are usually of 3-, 5-, or 10-min duration. Five-minute counts are frequently recommended over longer counts (Ralph et al. 1995a; Rosenstock et al. 2002; Thompson et al. 2002), because it is statistically more valuable to conduct more counts in additional locations than to detect a few more birds at fewer count sites. Where travel time between sample stations is great, however (such that shorter counts will not allow many more sites to be visited), 10-min counts may be preferred to ensure as many registrations as possible (and to detect as many species as possible, if inventory is one of the objectives of the study). Ten-minute counts have also been recommended when there are many birds to be counted and for bird–habitat association studies to reduce the numbers of birds overlooked (Hutto and Young 2002). Perhaps more importantly, conducting 10-min counts in which birds are recorded separately within intervals (e.g., 3-, 2-, and 5-min counts within the 10-min period) permits use of statistical techniques to reduce bias (Farnsworth et al. 2002; see section 1.4). Dividing 10-min counts into timed subsamples also maximizes the opportunity to compare results with those from other point count studies (Ralph et al. 1995a).

Another technique for counting birds, essentially a variation on the point counting technique, is to use microphones at a sampling site to record sounds for a standardized period of time (Hobson et al. 2002). Recordings are later analyzed to identify species and to estimate (using data from stereo recording) the number of individuals calling. Chief advantages of the method are that fieldwork can be conducted by personnel with no bird identification skills, songs can be replayed repeatedly if needed for identification purposes, multiple observers can listen to the recordings to control for observer effects, field data are unaffected by observer quality, and there is a permanent archive of recordings that can be rechecked in future. Drawbacks include the cost of equipment, the ongoing need for skilled observers to analyze recordings, limited ability to make recordings in the presence of loud background noise (especially from traffic and wind), lack of information on distance of the bird from the microphones, and inability to detect birds that may be visible but remain silent. For a complete inventory of species, sound recording should be combined with some visual observation. As technology improves, automated identification of species' songs may become practical. Distance estimation is theoretically feasible with an array of three or more microphones, such that the technique may eventually be useful as more than an index count method (see section 1.3.2.2).

1.3.2.2 Methods for estimating detection probability

Nearly all bird counts fail to detect some proportion of the birds that are actually present, so the resulting counts are an *index* rather than a complete count. A comparison among samples is said to be unbiased (even though some birds were missed in every sample) if the detection probability—the ratio of the count to the true number of birds present—is the same in each sample. Unfortunately, the proportion detected is known to differ among samples, so index counts could lead to inappropriate conclusions based upon them (Thompson 2002; Sauer and Link 2004). For example, if an observer detects 50% of the birds present in the sample plot for one habitat or treatment but 80% in another (because of differences, for example, in density of undergrowth or height of canopy), the study will suggest a substantial difference in density even if none exists. Similarly, if a small proportion of the population is counted in early years of a survey and a much larger proportion is counted in later years (perhaps as a result of habitat change in the sample areas or increasing skills of observers), then the trend estimate will have substantial bias.

Most volunteer surveys generate index counts that are simple tallies of birds detected. Results are often used as evidence of long-term trends in population size, on the assumption that there is no temporal trend in detection probability. While this may normally be true, there is always the possibility that the assumption is false. We suggest using techniques, whenever practicable, to estimate detection probability, especially for studies whose results are to be used in hypothesis testing or management decisions. This type of study is likely to employ paid staff to conduct some or all of the counts, in which case higher data collection standards can be asked of the observers. Bias reduction techniques can include the selection of field methods that estimate detection probability (see section 1.3.2.2.3; Thompson 2002), but also adjustment for known biases during analysis (e.g., as with observer improvement adjustments in North American Breeding Bird Survey [BBS] analysis; Sauer et al. 1994).

There is ongoing debate on the need for, and efficacy of, some of the bias reduction techniques (e.g., for a discussion of the relative advantages of incorporating distance sampling methods into point count surveys, see Ellingson and Lukacs 2003; Hutto and Young 2003). There is field evidence that within species and in uniform habitat, index counts can detect trends and annual fluctuations in the same directions, if not with the same magnitudes, as distance sampling, even in the face of large differences in detection probability among samples (Norvell et al. 2003—although the authors did not point this out; Howell et al. 2004). While we recommend the use of bias-reducing field techniques, this is not because we think index counts necessarily give incorrect results or because we believe that bias reduction techniques are wholly effective. Rather, like Nichols et al. (2000), we are uncomfortable with the knowledge that results from index counts are based on assumptions that can frequently be at least partially addressed without much additional effort. If only for the sake of credibility in the eyes of the scientific community, it is wise to use bias reduction techniques whenever feasible. At the same time, however, we cannot unconditionally endorse any of the suggested techniques. Moreover, we recognize that it is not always possible to use field techniques that allow estimation of detection probability (as in some volunteer surveys). If the choice is between having no information at all and collecting information using index methods that can reflect the general status of bird populations and point to problems requiring further investigation, then we support the use of index counts.

The methods we discuss below for estimating detection probability can each reduce bias to some degree, but each one also has important assumptions, and the potential for failing to meet those assumptions should be considered when selecting the field method. It should be remembered that bias-adjusted estimates can still be biased. For example, if 50% of birds are detected in one habitat or treatment and 80% in another, adjustment for detection probability may improve estimations to 80% and 95%, respectively—making the estimates more comparable, but failing to remove an inherent bias. In extreme cases, if the assumptions of a method are severely violated, then estimates corrected for detectability could be more biased than the original, uncorrected estimates.

More field research is needed to allow direct comparison of counts with and without estimation of detection probability to evaluate the magnitude of difference in conclusions drawn and the likely effect that those differences would have on taking action as a result. However, techniques for bias reduction are evolving, and new field methods and approaches to the analysis of data are being developed. It is therefore important that planners review the literature for new developments when designing a study.

1.3.2.2.1 Adjusting index counts: distance sampling

Distance sampling is an adjustment method that, if the assumptions are met, allows estimation of actual densities of birds, and not just an index of abundance. During point counts or transect counts, a record is kept of the distance of each bird from the observer (in the case of transect counts, the distance is perpendicular to the transect path). The distance is recorded either exactly or within specified zones (e.g., <50 m, 50–100 m, >100 m). Because birds closer to the observer are usually detected with a higher probability than those farther away, the rate of decline in numbers detected as a function of distance can be used to estimate detection probabilities, and hence density, at each distance. If the assumptions are met, this technique reduces bias caused by differential detection of species at different distances in different habitats and can also adjust for annual or inter-observer differences in detection distance (Diefenbach et al. 2003; Norvell et al. 2003).

However, distance sampling requires careful training of observers in order to achieve accuracy and consistency in their estimation of distance, as estimates by untrained observers can differ by an order of magnitude (DeSante 1981). Even with extensive training, which can reduce errors to as little as 10% (Scott et al. 1981), it remains very difficult for observers to estimate the distance of singing birds (the main means of detecting birds in forested habitat). Laser distance finders can be helpful in open habitats where birds can be seen and where there are scattered large objects at which to point the laser, but they are not useful in many habitats. Paying attention to distance estimation may also distract observers from bird detection.

Recording bird locations within zones of distance rather than to an exact distance improves consistency among observers and lessens distraction, but reduces the precision of abundance estimates. Rosenstock et al. (2002) recommend using 4–8 zones, with no limit to the outer zone and with zones increasing in size as the distance from the observer increases (e.g., 10, 25, 50, 100, 200, and >200 m). Alternatively, distances can be estimated exactly in the field and grouped into zones during analysis, as recommended by Norvell et al. (2003). Distance sampling can also be conducted using only two zones (e.g., ≤50 and >50 m, combining a "fixed radius" of 50 m and "unlimited distance" counting). The latter is often considered for surveys in habitats for which distance estimation is particularly difficult (as in forested habitat) or when surveys will be undertaken by volunteers or other large groups such that training in distance estimation must be simplified. Use of only two zones assumes that essentially 100% of birds in the innermost zone are detected, which will rarely be the case. Nonetheless, in a study of four species, Norvell et al. (2003) showed that a 50-m fixed radius count produced abundance estimates roughly similar to results from distance sampling (although a 25-m fixed radius count did not). More such comparative studies are needed.

The most important assumptions in the distance methods are that point count stations or transects are selected using a good sampling design (i.e., are randomly located with respect to the location of birds/habitats; see section 1.5.1), that 100% of birds very close to the point count stations or transects (in the innermost zone if the distance bands are grouped) are detected by the surveyor, that distances are recorded accurately and without bias, and that there is no undetected movement of birds in response to the observer. These assumptions may often be violated. For example, distance sampling is unlikely to be suitable in roadside surveys, because habitats, and hence bird densities, near the road are likely to differ from those farther away. Similarly, the assumption that all birds close to the surveyor are detected is often not met. Birds in habitats that are dense or have a high canopy are often undetectable unless they sing, even if they are very close to the transect. Birds may also move away from the surveyor without being detected—a number of studies have found lower apparent densities closer to the observer than farther away (Hutto and Young 2003). If the accuracy of distance estimation varies among habitats, it could also lead to bias in comparisons among habitats. Distance-adjusted counts thus may still be biased. Although the bias may be smaller than with unadjusted index counts, there is a risk of getting a false sense of accuracy unless assumptions are carefully assessed.

Another important limitation to distance sampling is that up to 80 detections of a species are required to calculate a reliable distance–detection function (Buckland et al. 2001). Use of transect surveys instead of point counts may increase detections, allowing more precise estimates, because the area of the closest distance bands to the observer (crucial for estimating detection probabilities) is relatively larger (Rosenstock et al. 2002). Nonetheless, because many species are detected in only a small proportion of samples, distance methods cannot be used for many species, especially in small study areas. Some authors have used data pooled from several studies to determine an average detection function, then applied the result to data collected at a more local geographic scale (Nelson and Fancy 1999). However, this does not lead to much improvement over an index count if the detection functions vary with time, place, habitat, species, or observer. If the study objective is estimation of trend, it is important to obtain sufficient samples to estimate detection probabilities separately for each time period.

1.3.2.2.2 Adjusting index counts: double-observer method

Variation among observers in the proportion of birds detected and identified can be an important source of bias in comparing indices. Even experienced observers usually miss some detectable birds during a count. Although correcting for observer variation alone is not sufficient to generate an estimate of bird density (because detectability of birds varies for other reasons as well), it can greatly improve index counts in cases where density estimation techniques, such as distance sampling, cannot be used.

The double-observer method is one approach to estimate the number of birds missed by an observer. Two observers count birds simultaneously, one observer serving as the primary observer and one as the recorder. In addition to recording what the primary observer sees, the recorder also notes birds he/she detects that the primary observer missed. The two observers switch roles between samples. Alternatively, a third person can participate as data recorder so that the secondary observer is not distracted by this task. Estimates may be even better if both observers record birds completely independently, but this can be difficult to achieve logistically (Nichols et al. 2000).

Use of this method results in the reduction of bias caused by missing detectable individuals, and more individuals of each species are detected. Nonetheless, because each observer must be the primary observer at enough count locations for modelling of observer effects (Fancy and Sauer 2000), sample size targets may not be reduced. Disadvantages are that the method may require twice the personnel as regular counts (unless safety or other considerations already require that observers work in pairs), the technique is relatively untested, and it does not work well for uncommon or poorly detected species (Nichols et al. 2000).

Although the double-observer technique helps ensure that detectable individuals are accounted for, it cannot estimate the proportion of birds present that remain both silent and hidden (McCallum 2005), nor can it estimate the distance over which birds are being sampled. Because of the latter limitation, this method is often used with fixed-radius point counts (e.g., 50 m); even then, however, conversion of counts to densities requires the assumption that all birds were detectable within that radius. It is also worth noting that the analysis described in Nichols et al. (2000) is appropriate only for estimating detection rates at the sites where the counts were taken, with no provision for among-site variability in the variance estimate. A variance estimator appropriate for extrapolation to a target population remains to be developed.

This method may be particularly useful in circumstances in which a small number of observers are likely to do most of the sampling for a study and where those observers may change over time. In this case, sufficient samples are required to calculate species-specific correction factors for each observer, to eliminate observer variation from any trend estimates.

An alternative approach for observer correction of point counts is to simultaneously use microphones to record bird vocalizations, allowing a second "observer" (listener) to compile an independent list of bird numbers at a later date. Results can then be analyzed using similar approaches to those advocated by Nichols et al. (2000). This method has the added advantage that it creates a permanent archive of the data (provided that the recordings are properly maintained), so that future observers can check them. It has the disadvantage that it detects singing birds only—but in many habitats, most birds are detected vocally in any case.

1.3.2.2.3 Adjusting index counts: analysis of detection intervals

If the numbers of birds detected during subintervals of the total count duration are recorded separately, analysis based on closed population capture–recapture methods can estimate the number of birds that were within hearing range of the observer. If the recording is limited to new detections in each period, then data can be analyzed using removal sampling models (Farnsworth et al. 2002). Subintervals could be 3-, 2-, and 5-min periods within a 10-min count (intervals recommended by Ralph et al. [1995a] for maximum comparability with other studies), but analyses are more powerful with four or more intervals, and models are simplified if intervals are equal in length (e.g., five 2-min intervals within a 10-min count).

Advantages of this technique are that it requires relatively little additional effort in the field and can be combined with other field methods, such as distance sampling or analysis of sound recordings. This technique can also adjust for much variation among observers, at least as long as all observers can identify all species potentially present. When combined with distance sampling, this technique holds promise for estimating all components of detection probability, including the proportion of birds that may have been present but remained hidden and silent throughout the count (McCallum 2005), although other assumptions of distance sampling would still have to be met.

The original description of this method by Farnsworth et al. (2002) allowed for variation among individual birds in their detectability, but assumed that detectability would not vary over time. Given that many birds sing in bouts, it is not yet clear how well the method will work for species with long song bouts interspersed with long periods of silence (McCallum 2005). More robust analytical methods are possible if a record is kept of the interval in which each individual bird is detected, but this approach has not yet been explored with respect to the observed singing behaviour of birds. Furthermore, Farnsworth et al. (2002) note that their proposed variance estimator does not incorporate among-site variability, and a variance estimator must be developed that is appropriate for extrapolation to a target population. As with other approaches to adjusting index counts, large sample sizes may be needed for the technique to work effectively.

Interval sampling has only recently been considered for use with bird counts and will doubtless be investigated further. Given the relative simplicity of apportioning counts into timed subsamples (which can have additional advantages for comparison among studies using different time period point counts), use of the technique is likely to be an improvement over a simple index count. However, the extent to which it reduces bias in trend estimates or comparisons among study areas remains to be seen.

1.3.2.2.4 Conducting "complete" counts

Small study areas (of at least 10 ha for closed habitat and at least 40 ha for open habitat) can be thoroughly and repeatedly searched in order to determine the number of territorial birds (see Breeding Bird Census [Appendix 1]) or, for single-brooded species, the number of nests present. Both parameters are assumed to represent the total number of birds attempting to breed. Observers must visit the site repeatedly, recording the exact location of each bird or nest detected (using a global positioning system [GPS] or gridding the study site and marking the location on a detailed map; Van Velzen 1972; Dobkin and Rich 1998; Bart and Earnst 2002; Dieni and Jones 2002). After a series of visits, the likely territorial boundaries of each bird can be deduced, and the total number of territory holders determined.

The chief advantage of this method is that it may provide less biased density estimates for many species than do other methods. This method is particularly suitable if the study area of interest is very small, such that essentially the whole area can be surveyed (although it should be large enough that a high proportion of territories fall entirely within the boundaries). Disadvantages are that it is very time-consuming, does not work equally well for all species (Bibby et al. 1992; Dieni and Jones 2002), and is subject to observer bias and variation among data analysts in inferring the actual number of breeding birds (Oelke 1981; Verner and Milne 1990). Moreover, the method is useful only for estimating the density of birds during seasons when birds are nesting or hold territories. Under other conditions, area search can yield only index counts, because movement rates of nonterritorial birds are relatively high, and chances are low that all individuals in the target population will be present during any given search.

Even in larger study areas, it may be practical to conduct essentially complete censuses for certain species, such as very rare species or those that occur in concentrations (e.g., colonial nesters). Indeed, it is often for the most uncommon species that knowledge of total numbers is most needed for management purposes, and these species are often poorly sampled by standard multispecies surveys. Essentially complete counts will usually require species-specific methods (e.g., searches of all suitable habitat, use of tape lures, etc.), which we do not address here.

1.3.2.2.5 Mark–recapture modelling

Total population size can also be estimated through regular capture of individuals in a population, recording recaptures or resightings whenever they occur, and then estimating the probability of recapture with mark–recapture analysis programs. An advantage of the mark–recapture/resighting method is that separate estimates can be developed for each age and sex group that can be distinguished when birds are in the hand (Ralph and Dunn 2004). Among the disadvantages are that assumptions are often violated (especially the assumption that the population is "closed," i.e., that there is no turnover in individuals present), the method is labour-intensive, and it requires skilled personnel with bird banding permits. Estimating density requires knowledge of the area from which captured birds are drawn. (For example, Nur et al. [2004] showed for one species that birds with territories >200 m from mist nets had essentially no chance of being captured during the breeding season, but that figure could differ among species and perhaps even geographically.) Mark–recapture is most likely to be useful for estimating total population size in studies that require intensive banding in any case to meet other study objectives.

1.3.2.2.6 Adjusting index counts: double sampling

Essentially complete counts and mist net mark–recapture studies are usually feasible only for very small areas. However, if conducted on appropriately selected sample plots, they can be used to generate correction factors for index counts conducted over a larger area in a double-sampling design (Bart and Earnst 2002). The sampling design is set up for a relatively simple and inexpensive count method (e.g., point counts, with or without distance sampling), which can be done relatively rapidly. A subset of the sample sites is then selected randomly from each sampling stratum, and essentially complete counts are conducted at these sites, usually with one of the techniques mentioned above (e.g., intensive, repeated area search or mark–recapture). The results from the intensive plots are used to calculate a correction factor for the rapid counts. This approach is used in waterfowl studies, in which ground surveys (which are believed to detect nearly 100% of the birds) are used to determine correction factors for aerial survey counts (Prenzlow and Lovvorn 1996).

Advantages of double sampling are that it combines the cost-effectiveness of rapid survey methods (often index counts) with the ability to estimate detection probability, the rapid methods can be changed over the life of the study without loss of data, total population size can be estimated, and valuable extra data can be collected during the intensive surveys (e.g., productivity measures from a nesting survey). Surveys of this design do not require pilot studies to evaluate biases in the rapid method, because double sampling includes ongoing evaluation as part of the survey design. To the extent that the intensive plots are complete counts, estimation of detection probability during the rapid counts will include the probability of birds being present but undetected because they remained hidden and silent.

One disadvantage of double sampling is that the intensive plots need to be a representative sample of the locations surveyed using the rapid method, which could lead to bias if some sites are excluded from the intensive survey due to constraints such as difficult access or particularly rough terrain. Another disadvantage is that a substantial fraction of the resources available for the study may have to be devoted to the intensive plots. Finally, there is not yet consensus on methods that can provide the best complete counts for most species or habitats or on whether any complete count is truly unbiased (see section 1.3.2.2.4). Where double sampling is feasible, however, it is probably the best approach to estimating detection probability.

1.3.3 Reproductive success

1.3.3.1 Nest finding

The best means of tracking reproductive success on specific study plots is intensive nest finding and monitoring. The Breeding Biology Research and Monitoring Database (BBIRD) program (see Appendix 1) has a protocol that provides valuable guidance on nest finding and data recording, and more details can be found in Martin and Geupel (1993).

The advantage of nest finding is that it gives the best possible information on nest success and factors that affect it (the latter depending on auxiliary data collected, such as predator abundance). Source–sink dynamics can cause large differences in nest success that are readily detectable using this method (e.g., DeCecco et al. 2000). The method also produces an essentially complete count of breeders, doubling as a measure of breeding density, although special methods such as colour-banding may be required for multibrooded species.

Disadvantages are that the method is labour-intensive and requires frequent visits to the study plots to determine the outcome of all nests (including multiple nestings by the same female). There could be differences among sample plots in the ease of finding nests or in finding successful versus unsuccessful nests, which could introduce bias.

1.3.3.2 Mist netting

Another means of monitoring productivity is constant-effort mist netting, such as the protocol used by MAPS (see Appendices 1 and 2). The main advantages over nest search are that the detectability of birds is not affected by observers' nest-finding abilities and that the index of productivity integrates information over the entire season. In addition, this approach can provide information on adult survival rates through capture–recapture analyses.

The main disadvantages of constant-effort mist netting are that it is time-intensive (although no more so than season-long nest finding), requires trained personnel who hold banding permits, and generates indices of productivity that are at least as subject to bias as are index counts from visual/aural surveys (Ralph and Dunn 2004). The method provides an index of productivity for a region rather than for individual sample plots (Nur and Geupel 1993) and does not provide data on the number of fledglings produced per female.

1.3.3.3 Breeding activity

A third approach to generating indices of reproductive success is to record evidence of breeding activity. Buford et al. (1996) counted numbers of adult birds with and without fledged young in attendance. A similar approach is to conduct repeated and intensive area searches, assigning a code for parental behaviour to every bird detected (e.g., adults carrying food, which indicates successful hatch; Vickery et al. 1992; Dale et al. 1997). These approaches require a great deal less effort than nest search or mist netting, although multiple surveys each year are required to encompass individual differences in nesting schedules within and between years. Moreover, these methods have not been well tested.

1.4 Statistical quality of the data

It is relatively easy to collect count data. However, to be meaningful, the data must be representative of the population about which inferences are to be made. To ensure that this is true, many samples must be collected, in a way that reflects spatial and temporal variation in bird numbers across the study area. This is an issue of sampling design, which we discuss in the next section of this document. However, sampling design depends in part on the target sample size, which in turn depends on desired accuracy and precision of results. Here we provide some background on these issues.

1.4.1 Accuracy, bias, and precision

The *accuracy* of an estimate indicates how close it is to the true value. Accuracy is usually subdivided into two components: bias and precision. *Bias* is the difference between the estimate (with an indefinitely large sample size) and the true value. For example, if the true population is 50 and the average count is 48, bias is relatively small; if the average count is only 30, however, then bias is large. *Precision* is a measure of how much error is caused by random factors. If sample counts from the hypothetical population of 50 birds were all similar, then we would say precision was high, whereas if they varied substantially, we would say precision is low. With a large sample, an estimate might be highly precise but also have substantial bias. Alternatively, an estimate with a small sample size is likely to have relatively low precision, whereas bias could be either high or low.

An important distinction between bias and precision is that the level of precision can usually be estimated by examining the samples using standard statistical methods, whereas the degree of bias cannot be estimated from the samples without additional information. Furthermore, precision can be improved by increasing the sample size, but bias can be improved only by changing the sampling methods or gathering other types of data. Knowledge of precision is important in inferring whether differences among sites or over time are statistically significant (i.e., too great to have occurred by chance at a specified level of probability). If bias is high, however, then standard statistical methods will give a misleading indication of the significance of differences. Statistical textbooks usually assume that bias is negligible; in wildlife studies, however, this is seldom the case. Therefore, much effort must be invested in developing methods that have small bias and in estimating the amount of bias that is likely to remain in the estimates (see section 1.3.2.2).

It is well known that detection probability is not constant for all species and under all conditions. Many factors contribute to variability, including habitat type, abundance of the species, time of day, and state of breeding. Norvell et al. (2003), for example, demonstrated substantial variation in detection probability between years using distance sampling methods and found systematic changes over time that appeared to be related to improvement in observer skills. When there is variation in detection probability, there can be apparent differences between samples where there are no actual differences between their true populations (Sauer and Link 2004). This is the reason we recommend use of bias-reducing techniques, as discussed in section 1.3, to help increase the credibility and reliability of monitoring results.

In addition to addressing issues of bias, it is important to achieve a good level of precision in counting birds. Precision is affected by all the survey design issues covered in this document: choice of method, standardization of sampling protocols, selection of sampling strata, and number of sample points. Before designing a survey in detail, therefore, it is important to decide on the level of precision required for the study. This is usually determined based on the desired level of power to detect a particular difference in counts. *Power* is the probability of rejecting the null hypothesis (usually that there is no trend or no difference) when a specified difference or trend that you wish to detect actually exists (e.g., a population decline of 50% over a 20-year period).

Calculating power helps us design surveys, because we can estimate the sample size required to detect specified changes (i.e., to reject the null hypothesis in our statistical test). Setting power objectives is difficult, however, especially for small study areas. We suggest careful consideration of how the results will be used. For example, is management action likely to be taken if populations decline by less than 50%? If not, then there may be no need to detect smaller declines (which will require greater effort). Is it important to detect differences among samples with a high degree of probability (thereby failing to detect some true differences), or would it be better to have a higher chance of detecting all the differences (at the cost of a few differences that are false positives)? While it may always seem desirable to have high power, there is usually a compromise between the power of the survey and the cost of the survey. Achieving higher power than required means that excess resources are used for surveys that could have been used for other activities, such as management. On the other hand, if adequate power cannot be achieved with available resources, then it is worth reconsidering whether the survey should actually be initiated.

Once these issues have been addressed, a statistician can help set appropriate goals for power and estimate the sample sizes that will be required to achieve those goals.

1.4.2 Strategies for increasing precision and reducing bias

Keys to increasing precision and reducing bias include using field methods that minimize bias or allow adjustment for bias in the analysis stage, using standardized data collection protocols, and employing good survey design (representative sampling). Good sampling design is also important for efficient surveying and, because of its importance, is discussed separately in section 1.5.

Standardizing field methods is one of the most fundamental means of reducing superfluous variance in bird counts. An operations protocol should be written that lays out rules for conducting the surveys, including:

- timing of surveys (dates, time of day);
- duration of counts (require the use of a timing device to ensure that counts are done consistently);
- exact locations of counts, which in most survey designs are the same each year;
- sequence of visiting sample points; points to be visited repeatedly should be visited in the same sequence on every visit (or switch the sequence in a systematic pattern);

- weather conditions under which counts may be taken (since wind and rain affect detectability of birds); some judgement is required, since limiting fieldwork only to ideal conditions could make surveying impractical and lead to reduced sample sizes; and
- special rules for counting (e.g., should fly-overs or young of the year be counted?).

Achieving good standardization requires not only designing a good protocol, but also ensuring that it is adequately followed. Fieldworkers are more likely to comply with the protocol if its importance is well explained to them.

If the standard protocol must be altered, follow the old and the new protocol either on alternate days or on randomly selected subsets of sample points over a period long enough to provide data that can be used in analyses to model the effect of the protocol on results.

Another important means of increasing precision and reducing bias is minimizing observer effects (i.e., differences among observers in their ability to detect and identify birds). There are several approaches to accomplishing this:

- Ensure that all observers meet a predetermined standard of bird identification skill.
- Provide observers with field training in count methods. This could involve a mixture of listening to recordings and carrying out fieldwork with experienced observers. Training should include issues such as the easiest way to record observations, how much to concentrate on visual versus aural identification, how to deal with call notes or other hard-to-identify sounds, etc.
- If the survey involves distance estimation, train all observers and give them practice in the field. With good training, the average distance estimation error for visible birds can in some habitats be reduced to 10% (Scott et al. 1981). Accurate laser distance finders are available for several hundred dollars and can be helpful tools for training and, under some circumstances, for use during counts.
- Avoid enrolling a “super-birder” for monitoring work in which only a few observers will be involved in counting, because it will be difficult to maintain the same level of skill once that person leaves.
- Involve several observers each season and rotate them among sample units on a regular schedule to avoid the possibility of a systematic observer bias. This is good practice even if bias reduction techniques are being used to adjust for observer differences.

If very few observers will be involved, consider using double-observer methods (Nichols et al. 2000) or evaluate the magnitude of observer effect using microphones (Hobson et al. 2002).

1.5 Survey design

The numbers and species of birds that will be detected in any kind of survey vary both temporally and spatially. Samples must therefore be distributed across this variation to ensure that results represent the entire population about which inferences are to be made. Even surveys with modest goals of education and outreach should follow well-conceived sampling plans so that results can be appropriately interpreted and sampling can be replicated at later intervals (see Part 2).

This section discusses steps needed to ensure representative temporal and spatial sampling and provides guidelines on the number of samples needed to achieve common study objectives. Our overview must be brief; although we provide information on sources for further information (including appropriate software), it is a good idea to consult a statistician when designing a new survey.

1.5.1 Spatial sampling

By definition, sampling results in only a portion of the area of interest being visited. Surveyed sites must therefore represent those parts of the area that have not been visited. Sample locations should be selected in some random or systematic manner that allows statistically appropriate extrapolation to the entire area being studied. Selecting the survey areas because they are known as good birding spots, for example, would produce an unrealistic view of bird life in the region as a whole. If a portion of the region is randomly sampled, but another portion is inaccessible and no surveys can be done there, it is not justifiable to extrapolate results to the unsurveyed area. Ensuring that sample points are representative of the entire area of interest is as important for species inventory and demographic work as it is for abundance estimates.

1.5.1.1 Stratified sampling

One of the simplest and most effective means of designing an efficient survey is to partition the survey area into separate sampling units, called strata. The sample sites to be surveyed are then selected independently within each stratum. For long-term studies, strata should normally be based on features that do not change, because once defined, strata must usually remain fixed. (Note, however, that strata can be redefined for analysis purposes when sampling intensity is constant across strata, as described in Appendix 3 under "Systematic sampling." This approach is often useful for studies with multiple objectives.)

Four designs for stratified sampling are suggested for use in U.S. National Parks by Fancy (2000). He includes comments on the positive and negative aspects of each design.

Stratification is done for any of three reasons:

1. when *separate estimates are required for different strata* (e.g., comparisons of bird abundance among habitats, treatment effects, altitudinal zones, forest patch sizes, etc.);
2. to *improve precision* of the estimate. If the survey area is very heterogeneous, randomly located samples will result in highly variable counts, and overall

parameter estimates will have low precision. If samples are collected in more uniform strata, however, the variation of counts within each stratum will be lower, and the final estimate for the whole area will be more precise. For improving the precision of estimates, it is probably not useful to partition the population into more than six strata (Cochran 1977); and

3. to *reduce survey costs*. Sample size does not have to be equal among strata, so strata can be designed to allow for lower sampling effort in some areas (e.g., where the cost of data collection is higher due to inaccessibility, or in a habitat where the target species has a much lower chance of being present). For example, a common error in monitoring rare and colonial species is to sample sites where the species is known to occur at present, while failing to sample other suitable spots where it may occur in future. Stratified sampling, with lower effort in currently unoccupied habitat, is a cost-efficient means of removing this potential bias while also allowing detection of the species in new places.

If resources for sampling are limited, several different sites can be joined together in a cooperative survey, each serving as a stratum for a larger study (e.g., monitoring population trends in all regional parks as a unit). This will require less sampling within each park than if trends had to be determined for each park separately. However, if the objective is to compare parameters between parks, sampling will have to be more intensive than if the objective is to obtain only a single overall estimate.

While population monitoring at small geographic scales may be focused on the surveyed area itself, interpretation of population dynamics at the study site usually requires knowledge of what is happening in the surrounding region. For example, if populations are declining in a managed area, it could be important to know whether the declines are restricted to that area or whether change is occurring in the surrounding region as well. Similarly, it may be desirable to learn whether population status in relatively pristine protected areas differs importantly from that in human-impacted landscapes. One solution is to design the study with one or more strata chosen to represent the wider area with which the study site population estimates can be compared. Site managers and project funders may not initially understand the value of conducting work outside the focal area. However, this approach will allow much stronger inferences about differences on and off the study site and will provide important perspective on how best to manage the site itself.

This approach can often benefit from a comparison of local survey results with those from large-scale surveys such as the Breeding Bird Survey (BBS) (see Appendix 2). However, due to sample size limitations, BBS trends can often be calculated only for very large regions (e.g., province/state). Taking responsibility for running one or more BBS routes in the region surrounding a study site can be an important part of a comprehensive site monitoring plan, because it will improve the chances of finer-scale BBS analyses being available for comparison with results from the study site. In some regions, monitoring data may be available from additional sources, particularly where provincial or state monitoring programs have been established. Opportunities for comparison with other data sets and assisting in developing those data sets should be considered when designing a new survey.

When an entire site is under management, it may not be possible to reserve control plots as a separate stratum for data collection. Questions about management effects can still be addressed in this instance, however, using adaptive management models. Models are built in which predictions are made, and bird counts are conducted in appropriately defined strata to test these predictions (e.g., birds will be more abundant in older-age forest stands than in younger stands). Results can then be used to improve the predictive model or to modify management objectives (Walters 1986).

1.5.1.2 Distributing samples

Within each stratum, or within the survey area as a whole if there is no stratification, samples should be distributed in an unbiased way. This means selecting points either at random or in a systematic pattern from a random starting point. In Appendix 3, we describe practical means of selecting locations for samples. The U.S. National Park Service provides additional examples of sample point allocation (see Appendix 1).

For most typical monitoring objectives, it is best to establish permanent sample points and visit them every year (Fancy 2000). However, when the sample size that can be covered in a single year is not as large as desired, and if detecting long-term trends is a more important objective than year-to-year comparisons, then a rotating panel design may be appropriate (Urquhart and Kincaid 1999). For a 3-year rotation, for example, three times the number of points that can be covered in a single year are selected within each stratum, and each point within a stratum is randomly assigned to a year in the rotation schedule (i.e., to be covered in year 1, 2, or 3). Results can be difficult to analyze if multiple strata are involved, however, so it is advisable to discuss this with a data analyst when designing such a study (Fancy 2000).

1.5.2 Temporal sampling

1.5.2.1 When to count

Because bird detection rates and the presence of birds in an area may differ with season, date within season, and time of day, it is important to determine the time windows (seasonal and daily) within which surveys should be completed and to ensure that the same timing is used at each sampling site and in each year.

Sometimes accessibility to remote areas will be easier in winter (e.g., by snowmobile), and some resident species (e.g., early-nesting woodpeckers) may be better monitored in winter than in the usual months for breeding season surveys. Most breeding season surveys are conducted early in the nesting cycle, when territorial birds are singing the most frequently. BBS guidelines (see Appendix 1) recommend June surveys in order to cover the maximum number of breeding species; in parts of Canada, however, surveys can run into the first week of July, whereas in the most southern portions of the United States, they may start in late May.

For the detection of singing birds, it is usually important to start counts near dawn and stop sampling before 10:00 or 11:00 a.m., because birds sing most frequently in the morning. Smith and Twedt (1999) showed that species richness and abundance may be underestimated in evening counts, both in the breeding season and in winter. However, studies in other locations may not necessarily give the same results, and for some species evening surveys may be a useful alternative, particularly if the methods are standardized or appropriate bias corrections are used. Providing this option may lead to increased survey participation by, for example, volunteers.

If population parameters are being compared between sites, samples should be taken concurrently or in visits that alternate between the sites, so that samples from the sites are not biased by differences in the dates on which, or hours in which, data were collected. If sample sites are visited more than once in a season or in multiple years, either they should be covered in the same sequence at each visit or the sequence should be randomized at each visit. Visiting in a standard sequence is the simplest approach but has the potential to limit opportunities for post hoc hypothesis testing.

When multiple visits are made within a season, they should be spaced among clearly defined sample periods to ensure consistency of temporal sampling and to ensure that differential phenology between samples or years will not bias results (e.g., sample every 10 days or once per month). Some leeway can be allowed in the date of sampling within each sample period, but the longer the period (e.g., monthly sampling), the more important it is to specify the sample date more finely (e.g., sample within first 10 days of each month).

1.5.2.2 How often to sample

Visiting each sample point more than once in a season increases the precision of estimates. However, most studies of the subject have found that it is more efficient to expand the number of sample points and visit them only once than to visit fewer points more often (Ralph et al. 1995a; Thompson et al. 2002). Nonetheless, repeated sampling is important for surveying species that may be present in the study area for a short and unpredictable portion of the season, such as irruptive finches in wintering areas. Furthermore, repeated visits can provide opportunities for bias reduction through estimating numbers of species missed on each visit (e.g., Nichols and Conroy 1996).

1.5.3 Sample size

The number of samples to be selected in order to meet precision targets (see section 1.4) is affected by the survey design and objectives. Here we provide general guidelines on the magnitude of sample size required for common study types. We provide information on software that is available for helping determine the appropriate sample size and urge that these tools be used. Population studies require a great deal of effort and expense, so while it is important to ensure that precision targets will be met, care should also be taken that sampling is not excessive.

1.5.3.1 Species lists

Species lists are often most efficiently compiled using area search, in which case “sample size” is less an issue than is total time spent searching. Analyses of data from breeding bird atlases on the cumulative number of species detected as a function of cumulative time in the field have suggested that in 10-km blocks with good road access, it is possible to detect 75% of the expected number of species present with 15–20 h of area search, although this figure will of course vary with region, conditions, access, intensity of effort, and observer experience (Robbins and Geissler 1990). Analyses can be conducted after a pilot project in order to select a target effort level for the rest of the study or in a post hoc analysis to evaluate the quality of coverage that was actually attained.

The percentage of species detected in inventory studies can also be estimated using mark–recapture analysis (Nichols and Conroy 1996). Each site must be visited at least five times, with standardized effort per visit, and each site must be visited in time periods capable of sampling all species of interest. If some species (e.g., nocturnal species) are not adequately sampled by the standard visits, then they must be considered separately.

If species lists are to be developed as a by-product of point or transect counts, the sample size necessary to detect a target proportion of the species expected in the area can be estimated using software designed for this purpose (see Appendix 1). These methods may not be efficient for developing a complete species inventory, however. As an example of sample effort that may be required, Swanson and Nigro (2003) found that with stratified sampling in a large (1 million hectares) reserve in Alaska, only 63% of expected species were detected with approximately 1400 point counts over a 2-year period. This figure rose to 86% when species were added that were detected while observers moved between count sites and could potentially have been increased further with additional observations targeted at rare habitats or species that are rarely found on point counts.

1.5.3.2 Abundance monitoring

In order to determine an appropriate sample size, decisions must already have been made on precision targets, field methods, and study design. To estimate needed sample size, at least some information must be available on the expected variability of counts, either from pilot work or from a similar study in another location. Results from the first season of data collection should be analyzed to determine whether sample size targets require adjustment.

Many software packages are available to estimate the sample size needed to attain a given level of precision and power, based on known or estimated sample variance, but calculations can also be done by hand (for instructions, see Hamel et al. 1996). Some of the most popular software programs were reviewed by Thomas and Krebs (1997). Although rapidly becoming dated, this review provides an overview of program capabilities, as well as names of vendors that can be used in searching the Internet for information on updated products. Other vendors can be found by doing an Internet search on “power analysis software.”

It is important to recognize that all of these software programs require assumptions about the nature and sources of variance that will be encountered, as well as the methods that will be used for analysis. Because these assumptions are often only approximately met and because the variance estimates are often imprecise, it is usually worth varying the input parameters to the models to determine their impact on the estimated sample size required. Although the results may be somewhat variable, they can nevertheless give valuable indications of at least the approximate sample sizes required to achieve the desired results, and hence the feasibility of the study.

While it can be costly to oversample, it can be far more costly to collect too few samples for study objectives to be met. It has been found that at least 200 to over 1000 point counts will normally be needed to detect a 20% change in abundance between sampling areas in the area on the order of 80 000 ha (Manley 1992; Ralph et al. 1995b). Larger samples will be needed for less common species, and even the largest studies will not be able to monitor every species at target levels of precision. When there are only one or two target species, playback of taped calls can be used to increase registrations and thereby reduce required sample size (Sliwa and Sherry 1992).

As a rule of thumb, at least 60–80 detections of a species are required in distance sampling for good determination of the rate at which detectability declines with distance. Note that these sample sizes must be met for each stratum or each year for which estimates are required. Large samples are also likely to be needed for removal models. For areas too small to contain sufficient sample locations, double sampling may be the best option for bias reduction.

With transects, the appropriate sample size will depend on the length of the transects, as well as their number. Surveying more and shorter transects is usually more efficient than covering fewer, longer transects (Hanowski et al. 1990). However, longer transects are better at detecting abundance differences in less common species, because the species will be detected on a higher proportion of samples.

1.5.3.3 Trend monitoring

When estimating long-term trends, the required sample size depends not only on the number of samples taken in a given year, but also on the number of years allowed for detection of the trend. The more years of sampling, the greater the precision of a long-term trend, even though the precision of each annual estimate remains unchanged. Thus, a precision target for detecting a trend over 20 years will require fewer samples than detecting the same rate of change over 10 years (Bart et al. 2004).

1.5.3.4 Productivity

The number of nests that must be found to allow a comparison of nest success between two areas or two years can be estimated using sample size software (see section 1.5.3.2 for more information). As few as 6–8 netting stations in a study area (each operated once per 10-day period throughout the summer) may be sufficient for estimating productivity representative of the whole area (Bart et al. 1999), but other studies show that up to 30 or more stations can be necessary to detect a 25% change in productivity between years (Ralph et al. 2004). However, more work is needed on the relationship between index counts and true productivity over a wide range of productivity values.

1.6 Other issues to consider when designing a monitoring program

1.6.1 Auxiliary data

To meet study objectives, it is often necessary to collect data other than bird observations, such as data on vegetation type and structure, level of human disturbance, weather, or abundance of mammalian predators. Collection of auxiliary data should be carefully planned to meet the objectives of the study, and not done "just in case." For example, species of plants at a site usually are less related to bird numbers than is vegetation structure, and vegetation close to a count point may be less important than habitat in a wider area around that point. Characterizing habitat can require as much effort as or more effort than conducting bird counts, and habitat data frequently prove very difficult to analyze. As in developing overall study objectives, one should always ask "Why do I want these auxiliary data?"; "How do I plan to analyze them?"; and "Are they what I need to answer the question I am posing?"

Auxiliary data may be obtainable from an existing source (e.g., local weather station, existing vegetation maps, remotely sensed habitat data). If new data must be collected, commonly used, standard procedures should be selected whenever appropriate (e.g., see Hamel et al. 1996 on habitat measures). It saves time and money to take advantage of available instructions and data forms that have already been developed (such as the vegetation recording forms cited in section 1.6.2). In developing project budgets, it is important to include money for training observers to collect consistent vegetation data.

1.6.2 Data forms and instructions

Standard data collection forms should be designed for all aspects of the project (bird counts, vegetation sampling, etc.), and these should be accompanied by clear and complete instructions for observers. Data forms should call for the recording of all data needed to ensure that the protocol was followed correctly, such as date (including year), count site, time of day, count duration, and name of observer (or ID code), as well as appropriate auxiliary data (weather, vegetation, etc.). Keys to codes required for data recording should be printed on the field forms for ready reference. Developing scannable data forms that reduce data entry effort may be cost-effective for some large projects. Internet data entry programs can also be considered, particularly for projects involving volunteer surveyors.

Instructions must give a clear explanation of where, when, and how to conduct fieldwork and how to record data (including explanation of any codes). They should also address contingencies, such as the procedure to follow if weather conditions deteriorate, if the presence of a predator is disrupting counts, if the characteristics of the count site are not as expected, or in case of emergency.

In addition, there should be formal documentation of any additional metadata concerning the study that are not included in the forms and instructions (e.g., more complete maps, GPS coordinates of all sample locations matched with the codes or names used in the field, a brief description of primary habitat type, a photo for each point if no detailed habitat data are collected). Together, the forms, instructions, and additional information should be sufficiently complete to allow a new person to replicate the study exactly (same place and methods). These materials (including all versions if there were any changes during the life of the project) should be preserved in one place as an archival record (see also Oakley et al. 2003).

Sample protocols, field forms, and data entry software are available for some of the field techniques we recommend:

- Distance sampling forms and instructions: http://www.fs.fed.us/pnw/bird-populations/index.htm
- Double observer: field sheets and protocols available on request from U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland (Fancy and Sauer 2000)
- MAPS (constant-effort mist netting for monitoring of productivity): manual, forms, and data entry program (including vegetation recording): http://www.birdpop.org/manuals.htm
- BBIRD (intensive nest finding) instructions and forms (including vegetation recording): http://pica.wru.umt.edu/bbird/protocol/protocol.htm
- eBird (checklist program—see Part 2): instructions; website itself can be used for data management: http://www.ebird.org/content/
- Atlassing (mapping of species distributions based on area search): links to instructions, software for data management: http://www.bsc-eoc.org/links/links.jsp?page=g_atlas

Keeping a daily field log is a useful way of capturing additional information that can help in analysis and interpretation of results, such as events that may have interfered with fieldwork and observations not recorded on standard forms (e.g., unusual behaviour, mammal encounters, unusual birds recorded between sample locations). Requiring a standardized log form to be filled in daily will help ensure that miscellaneous information is consistently reported.

1.6.3 Data storage and analysis

Regardless of the number of data to be collected, it is important to think about data management and analysis before fieldwork even begins. Those tasks may be eased if certain things are incorporated into field forms (such as observer ID codes), and layout of forms should consider ease of computer entry. Data management and analysis also cost money, and this must be taken into account in project budgets. Unless careful thought is given to these issues prior to starting the project, the cost of data management and analysis will almost certainly be underestimated. Projects with volunteer data collection may cost even more than those with paid counters (other than labour costs) because of the need for recruitment, feedback, data entry, and extra analysis costs connected with incomplete data or other problems with less-than-perfect sampling. Partnerships in which data management and analysis might be done centrally for several related studies, reducing expense for all, should be considered.

With large projects, a detailed data management plan should be developed, indicating how data are to be entered into the computer, verified, stored, secured, made accessible to users, etc. (For an excellent example, see DeBacker et al. 2002.)

Resources exist for managing data (such as the eBird website) or for archival storage (such as the Bird Point Count Database, which allows a wide variety of habitat information to be archived along with bird data) (see Appendix 1). Also, there is often free software available for analysis of monitoring data (see examples in the following paragraph). It is important to understand ahead of time what data are required for the analysis program, to ensure that field protocol includes all necessary data collection.

Analysis software that can be downloaded from the Internet includes the following:

- Distance sampling (points and transects): http://www.ruwpa.st-and.ac.uk/distance/
- Estimating proportion of species detected (SPECRICH2): http://www.mbr-pwrc.usgs.gov/software.html
- Estimating population size from mark–recapture (e.g., MARK, POPAN): http://www.phidot.org/software/

1.6.4 Recruitment and training of field personnel

Some monitoring work can be conducted using volunteer help, and doing so may even be one of the objectives of the survey. However, volunteers will not be equally enthusiastic about all field techniques, and many kinds of study will require paid observers. Sometimes paid personnel can be used to fill gaps in otherwise volunteer monitoring.

All participants, volunteer or paid, should learn about the objectives and protocols of the survey. People are much more likely to adhere to survey protocols if they understand the rationale for the specific procedures.

For certain volunteer surveys, it may be sufficient to specify required skills and count on participants to self-select and to provide materials for self-administered training. If a high level of skill is needed, however, particularly in identifying birds by song, potential personnel must be screened and trained in the specific techniques to be used in the study, such as estimating distance of birds from the observer or aging birds in the hand. To encourage uniformity of approach, even experienced personnel should participate in training, because it is easy to develop an individual style that varies from the standard. For the same reason, spot-checks of skills throughout the life of the study should help ensure that counting style does not drift over time.

1.6.5 Pilot study

Whenever a monitoring study is established, results from pilot work or from the first season should be analyzed as soon as possible. This will ensure that any problems with protocol or data forms can be identified and corrected early on, but will also allow re-evaluation of survey design. For example, the target number of sample points may have been based on sample variance estimated from another location, and sample size targets may need adjusting once the variance of actual data has been assessed. Index count methods require strict adherence to a predefined sampling protocol, such that experimentation should take place during a pilot season.

1.6.6 Monitoring plan and protocols

After all planning is complete, it can be very valuable to write a complete monitoring plan (e.g., Hanowski and Niemi 1995). This will be invaluable for obtaining funding and approval of supervisors, because it will provide clear evidence that the project has been well planned.

In addition, detailed protocols should be written to provide complete instructions for field operations. Some good examples of monitoring protocols can be found at the U.S. National Park Service Inventory and Monitoring Program website (see Appendix 1) and in Huff et al. (2000). It can also be very useful to write protocols for other aspects of the program, such as the steps needed to prepare for each field season, tasks to be completed at the end of each season, and data management procedures.

Part 2
Guidelines for a site-specific checklist survey

2.1 Introduction

Part 1 of this document contains advice for developing a high-quality monitoring program that will be suitable for hypothesis testing and decision support. Part 2 provides options for a *checklist survey*, which is more suited to involving volunteer observers and can thus accomplish outreach and educational objectives at the same time as gathering useful information on bird populations. Depending on options selected, the value of results for scientific and conservation applications can range from low to high. The quality of the results will depend on the completeness and consistency of the coverage, so a good program will require commitment to organization, oversight of data collection, recruitment of volunteers, filling of gaps in coverage when necessary, and ensuring that results are well used. While volunteers may conduct much of the organizational work as well as collecting data, such programs will have a much better chance of success if there is a sponsoring organization that can contribute the time of at least one employee to be responsible for the survey (see section 2.3), as well as to cover direct costs (e.g., for printing and distribution of survey materials).

Although Part 2 can be used without reference to Part 1, project organizers are urged to read the Introduction at a minimum, and preferably the whole document, before designing a checklist survey. This should lead to better understanding of the implications for survey quality of selecting among the options below.

2.2 Project description

Birders routinely collect information on bird abundance, collectively covering thousands of individual sites, and are usually eager for their observations to be used for scientific or conservation purposes. An organized checklist survey takes advantage of the large pool of skilled birders who routinely do fieldwork, giving them instructions on where and when data should be collected in order to increase the quality and interpretability of the results.

"Checklists" get their name from regional lists of species on which observers can simply check off the species seen, regardless of time or place. For a site-specific checklist survey that will be useful for monitoring, however, observers should also record the number of birds detected (by sight or sound) and keep separate records for each day and location (Dunn 1995).

A checklist survey can be run with minimal professional participation. Data can be collected at times and places that will allow reasonable inferences to be drawn about the birds that can be seen and heard within the set of sample sites or, if the project is well designed, throughout the entire study area. The guidelines below were developed with monitoring of nature preserves, large parks, or wilderness areas in mind, but are easily adapted for use in townships, counties, or even much larger areas (Droege et al. 1998).

A well-designed site-specific checklist survey can provide:

- a list of species present in the area of interest, with documentation of change in species composition over the course of the year and over longer time periods;
- qualitative information on relative abundance, indicative of the likelihood of encountering a species in an area and in what numbers; and
- with good sampling design and adequate coverage by skilled observers, credible information on relative abundance of detectable populations at the sample sites or (depending on design) the area as a whole. Change in those populations over time can be detected by replicating the survey at intervals (whether annually or at long intervals of a decade or two). Results are unlikely to be statistically robust enough for hypothesis testing or to justify management action (in large part because the number of sample sites is likely to be too low), but can readily detect worrisome changes that imply a need for further, more rigorous investigation.

A site-specific checklist survey should not be selected as the method for monitoring when robust quantitative information on bird abundance is desired for research purposes or for making management decisions. It can be a good choice, however, when no inventory or monitoring would otherwise be done and for documenting the status of bird life in areas of particular interest to the organizing group. A checklist project can also fulfill objectives for education—whether encouraging beginners to learn more about birds or providing information to visitors on the status of local bird populations—and as an outreach program to encourage volunteers to become more interested in protection of special areas. In addition to being used for local purposes, the data can be contributed to regional checklist programs and/or to the eBird continental database (see Appendix 1) for others to use for a wide variety of research and conservation studies relevant to broader geographic scales.

2.3 Organizer responsibilities

Anyone wishing to organize a site-specific checklist survey should think carefully about objectives and operational procedures before preparing printed materials and starting fieldwork, as detailed below:

- Develop clear **objectives** for the study:
  - First, **what do you want to learn?** Examples include: What species are present in the area? What is the distribution of species within the area? What is the relative abundance of species in the area? What changes in species lists (or apparent abundance) occur seasonally or over the long term?
  - Next, decide on the **area** for which you wish to have results. Are you content to gather data that reflect the status of birds within the set of places where birds are actually observed (e.g., along a series of trails or a set of waterfowl lookout points), or do you want results to represent the status of birds across a broader area (e.g., an entire park)? In making this decision, you should have clear goals for the use of the results. Why do you want to have these data, and what use is to be made of the results? Projects should not be started without clear objectives and plans for using the results, because survey design options need to be selected accordingly and because collecting data that will not be used for anything is a waste of everyone's time and effort.
  - Finally, determine the **quality of results** that you want to have. If objectives are primarily educational or recreational, the most basic survey options (see below) may be appropriate, whereas the most stringent options will be required if the intention is to obtain quantitative data on observable populations and their changes over space and time.
- Decide on **project duration**. While ongoing surveys can gather useful data, results will usually be of much higher quality if the survey is targeted for completion within a set period (e.g., 1, 3, or 5 years). The value of the results will depend largely on good temporal and spatial coverage, and good coverage is often attainable only if participants know that there is a time limit on their efforts. Even if the intention is to continue indefinitely, targets should be set for the level of coverage to be achieved in a particular period, with appropriate reporting and analysis. If the survey is to be of limited duration, decide whether the intention is to repeat the survey again at a later time (e.g., in 20 years).
- Consider whether **resources** (financial and human) are likely to be available to achieve the objectives. After preliminary thought on objectives and possible project design, talk to some local birders to see if they can be brought on board. While there will often be skepticism about the prospects of attracting enough qualified volunteers, enthusiasm among a few core people at the start is usually indicative that interest can be developed among others as well.

- Design the **sampling frame** in detail (see section 2.4).
- Develop **instructions** for volunteers (see Box 2.1). Recruit volunteers to **field test** the instructions and checklists, to ensure that the latter are clear and unambiguous.

Box 2.1. Instructions for volunteers

Instructions for observers should include:

- A brief overview of the aims and structure of the project.
- Where counts should be taken: Provide detailed descriptions of the sample locations, and how their boundaries can be identified.
- When to make counts (dates and allowable times of day).
- How long counts should last (allowable time periods for each sample location).
- What to record (following are some recommendations):
  - Record number or best estimate of each species detected by sight or sound. Do not try to estimate numbers that might be present but were not actually detected.
  - If numbers have to be estimated (because of large flocks or incomplete views), record the midpoint of the low and high estimates (e.g., if flock size is 500–1000, record 750; if 500–700, record 600). Please do not make up your own rules (such as recording "ca. 500" or "500+"). Among other reasons, such notations are not computer-friendly.
  - If a bird flies over the area, then it can be recorded, but birds detected only outside the boundaries of the sample area should not be recorded or should be mentioned only in the Comments area on the checklist.
  - If observations are being reported for an incomplete count (e.g., reporting is for selected species and not for every species that was detected), then check off the "incomplete count" box on the checklist.
- If data are to be collected on breeding evidence, full instructions for using atlas codes (see Laughlin et al. 1990).
- Instructions on appropriate comments: e.g., unusual conditions (such as weather that interfered with observing birds), list of additional species seen outside the sample area, or documentation of rare species.
- Key to sites, with details on location and boundaries.

- Set up a **data entry** site on the eBird website (see Appendix 1 and Section 2.5).
- **Print** final checklists (see Box 2.2) and instructions.
- **Recruit birders.** Participants should be willing to bird at specified times and places in order to achieve the survey objectives. They should be directed to visit a variety of sample sites rather than adopting one or a few sites as "theirs" to reduce the potential for variation in birder skills being linked to particular sites. Birders can be recruited through local bird clubs, by posting notices on birder hotlines or listserves, by posting a project on the American Birding Association's volunteer projects listing (see Appendix 1), or by contacting a few active local birders and asking them how best to reach others in the area.

Box 2.2. Contents of printed checklist

Printed checklists should contain the following:

- Name of project, basic contact information, and where to submit data.
- Field for entering name of observer (and code or observer number, if this is required for database entry).
- Separate fields for entering day, month, and year (to ensure that all three are recorded).
- A list in taxonomic order of species likely to be found in the study area. A few blank lines should be provided for additions. Species requiring extra documentation can be marked with an asterisk or other symbol.
- One or more columns for recording number of birds detected by sight or sound at a particular sample location. Multiple data columns can be provided if observers are likely to visit several sample locations within a single day.
- For each data column, provide fields for reporting location (e.g., site number), start and end time of observations taken at that location, total hours of observation (in case start and end times include lengthy breaks), and a check-off box to tick if the observations were incomplete (see Box 2.1).
- If evidence of breeding is to be collected, two columns for each location: one for number of birds, and one for breeding evidence.
- An area for comments, with a note to see instructions.
- A brief key to site locations and their names (or codes for use in data recording). Full details on location and boundaries should be given in the instructions.
- A key to any other codes to be used on the form (e.g., for breeding evidence).

- **Check regularly** on incoming results to determine whether more recruitment effort is needed or the study design needs adjustment, and prepare interim summaries as **feedback** to volunteers. Regular feedback is an important tool for building interest in and commitment to the project and for encouraging the filling of data gaps. Results, announcements, and human interest stories from participants can be distributed through a listserve, e-mail, a project website, or a printed newsletter (with the latter being the most costly).
- Once the project is under way, determine whether **funding** will be needed to hire one or more surveyors to visit sample sites that are not getting visited often enough (or at all) by volunteers. If so, do some fund-raising. While it is possible to add an extra year or two at the end of the project to finish it off, discouragement can set in quickly if it becomes clear that the initial target is not going to be met.
- Prepare one or more **final reports** on results for volunteers, funders, managers, landowners of the study area, local bird clubs, or other interested parties. Even if the project was incomplete, it is important to report on what was accomplished and what lessons were learned about running a similar project in future. Use results to the extent feasible—e.g., to prepare a list of species in the area of interest for use by visitors, or to inform managers of locations within the study area that are of special ecological interest.

- Ensure that full information on the project is placed in an **archive** for future reference. This should include full details of each sample site (location and boundaries), a brief description of the habitat at each sample site (and preferably some photographs), a set of forms and instructions, a copy of the eBird data set, keys to any codes for observer or location, and copies of all reports on the project. These materials will ensure that a repeat project can accurately replicate the sampling frame so that results between sample periods will be comparable.
- Consider continuing to **collect data** opportunistically after the end of the official project or developing new, follow-up projects to address any specific questions that may have been raised by the first project.

2.4 Project design

We describe several options for sampling designs for site-specific checklist surveys, which differ in attention paid to spatial and temporal sampling and therefore in the quality of information that can be collected. We do not recommend reliance on opportunistic sampling, in which the organizer simply prints checklists and instructions, provides them to birders visiting the area of interest, and collates whatever results are turned in. Even if large numbers of checklists are collected in such a program, the data are likely to come from only one or a few popular locations in the area of interest, at times of the year when most birds are present. Although a fairly complete list of species can eventually be compiled from such an approach, it will be impossible to interpret data on relative abundance or changes over time in the study area as a whole. Even for the specific locations that are visited most often, opportunistically collected data may support only weak inference.

Instead, a site-specific checklist survey should have a consciously selected spatial and temporal sampling design. Below are some options, with examples listed from most basic to best under each heading. Along with the increase in quality of data with later examples, design becomes slightly more complex, more direction of volunteers is required, and lower numbers of volunteers may perhaps be interested in taking part. On the other hand, the quality of observers who do participate is likely to be higher, because unskilled birders are less likely to join a project that looks "official" and requires adherence to rules about where and when to count birds. As the commitment to collect useful data increases, the greater will be the need for recruiting observers to provide continuing coverage throughout the duration of the project.

Box 2.3. Sampling design for site-specific checklist surveys

- Select sample locations
- Decide on number of sample locations
- Decide how long each count should last
- Decide on frequency of visits

2.4.1 Sample locations

***Option 1**:* Select popular birding spots within the study area that are clearly distinguishable from one another, have definable boundaries, and are of a size that can be traversed on foot in about an hour or less (not more than about 3 km^2). The sites can be heterogeneous; e.g., one might be a waterfowl viewing point, while another is a marsh, woodlot, or trail. Define the borders of the sample locations using visible landmarks whenever possible (e.g., "Site 1 extends from the waterfront to the far edge of the field to the north and is bordered along the west and south by a dirt road"). Results from a set of popular birding spots will probably not be representative of the area as a whole (unless the study area is so small that all parts are included as sample sites), but, combined with good temporal sampling, can be acceptable for the sampled areas themselves.

Option 2: Divide the study area into 2–6 segments or "strata" (e.g., four equal quarters, zones around separate access roads, or areas with quite different habitat or topography). Within each stratum, select one or more accessible locations as sample sites. This procedure will ensure that sample locations are spread throughout the entire area of interest. Attempt when possible to select locations representative of the entire stratum. If sample locations are special (e.g., a marsh within woodland or a wooded trail surrounded by fields), then results may be only slightly more representative of the entire area than by using the first option described above. However, if sample sites are similar to other parts of the strata in which they occur and if all sample sites are about the same size, then results should be reasonably reflective of bird status in the study area as a whole.

Option 3: Divide the study area into strata, as described in Option 2 (above). Select sample locations within each stratum using a random or systematic approach, as described in Appendix 3. Define a standard sample plot size, a size suited to thorough coverage by area search within 1–4 h. If only one or two sites are going to be sampled in each segment of the area of interest, the location of samples may not be much different from that in Option 2 (above). Defining a standard size, however, will result in more uniform effort at each sample point and greater comparability of counts from different time periods. Plots should be flagged or otherwise marked to ensure that their boundaries are clearly visible to observers.

2.4.2 Number of sample locations

Option 1: If the aim is to track bird status in the sample sites themselves, then number of sample locations is not an issue.

Option 2: If the objective is to determine bird status throughout a study area that is larger than the sum of the sites being sampled, then the rule of thumb should be to cover as many sample locations as possible, covering many portions of the total area. Collecting data from more locations will generally be more valuable than collecting an increased number of data from fewer sites. However, the target number of sample locations must strike a realistic balance among several factors: the size of the study area, number of participants, skill and commitment level of participants, and accessibility of sample locations.

2.4.3 Duration of counts

Option 1: Allow observers to search sample areas for as long as they like, at any time of day, requiring only that a single checklist be turned in for each day's birding at a sample location.

Option 2: Ask that participants move through the sample site systematically, at a steady pace but allowing stops or detours to identify elusive individual birds. Suggest a generous maximum period within which it should be possible to cover each sample site, even at a very slow pace (e.g., 1 h at site 1, 20 min at site 2, 4 h on trail X, etc.). Ask that observations be taken at the time of day when birds are most active (usually before noon).

Option 3: Where sample sites are of a standard size, specify a standard sampling period (e.g., 20–30 min per site). Set the standard period to allow thorough coverage under normal conditions, using a steady pace but allowing stops or detours to identify elusive individual birds. Specify the time of day that is allowable for counts.

2.4.4 Frequency of visits

Option 1: Set a target number of checklists for each season of interest. For example, the target might be to collect 25 checklists per sample site per season over the life of the project (from all observers combined). The target should be based on realistic expectations, given the number of participants, how far they have to travel to take part, how long the project will last, etc.

Option 2: Specify the target number of checklists based on what is needed to meet the objectives of the survey, with the understanding that greater organizational effort will be required to meet those targets and paid staff may be required to fill in gaps. For example, set separate targets for periods within seasons (e.g., a total from all observers combined of 10 checklists from each site in each winter month, 10 per week during the migration season, and 10 per month in the breeding season). This will ensure more even temporal sampling, better describing seasonal fluctuations and timing of bird movements.

Option 3: As above, but set targets for number of checklists to be collected in each period within each year (not simply over the entire survey). This can provide an indication of annual variation.

2.5 Data management

You can use the eBird website (see Appendix 1) to manage the data for a specific project. The easiest way to do this is for the organizer to register him/herself on the eBird website and to register each of the checklist survey sample plots as a “hotspot.” The organizer then registers him/herself multiple additional times on the website, each time setting up a new username and password. One of these “identities” is then given to each participant in the checklist project, who will use that username and password to get into the website and enter data for the “hotspots” visited by that participant. Any person using eBird, whether a participant in the organized checklist survey or not, can submit observations made at any of these hotspots, and any person can look at summaries of all data from each of those locations. The organizer, however, can access the data submitted by survey participants alone (by using the project participants’ usernames and passwords). As well, the organizer can ask eBird managers to provide data for the entire set of “identities” registered under his or her name.

Using eBird in this way means that there is no need for the organizer to develop a data entry or database management system, observers enter their own data, the database is also the long-term archive, and all data automatically become part of eBird’s continental database for use by others. More complicated and project-specific arrangements can be made through negotiation with eBird managers.

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Appendix 1. Internet resources[1]

American Birding Association, Directory index of opportunities for birders, Colorado Springs, Colorado:
http://americanbirding.org/opps

Bird Point Count Database, Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland:
http://www.pwrc.usgs.gov/point/help/index.cfm

Breeding Biology Research & Monitoring Database (BBIRD), Montana Cooperative Wildlife Research Unit, University of Montana:
http://pica.wru.umt.edu/bbird/info.htm

Breeding Bird Census (BBC), Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland:
http://www.pwrc.usgs.gov/birds/bbc.html

Christmas Bird Count, National Audubon Society, New York:
http://www.audubon.org/bird/cbc

eBird, National Audubon Society and Cornell Lab of Ornithology:
http://www.ebird.org/content

Effort Predictor V1.0, Spatial Information Research Centre, University of Otago, Dunedin, New Zealand:
http://divcom.otago.ac.nz/sirc/peterw/effort.html

Monitoring Avian Productivity and Survivorship (MAPS) Program, Institute for Bird Populations:
http://www.birdpop.org/maps.htm

North American Breeding Bird Survey (BBS), Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, and Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland:
http://www.pwrc.usgs.gov/bbs

U.S. National Park Service Inventory and Monitoring Program:
http://science.nature.nps.gov/im

[1] Internet addresses for cited literature are given in the Literature cited section. All website URLs were correct as of November 2005.

Appendix 2. Existing broad-scale monitoring programs to which volunteers can contribute data from sites of their own choosing

Participation in useful monitoring adds a satisfying sense of purpose to one's birding pleasure, and many people want to contribute to bird population monitoring in their local area for that reason. However, not every such person is interested in designing or implementing his or her own survey. The ideal solution is to take part in one of the many cooperative surveys to which data can be contributed from a site of the observer's choosing. These include a wide range of studies, from recording species presence or counts to determining reproductive success. Some projects are North American in scale, whereas others are regional. Skills required vary from beginner to expert, depending on the program, and requirements for participation range from a single day of birding to intensive effort.

The website for the American Birding Association (see Appendix 1) gives a comprehensive list of more than 600 volunteer ornithological projects, with details on survey objectives, skill level, and time commitment required, as well as links to project-specific websites. In Box A.1, we show a small sample of the broad-scale surveys to which observers can contribute data from a favourite location. There are dozens of additional projects that are regional in nature, also described on the American Birding Association website.

Box A.1. Sample of cooperative monitoring surveys in North America to which participants can contribute data from a location of the observer's choosing

Distribution of species, and timing of occurrence:

- eBird (checklist survey, requires Internet access)
- Great Backyard Bird Count (once per year checklist, requires Internet access)
- Project FeederWatch (bird feeder survey)

Reproductive success:

- MAPS (Monitoring Avian Productivity and Survivorship; requires banding permit)
- Bird House Network (nest box monitoring)
- Project Nest Watch (nest finding, Canada)

Species- or habitat-specific surveys (not all sites will be suitable):

- Marsh Monitoring Program
- A Swift Night Out (Chimney Swifts)
- Purple Martin Project MartinWatch
- Project Pigeon Watch
- Urban Bird Studies
- Golden-winged Warbler Atlas Project

Details on these and other projects can be found on the American Birding Association website (see Appendix 1).

One of the most important cooperative monitoring programs in North America, whose data are used extensively for conservation and research purposes, is the North American Breeding Bird Survey (see Appendix 1). This survey is not listed in Box A.1, because survey route locations are preselected by the organizers. While observers may choose among available routes, they cannot participate at a location they select themselves. It is partly because this survey has a representative sampling design that it is so valuable. Nevertheless, interested observers can contact their regional compilers to determine if there are routes near them that require coverage.

Another popular cooperative program not shown in Box A.1 is the Christmas Bird Count (see Appendix 1). There are close to 2000 existing sample sites, and people wishing to take part can usually find a circle that is at least close to their favoured birding haunts. New circles can also be established, if the participant is willing to take on some organizational responsibility. Birders who wish to contribute to monitoring programs and are not set on observing at a particular location are urged to consider participating in these programs.

Readers of this document may wonder whether it is worthwhile contributing data to the many cooperative surveys that allow observers to choose their own sample locations, since these sites will usually not be representative of the landscape as a whole (see Part 1). Although such studies may be less powerful than designed studies, they are, in fact, valuable for many purposes. Such data are well suited to documenting shifts in species' ranges at broad geographic scales. Moreover, pooling count data from a great many sites helps ensure that most of the landscape is indeed represented, and some of the deficiencies of sampling can be dealt with in analyses (such as post hoc habitat stratification). Finally, if the same sites are visited repeatedly, then population trends will reflect changes that represent the pool of sites as a whole, even if not the entire survey area. This result can be valuable in itself (e.g., indicating a decline in a species at suburban bird feeders or a reduction in the abundance of species found in protected areas) and can help set directions for confirmatory research.

Appendix 3. Practical methods for selecting sample locations within strata

Here we provide simple methods for selecting sample points that will be representative of the entire study area. While more sophisticated advice should be sought for complex sampling designs, the techniques here will be sufficient for many surveys.

Systematic sampling

We recommend choosing sample points systematically. In effect, this divides the sample area into equal units, with one sample site being selected within each unit. Map the outline of the study area (or stratum), and draw a rectangle around it. The rectangle should be oriented to cover the entire area within as small a rectangle as possible. For ease of description here, it will be assumed that the rectangle sides are oriented east–west and north–south. Select two random numbers to represent a distance east and north from the southwest corner of the rectangle (e.g., 12 cm east and 5 cm north). This can be done by preparing a slip of paper for each unit of length along the side of the rectangle (e.g., 1 cm, 2 cm, 3 cm, etc.) and drawing one slip randomly after mixing them up in a container. (Return the chosen slip to the container before the next draw.) If the sample stratum is irregular in shape, then the resulting point may not fall within the boundary. In this case, simply proceed as described below, and, after completion, discard any points that fall outside the study area boundaries.

Select a single random point as described above, and lay out a regular rectangular grid with this point at one of the grid intersections. Each intersection is taken to be the site of a sample point. The grid spacing in the east–west and north–south directions should be

$$g = \sqrt{A / n}$$

where A is the total area of the stratum and n is the number of samples. For example, if the stratum is 100 ha and 50 samples are desired, then the grid spacing should be 141 m, corresponding to a grid size of 2 ha (141 m x 141 m). This choice for sample spacing will work if the region is of comparable length and width. If regions are long and narrow, such as a river valley, the spacing might have to be modified to ensure that a sufficient number of points fall inside the boundaries.

Random sampling

Another approach is to select sample points randomly. Select the first random point as described above, then continue drawing pairs of points (replacing slips into the container after each draw) until the required number of points has been selected. While statistically ideal, however, random sampling can often be inefficient. Some sample points may be isolated from the rest of the sample, such that a large amount of time would be spent in transit between points and an observer could visit only a few sample sites in a day. At the other end of the scale, completely random sampling could produce clusters of sample sites that do not represent the entire region, especially if it is heterogeneous. At broad geographic scales, all habitats are likely to be sampled somewhere, but in small geographic areas, random samples may well miss important habitats.

However samples are drawn, a portion of them may be close to a boundary, such that some of the birds counted at that location would actually be outside the boundary. The best choice in this situation is to move the sample point away from the boundary, just far enough to ensure that all birds detected will be entirely within the survey area (e.g., 100 m from the edge if the count method is a point count with a 100-m fixed radius). When sample points are selected that are over water, they can be either moved to the closest shore or (a better choice if the move would be a large one) discarded entirely, and a new sample drawn.

If the sample sites are plots instead of point count locations, selection can take place as given above, with the sample "points" representing a particular corner of the plot (e.g., southwest). Similarly, if transects are being chosen, each point selected could be taken as the starting point of a transect. A second step is needed in this case, however, to select a randomly chosen direction for the transect to take from its starting point. A single direction can be selected for all transects to follow, or directions can be chosen for each one separately.

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