Guidance for Developing and Implementing Effective Shorebird Surveys

Program for Regional and International Shorebird Monitoring (PRISM) Steering Committee

December 2009

BACKGROUND

The purpose of this document is to provide general guidance for conducting shorebird surveys, with a primary focus on counts of individuals or flocks. The discussion presented here builds on a variety of past publications that address shorebird, and bird, monitoring ideas and methods, which including Bart *et al.* (2002, 2005), Farmer and Durbian (2006), U.S. North American Bird Conservation Initiative Monitoring Subcommittee (2007), and Lambert *et al.* (2009). Ideas and work by members of the Program for Regional and International Shorebird Monitoring (PRISM) Steering Committee also added context for this discussion.

PRISM was developed to provide a framework for shorebird monitoring in North America. Goals of PRISM, revised in 2007, are to 1) identify species at risk (or "over-abundant" species); 2) contribute to the identification of causes of declines or other disturbing trends; 3) help develop, evaluate, and refine management/conservation programs; 4) document progress towards, or away from, management/conservation objectives; and 5) assist managers and policy-makers in meeting their shorebird conservation goals (e.g., response to climate change). Originally, PRISM focused primarily on the problem of estimating population sizes and trends, and a four-part approach for estimating trends in population size was recommended: 1) arctic and boreal breeding surveys, 2) temperate breeding surveys, 3) temperate non-breeding surveys, and 4) neotropical and austral surveys. Recommendations provided here address the broader PRISM goals and generally apply to surveys undertaken at any scale. Further information on PRISM and associated documents can be found at: (<http://www.fws.gov/shorebirdplan/Prism.htm>).

Since the development of PRISM, there has been a growing concern about the loss of information previously collected on Western Hemisphere shorebirds. Many local and regional datasets have not been properly documented and archived and thus drain a potential source of useful information. The ability to capture data has increased with technological advances, and citizen scientists could play a larger role in furnishing information about shorebird populations; feedback to public participants is critical for sustaining their interest. Lastly, an enhanced ability to capture sightings of color-marked/flagged shorebirds would be useful to many shorebird researchers and could be used to engage more citizen scientists. A document describing the best data management practices for bird monitoring information is currently being developed by the U.S. NABCI Monitoring Subcommittee and should be available in the fall of 2009 (see <http://www.nabci-us.org/ > for availability).

Data collected on shorebirds varies in its complexity that is dictated by contributor and user needs and can be generally categorized as:

1) casual – no set protocol or design (e.g., eBird, World Birds),

2) protocol-based – field methods developed, but no specific spatial design (e.g., International Shorebird Survey, Neotropical Waterbird Census), or

3) designed – field methods, including detection considerations, developed within a probability-based spatial sampling frame (e.g., Breeding Bird Survey, Arctic PRISM and temperate-breeding shorebird surveys, and some temperate migrant surveys).

Shorebird monitoring projects undertaken to answer specific, local questions often have the potential to contribute to larger scale programs, thus increasing the utility of the information. Many core variables measured in shorebird monitoring programs can contribute to national and international programs, such as through the Avian Knowledge Network. Shorebird monitoring practitioners are encouraged to consider how information they collect can contribute to broader programs when designing projects to answer more local scale questions. Within the AKN nodes, modules are being developed to also harvest information from demographic studies. There are a number of programs and protocols already developed that provide sets of variables to be measured and general suggestions on how to count shorebirds. What is often lacking, however, is guidance on spatial design considerations and detailed discussion of measurement error and, for repeated surveys, measurement bias. Herein, we first provide information on opportunities to contribute casual shorebird observations and then review some current protocol-based programs that provide information about shorebird populations. Most of the discussion focuses on describing various elements that should be considered when developing rigorous designs for shorebird surveys. Many of the established programs have protocols that can be integrated into more fully designed surveys.

CASUAL DATA CONTRIBUTION

The purpose of eBird (<http://ebird.org/content/ebird/>) and World Birds (<http://www.worldbirds.org/mapportal/worldmap.php?m=1>) is to capture biological data from the multitude of birders who are afield observing birds. Developers of eBird suggest that the sheer magnitude of the information captured through the Internet portal will uncover ecological patterns useful to bird conservation. To submit data to eBird, observers fill out checklists that accept either presence or counts of individuals at specified sites at specified times. Observers set up their site as a “hotspot”. Core variables are fed into global programs to illustrate patterns of abundance. Tools to map reporting frequencies and depict seasonal abundance have been developed. Professional biologists are encouraged to have birding volunteers submit their casual sightings to eBird.

Protocol-based Programs

The second tier of information complexity involves collection of shorebird data that follows specific procedures, although data collectors usually choose which sites they will survey. Examples of protocol-based surveys that provide information on shorebirds include the International Shorebird Survey, Neotropical Waterbird Census, and Christmas Bird Count. We also briefly describe Avian Knowledge Network nodes and the Breeding Bird Survey.

International Shorebird Survey (ISS)

The ISS is a volunteer-based survey of migration stopovers and wintering sites used by shorebirds, primarily in North America. The program has been administered by Manomet Center for Conservation Sciences for more than 30 years. In eastern Canada, the survey is known as the Atlantic Canada Shorebird Survey (ACSS) and is administered by the Canadian Wildlife Service (see <http://www.bsc-eoc.org/nabm/index.jsp?lang=EN&proj=121>). In both surveys, observers follow a specific protocol and visit sites of their choosing at 10-day intervals. Observers can now enter their information through an eBird portal (<http://ebird.org/ content/iss/>). The initial motive for the ISS and ACSS was to identify important stopover sites and document seasonal use of these areas; however, ISS/ACSS counts have been used to explore declines in shorebird populations. Spatial sampling ideas outlined by PRISM are being incorporated into ISS surveys along the Atlantic Coast. Information on ISS procedures can be found at the eBird site or at: (<http://www.shorebirdworld.org/ template.php?g=13&c=11>). Two regional programs associated with Joint Ventures have used ISS procedures to monitor shorebirds and evaluate management objectives in the Lower Mississippi Valley (<http://www.lmvjv.org/ shorebird/>) and the Southern Atlantic coast (<http://samigbird.ncusfws.org/ index.htm>).

Neotropical Waterbird Census (NWC)

In 1991, the NWC was initiated in South America's southern cone as part of the International Waterbird Census. Over time, coverage expanded to northward to all countries in South America. The NWC is conducted during each February and July, and, like the ISS, observers choose which sites to survey. Information is used to identify important sites and track changes in waterbird use at those specific sites. Observers record all species of waterbirds. Nine overview reports published between 1990 and 2008 summarize the results and provide feedback to volunteers (see <http://www.wetlands.org/Whatwedo/Wetlandsandbiodiversity/ MonitoringWaterbirds/NeotropicalWaterbirdCensus/tabid/1220/Default.aspx>).

Christmas Bird Count (CBC)

Begun in 1900, the Christmas Bird Count focuses on enumerating wintering birds during the three weekends around Christmas. Observers, usually working in parties, tally all individuals of all species encountered within a 15-mile-diameter, chosen circle; feeder observers also contribute to counts. Tens of thousands of volunteers contribute annually to the CBC, which is administered by the National Audubon Society (<http://www.audubon.org/bird/cbc/index.html>). New analytical methods are being developed to estimate trends in wintering birds, including shorebirds.

Avian Knowledge Network (AKN) nodes

The Avian Knowledge Alliance, those organizations associated with development of the AKN, has been developing regional nodes to support storage and management of bird monitoring data. The nodes generally have the capability of capturing more data fields than are available to those who use eBird. Some core variables are harvested and transferred into eBird. Data entered into the nodes can come from fully designed studies, and data structuring for capture and presentation can be tailored to the needs of the local contributors and users. The Rocky Mountain Bird Observatory developed one such avian data center (<http://www.rmbo.org/public/monitoring/>), which provides data entry for their staff and displays results for the public. The Coordinated Bird Monitoring Databases website (<http://cbmdms.dev4.fsr.com/Default.aspx>) was developed to store data on aquatic bird surveys in the west. A central tenet of the AKN is the development of complete metadata for bird monitoring projects.

Breeding Bird Survey (BBS)

The BBS is a long-term, large-scale, international avian monitoring program initiated in 1966 to track the status and trends of North American bird populations and is administered by the U.S. Geological Survey's Patuxent Wildlife Research Center and the Canadian Wildlife Service, National Wildlife Research Center. Once a year during the breeding season, observers conduct a series of 50 point counts (3 minutes each) along a 24.5-mile roadside survey route. Over 4,100 survey routes are located across the continental U.S. and Canada, and the BBS is currently expanding into Mexico. Data from the routes provide an index of population abundance that can be used to estimate population trends and relative abundances at various geographic scales. Trend estimates for more than 420 bird species and all raw data are currently available via the BBS web site, which includes some breeding shorebirds. Routes are generally randomly selected with latitude-longitude blocks. BBS-style surveys have been used in the Prairie Pothole region to monitor population trends and provide data suitable for development of spatial models that predict shorebird occurrence based on associations with landscape characteristics (see <http://www.ppjv.org/hapet/hapet_shorebirdsbirds.htm>).

DESIGNED SURVEYS

The following discussion addresses key elements of designing a shorebird survey to answer management and conservation questions that can arise at any scale. We specifically focus on issues of spatial sampling, variable definition and measurement, and data reporting and management. Protocols developed in the above examples can be integrated into a fully designed survey, where applicable. References listed under "PRISM-related Shorebird Papers", following this section, provide examples of protocols used to implement designed surveys.

Rationale

Defining the management/conservation question

Scale is always important in framing any biological question, and the same consideration applies to monitoring projects that need to inform shorebird management and conservation decisions. At a local scale, for example, a protected area manager may want to know how manipulating water level will influence shorebird use of her area. This question could be applied to the regional scale, as is being addressed in joint ventures, to determine if a series of protected areas are providing adequate stopover habitat for migrant shorebirds. A variety of habitat management questions can be framed at local and regional scales, such as the effects of frequency or intensity of grazing or fire on breeding shorebird density, seeding mixtures and management treatments on breeding shorebird density, predator removal on shorebird reproductive success, or beach closures to vehicles on over-winter survival. Management and conservation questions can also be applied at continental or hemispheric scales; information at the larger scales would inform policy related decisions, such as those to give a shorebird population greater legislative protection under, for example, the Endangered Species Act or Species at Risk Act. Management and conservation actions might also require an increased understanding of basic shorebird biology so that the most appropriate management and conservation actions can be undertaken. Understanding where shorebird populations are limited, in a demographic sense, across their annual cycles is a daunting task, and monitoring programs contribute insights into where to direct additional conservation action. Regardless of the scale and intensity of the management and conservation action, it is important to be clear on how monitoring information will help direct the choice of the management and conservation alternatives under consideration.

Statistical Design

Matching management and monitoring scales

Once the management/conservation decision is clearly articulated, then the next step is to match ideas of monitoring with the scale of where and when information is needed. If a protected area manager wants to be confident in the information for his area, then any monitoring effort should be powerful enough to answer these questions at the protected area scale. In the most basic sense, inferences can only be drawn to the region included in the spatial sampling frame; there is no substitute for adequate effort. Inferences can only be drawn to the specified temporal population sampled, whether time is constrained by the season or a set of years. Managers and policy-makers will often, with recommendations from biologists, determine how far inferences can be made to populations or areas where sampling did not occur. It is easy to see that information needed for flyway-scale decisions would be difficult to infer from just a few protected area surveys, particularly if most of the shorebird population of interest occurs on areas not in the sample. Information on population dynamics requires monitoring at range-wide scales. Monitoring practitioners could increase the utility of their monitoring projects by working with other stakeholders who share the management or conservation information need. This approach has been used in the development of shorebird monitoring within the South Atlantic Migratory Bird Initiative.

Response and explanatory variable definition

Although much of the thought and effort in PRISM has been targeted toward the generation of estimates of shorebird population sizes and trends, it is important to identify what response variable will be most effective in informing the specific, scale-dependent management or conservation decision. Shorebird abundance and density are routine variables we think of collecting, but information on reproductive success, survival, or surrogates such as weight gain at a stopover may provide information that is more directly linked to the management or conservation question. For example, weight gain of Red Knots in Delaware Bay can directly address questions of food quality and quantity. Occupancy models have been used recently to estimate the abundance of relatively rare, sparsely distributed Mountain Plovers. Demographic information often provides more immediate feedback on the success, or failure, of a management intervention. Besides thoughtful definition of the response variable, careful consideration should be given to which environmental variables should be measured concurrently with shorebird response variables. In the example above, water level in an impoundment is an obvious choice to understand the response of passage shorebird use to water level management. Other examples might be the measurement of lemming numbers in the arctic to understand fluctuations in shorebird numbers, rainfall in the prairies to understand distribution of breeding shorebirds, or winter temperatures to understand differences in survival of oystercatchers. Effort to develop a solid list of appropriate covariates to measure should be as great, or greater, than time devoted to developing other elements of the survey. Defining the question, scale, and needed information is the perfect way to involve managers, biologists, and statisticians in an integrative approach to shorebird management and conservation biology.

Survey Methods

In general, the development of shorebird survey methods has focused on the need to maximize precision (variability of repeated measurements) and minimize bias (consistently over- or underestimating the number of birds). Effects of bias, in particular, vary depending on whether you are estimating population size or trend. More than any other element of bird monitoring projects, biologists have expended a lot of effort developing protocols that minimize effects of measurement bias of counting methods. Recently, issues of bias associated with imperfect detection have received much attention; Thompson (2002) and Johnson (2008) review the strengths and weaknesses of various analytical methods.

<u>Selection bias.</u> Once the sampling frame is established and is aligned with the inferential population that will address the management or conservation question, the next step is to be sure you have a representative sample of units within the frame. Deciding on the appropriate and manageable size of a primary sampling unit is not a trivial task, and there is a constant trade-off between maximizing the number of units sampled (and increasing precision) with the time needed to sample the unit and travel between units. Unit size is also related to the range of the response variable. If the plots are too small, an anticipated continuous responsible variable may, in reality, only take on binary values of 0 and 1, which then has analysis implications. If travel time greatly exceeds sampling time, you likely have an inefficient design and will lack precision. An easy way to distinguish between the response variable and the sampling unit is to ask "what piece of property will tell me how many birds are present". Thus, the piece of property (sampling unit) can be an impoundment, plot, transect, or point, and the response variable is the number of birds, perhaps by species, age, sex, or behavior.

A variety of selection procedures are available to draw a probability-based sample. Most often, access issues constrain the ability to draw a completely random selection of units. Stratification, by habitat type, ownership or anticipated shorebird use, can often be used to partition the sampling effort. For example, the percentage of grass in a township was used to create sampling strata for breeding Long-billed Curlews. Unless some sampling effort is expended in each strata, you can not make statistical inferences about the number occurring there. At least some minimal effort in spent in appropriate strata will help assess the effectiveness of your survey. It is possible to include a stratum of sites where large aggregations of birds are known to occur and to obtain a 100% sample of these areas, as has been done for American Oystercatchers wintering along the Atlantic coast and Hudsonian Godwits wintering in Chile. Geographic Information Systems are a major asset in developing spatial sampling plans. Careful designation of meaningful strata, which correspond to differences in shorebird abundance or density, will contribute to the design of methods to address detectability (see below).

Constraints. Measurement error and bias result from factors that affect the availability of shorebirds to be counted or the perceptibility of shorebirds to the observer; both lead to imperfect detection on any given survey. Biologists have long standardized conditions such as tide cycle, seasonal timing, time-of-day, weather conditions, and survey duration to reduce variability and bias in shorebird surveys. Differences in observer skill have been addressed either as a constraint, which is mitigated through training or recruiting the same observers for long periods of time, or analytically through double-sampling or double-observer methods, both of which have been used in shorebird surveys. The protocols described above provide examples of constraints that should be considered when designing shorebird monitoring projects.

Imperfect detection. Despite standardizing methods as much as possible, the constraints identified above can not always account completely for imperfect detection in field surveys. Partially controlled factors such as habitat and observer differences can greatly influence precision and bias of population size and trend estimates. Techniques of double-sampling and double-observers have been used in shorebird surveys and should be considered when designing monitoring programs; however, it is important to consider what factors drive differences in detectability when deciding on a method rather than lifting the most recent in-vogue approach from the literature. Double-sampling has been used to adjust density estimates of shorebirds breeding in the arctic and those passing through wetlands of the Mississippi River Valley. In brief, double-sampling includes two components; a large set of units where shorebirds are enumerated with imperfect detection and a sub-set of units where intensive surveys reveal the actual number of shorebirds present in a unit. Note that observers can overestimate numbers in a unit, so the detection adjustment is a ratio (i.e. can be >1.0). If you place constraints on survey methods, and shorebirds are highly perceptible during the survey (e.g., Whimbrels on linear beach segments at high tide), costs associated with estimating detectability might out-weigh the benefits of a small decrease in bias.

Sampled proportion. Some portion of a selected unit might not be able to be sampled due to physical obstructions of the sampling unit (e.g., vegetation obstruction, topography) that makes shorebirds unavailable to counts. This differs from imperfect detection, when birds can be unavailable because of behavioral nuances. For example, say you are counting shorebirds in two 20-hectare impoundments that each have 120 passage shorebirds, but one of the impoundments (A) has a line of willows that does not allow you to see 50% of the area and there are 60 shorebirds in the visible area. By dividing by the sampled proportion, the count for the entire impoundment would 120 shorebirds. In essence, this approach converts the numbers to density. Estimates of the proportion of the unit actually sampled during the survey have been used to adjust counts of migrating and breeding shorebirds.

Length of stay. Many managers are interested in knowing the number of shorebirds that use their area during migration. At a larger scale, estimates of passage shorebird populations are needed to set conservation and management objectives. Although peak shorebird counts have been used to quantify populations at local sites, they assuredly underestimate the actual number of birds passing through a site. Depending on the length of stay, peak counts can represent 14–70% of the passage population. Length of stay can vary through time within a season, between seasons, and among nearby sites. Length of stay estimates are most often derived from radio telemetry, although shorebirds at sites where they are fitted with radios might behave differently than at sites farther along the migration pathway. Turning counts of passage shorebirds into population sizes, even if adjusted for imperfect detection, is difficult and costly. Methods to develop unbiased estimates of shorebird use-days are probably the most efficient and effective to evaluate local management or conservation actions.

Analytical approaches

Definition of the sampling plan and response variables will narrow the choice of analytical techniques available to transform field data into information that is an integral part of the shorebird management and conservation decision-making process. Decisions on whether or not a response or explanatory variable should be continuous or categorical have major implications on the analytical options. Full consideration of available analytical approaches at the initiation of a shorebird monitoring project will ease, and expedite, the reporting phase and ultimately increase the utility of the information. Shorebird monitoring practitioners should not hesitate to seek those colleagues that can help them with analytical aspects of the monitoring projects. The PRISM Steering Committee has agreed to serve as consultants in this process.

Data management

Data collected on shorebird abundances, production and survival, and habitat quantity and quality are most useful when effectively applied to bird conservation and management questions. However, development of robust data management systems is often the most frequently overlooked component of many public and private enterprises that use such information in their decision-making. The Internet has revolutionized the way we collect and disseminate information, and a by-product has been the realization of the need to archive, in a usable way, the reams of information we have accumulated on shorebird counts and ancillary information. Even if we are slow to build national or regional repositories, thought should be given about how each project will archive data, provide access to collected information, and develop appropriate metadata (see the US-NABCI Monitoring Subcommittee report mentioned above). The Avian Knowledge Network has developed standards pertinent to data management, and most agencies now have data management standards.

Coordination and Communication

Stakeholder involvement

If shorebird monitoring is viewed as a component of a larger management and conservation process, then a cadre of biologists, statisticians, managers, and decision-makers is needed to contribute to the effective design of a shorebird monitoring program. Managers and their constituencies will determine management objectives and potential management actions, which will then dictate the appropriate design of a shorebird monitoring program. Armed with the prerequisites of management objectives, potential management actions, and models, statisticians should work with managers on the specifics of monitoring design, including the two critical issues of selecting spatial sample units and selecting an appropriate measurement and analytical method. The team of managers and scientists charged with program design should consider the potential for coordination. Other agencies or groups may be involved with similar management efforts for the same shorebird species, in which case coordination may involve an integrated or joint design involving all interested groups. Value added by coordination may involve benefits such as increased inferential power, incorporation of a fuller range of environmental variability, and possible economies of scale (e.g., a single statistical consultant may work on the entire program; joint workshops may be held to train field personnel). The degree and manner of coordination, as with monitoring itself, should be tailored to the specific programs and to the purposes that coordination is expected to serve.

Training

Even with small shorebird monitoring efforts, and regardless of the procedures, inadequate training can minimize the value of the information being collected. All observers should be fully familiar with field survey methods and should be briefed on the objectives of the survey effort. Adequate training will reduce recording errors, which could lead to reduced precision and increased bias of survey results. When observers are thoroughly familiar with field methods, they are able to concentrate on the task of measuring field variables and not be learning the methods while conducting official surveys. As we develop more sophisticated and complex surveys, observer competence plays a larger role in obtaining reliable information. Providing adequate training can empower citizen scientists to make a larger contribution to bird conservation and management.

Reporting

Bird biologists are lucky in that there are numerous outlets, at various quantitative levels, to disseminate results of their monitoring projects. Monitoring practitioners are encouraged to report their results in peer-reviewed journals, the *Wader Study Group Bulletin*, state ornithological journals, or through the Internet.

Checklist of a Well-Designed Shorebird Survey

Rationale

- ✓ Clearly articulated survey objectives that provide management and conservation context.

Statistical Design

- ✓ Geographic scope and inferential population explicitly defined.
- ✓ Primary response variables and causal environmental variables identified.
- ✓ Survey protocols addressing sampling units, count methods, precision and bias of estimates developed.
- ✓ Appropriate analytical procedures identified.

Data Management

- ✓ Long-term data management strategy, including metadata documentation, established.

Coordination and Communication

- ✓ Stakeholders of shorebird monitoring information involved.
- ✓ Training programs established.
- ✓ Information reported in appropriate outlets.

Literature Cited

Bart, J., B.Andres, S. Brown, G. Donaldson, B. Harrington, H. Johnson, V. Johnston, S. Jones, R. I. G. Morrison, M. Sallaberry, S. K. Skagen, and N. Warnock. 2002. Program for Regional and International Shorebird Monitoring (PRISM), version 0.7. Unpublished report, U. S. Shorebird Conservation Plan. Available at <http://www.fws.gov/shorebirdplan/USShorebird/CommitteeReports.htm>.

Bart, J., B. Andres, S. Brown, G. Donaldson, B. Harrington, V. Johnston, S. Jones, R. I. G. Morrison, and S. Skagen. 2005. The Program for Regional and International Shorebird Monitoring (PRISM). Pages 983–901 *in* Ralph, C.J. and T. D. Rich (editors). Bird conservation implementation and integration in the Americas: Proceedings of the Third international Partners in Flight conference. General Technical Report PSW-GTR-191, U.S. Department of Agriculture Forest Service, Albany, California.

Farmer, A., and F. Durbian. 2006. Estimating shorebird numbers at migration stopover sites. Condor 108: 792–807.

Johnson, D.H. 2008. In defense of indices: the case of bird surveys. Journal of Wildlife Management 72:857–868.

Lambert, J.D., T.P. Hodgman, E.J. Laurent, G.L. Brewer, M.J. Iliff, and R. Dettmers. 2009. The Northeast Bird Monitoring Handbook. American Bird Conservancy, The Plains, VA. 32 pp.

Thompson, W.L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.

U.S. North American Bird Conservation Initiative Monitoring Subcommittee. 2007. Opportunities for improving avian monitoring. Division of Migratory Bird Management, U.S. Fish and Wildlife Service, Arlington, Virginia. 50 pp. Online at <http://www.nabci-us.org/>.

Selected Monitoring Papers

PRISM-related Shorebird Papers

Andres, B.A. 2006. An Arctic breeding bird survey on the northwestern Ungava Peninsula, Quebec, Canada. Arctic 59: 311–318.

Andres, B.A., J.A. Johnson, J. Valenzuela, R.I.G. Morrison, L.A. Espinosa, and R. K. Ross. 2009. Estimating eastern Pacific coast populations of Whimbrels and Hudsonian Godwits, with an emphasis on Chiloé Island, Chile. Waterbirds 32: 216–224.

Bart., J. 2005. Monitoring the abundance of bird populations. Auk 122: 15–25.

Bart, J.R., and S. Earnst. 2002. Double sampling to estimate density and population trends in birds. Auk 119:36–45.

Bart, J., and S. L. Earnst. 2005. Methods for shorebird surveys in the Arctic. Pages 907-917 *in* Ralph, C.J. and T. D. Rich (editors). Bird conservation implementation and integration in the Americas: Proceedings of the Third international Partners in Flight conference. General Technical Report PSW-GTR-191, U.S. Department of Agriculture Forest Service, Albany, California.

Bart, J., A. Manning, S. Thomas, and C. Wightman. 2005. Preparation of regional shorebird monitoring plans. Pages 902-906 *in* Ralph, C.J. and T. D. Rich (editors). Bird conservation implementation and integration in the Americas: Proceedings of the Third international Partners in Flight conference. General Technical Report PSW-GTR-191, U.S. Department of Agriculture Forest Service, Albany, California.

Bart, J., S. Brown, B. Harrington, and R.I.G. Morrison. 2007. Survey trends of North American shorebirds: population declines or shifting distributions? Journal of Avian Biology 38: 73–82.

Brown, S.C., S. Schulte, B. Harrington, B. Winn, J. Bart, and M. Howe. 2005. Population size and winter distribution of eastern American Oystercatchers. Journal of Wildlife Management 69: 1538–1545.

Brown, S., J. Bart, R.B. Lanctot, J.A. Johnson, S. Kendall, D. Payer, and J. Johnson. 2007. Shorebird abundance and distribution on the Coastal Plain of the Arctic National Wildlife Refuge. Condor 109: 1–14.

Johnson, J.A., R.B. Lanctot, B.A. Andres, J.R. Bart, S. Brown, S. Kendall, and D. Payer. 2007. Distribution of breeding shorebirds on the Arctic Coastal Plain of Alaska. Arctic 60:277–293.

Jones, S.L., C.S. Nations, S.D. Fellows, and L.L. McDonald. 2008. Breeding abundance and distribution of Long-Billed Curlews in North America. Waterbirds 31: 1–14.

McCaffery, B.J., and D.R. Ruthrauff. 2004. How intensive is intensive enough? Limitation of intensive searching for estimating shorebird nest numbers. Wader Study Group Bulletin 103: 63–66.

Skagen, S.K., J. Bart, B. Andres, S. Brown, G. Donaldson, B. Harrington, V. Johnston, S. L. Jones, and R.I.G. Morrison. 2003. Monitoring the shorebirds of North America: towards a unified approach. Wader Study Group Bulletin 100: 102–104.

Skagen, S.K., D.A. Granfors, and C.P. Melcher. 2008. On determining the significance of ephemeral continental wetlands to North American migratory shorebirds. Auk 125: 20–29.

Stanley, T.R., and S.K. Skagen. 2007. Estimating the breeding population of long-billed curlew in the United States. Journal of Wildlife Management 71: 2556–2567 .

Thomas, S. 2005. Temperate non-breeding surveys — A key to shorebird conservation. Pages 918-923 *in* Ralph, C.J. and T. D. Rich (editors). Bird conservation implementation and integration in the Americas: Proceedings of the Third international Partners in Flight conference. General Technical Report PSW-GTR-191, U.S. Department of Agriculture Forest Service, Albany, California.

General Monitoring Concepts

Barrows, C.W., and M.F. Allen. 2007. Biological monitoring and bridging the gap between land management and science. Natural Areas Journal 27: 194–197.

Bart., J. 2005. Monitoring the abundance of bird populations. Auk 122: 15–25

Collins, B.T. 2007. Guidelines for using double sampling in avian population monitoring. Auk 124: 1273-1387.

Farnsworth, G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines, and J.R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. Auk 119: 414–425.

Gillings, S., P.W. Atkinson, A.J. Baker, K.A. Bennett, N.A. Clark, K.B. Cole, P.M. González, K.S. Kalasz, C.D.T. Minton, L.J. Niles, R.C. Porter, I. de Lima Serrano, H.P. Sitters, J.L. Woods, and T. L. Shaffer. 2009. Staging behavior in Red Knot (*Calidris canutus*) in Delaware Bay: Implications for monitoring mass and population size. Auk 126: 54–63.

Kery, M., J.A. Royle, and H. Schmid. 2005. Modeling avian abundance from replicated counts using binomial mixture models. Ecological Applications 15: 1450–1461.

Nichols, J.D., and B.K. Williams. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21: 668–673.

Nichols, J.D., J.E. Hines, J.R. Sauer, F.W. Fallon, J.E. Fallon, and P.J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117: 393–408.

Norvell, R.E., F.P. Howe, and J.R. Parrish. 2003. A seven-year comparison of relative-abundance and distance-sampling methods. Auk 120: 1013–1028.

Oakley, K.L., L.P. Thomas, and S.G. Fancy. 2003. Guidelines for longterm monitoring protocols. Wildlife Society Bulletin 31: 1000–1003.

Pollock, K.H., J.D. Nichols, T.R. Simons, G.L. Farnsworth, L.L. Bailey, and J.R. Sauer. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. Environmetrics 13: 105–119.

Rosenstock, S.S., D.R. Anderson, K.M. Giesen, T. Leukering, and M.F. Carter. 2002. Landbird counting techniques: current practices and an alternative. Auk 119: 46–53.

Royle, J.A., and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84: 777–790.

Salafsky, N., and R. Margoluis. 2003. What conservation can learn from other fields about monitoring and evaluation. BioScience 53: 120−122.

Sauer, J.R., B.G. Peterjohn, and W.A. Link. 1994. Observer differences in the North American Breeding Bird Survey. Auk 111: 50–62.

Smith, G.W. 1995. A critical review of the aerial and ground surveys of breeding waterfowl in North America. U.S. Department of the Interior, National Biological Service, Biological Report 5, Washington, D.C. 252 pp.

Tipton, H.C., P.F. Doherty, Jr., and V. J. Dreitz. 2009. Abundance and density of Mountain Plover (*Charadrius montanus*) and Burrowing Owl (*Athene cunicularia*) in eastern Colorado. Auk 126: 493−499.

Yoccoz, N.G., J.D. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology and Evolution 16: 446–453.