The Value of Monitoring Demographic Parameters and Associated Habitat: The BBIRD Program

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Abstract—To simultaneously conserve all species of nongame birds in North America, we need a long-term plan that includes an effective national monitoring program. Effective monitoring programs should provide (1) early warning signals about potential or developing population declines, (2) information on habitat requirements for population maintenance, and (3) information on the potential causes of observed population declines. A program that monitors demographic parameters can potentially meet these 3 criteria. The BBIRD program was established in 1992 as a national avian monitoring program that replicates intensive local studies of avian nesting productivity at sites across North America. After only 4 years, the program has been extremely successful. BBIRD participants have collected data on more than 25,000 nests from 76 BBIRD sites in 28 states, including data on >20 nests for 102 species. Products resulting from BBIRD nesting productivity studies include 24 papers in peer-reviewed journals, 10 technical reports, 5 book chapters, and 11 completed graduate theses/dissertations. The BBIRD program has both a national and local component and serves both a monitoring and research role, and should be instrumental in aiding avian conservation efforts in North America.

One of the ultimate goals of conservation efforts is to maintain regional species diversity by preventing local species extinctions. Preventing local extinctions requires preservation of local habitat features that maintain stable or increasing populations of all indigenous species. This task is challenging in the face of increasing anthropogenic changes to the environment and limited information on the effects of environmental perturbations on populations. Limited financial resources and personnel prevent intensive monitoring of all populations. Consequently, biologists and managers have tried to maintain regional biodiversity by focusing limited resources on conserving species, populations, or habitats at highest risk of declining. This approach is reasonable, but relies on timely identification of populations or habitats at risk. Broad-scale monitoring programs provide one means of identifying populations at high risk of future decline. To be most effective, programs should monitor population parameters that are sensitive to environmental disturbance and that can provide early warning signals indicative of future population decline. Early detection is important because reversing declining population trends can take decades (Green and Hirons 1991).

Monitoring programs also should identify the habitat features associated with healthy populations. Identifying critical requirements for maintenance of each species is necessary to provide managers with specific targets for recovery. This type of detailed data is currently not available for many species of North American birds, but is urgently needed because many populations of migratory birds are declining (Robbins and others 1989b; Askins and others 1990). Population declines are frequently blamed on anthropogenic changes to the environment (e.g., forest fragmentation; Terborgh 1989), which are becoming increasingly common. Ultimately we must preserve the critical habitat requirements of all species, so that in the future we can prevent population declines despite changing land-use patterns. Knowledge of critical habitat features will allow managers to develop local, regional, and national conservation plans with specific recommendations for maintaining healthy populations of coexisting species.

Traditional avian monitoring programs, such as the Breeding Bird Survey (BBS), have focused on estimating trends in species abundance. The BBS has been effective in identifying particular species and specific habitats that have undergone drastic long-term declines (Robbins and others 1989b; but see Bart and others 1995; Thomas and Martin 1996). However, trends in species abundance do not provide information on the potential cause of population declines. To be most effective in conserving species we need to know not only which populations are declining; we also need to know why they are declining so that we can implement appropriate recovery efforts. Indeed, delays in species recovery typically are the result of misidentification of the cause of the decline (Green and Hirons 1991). In summary, an effective national monitoring program would be one that: (1) provides early warning signals about potential or developing population declines, (2) provides information on critical habitat requirements for population maintenance, and (3) provides information on the potential causes of observed population declines. Traditional avian monitoring programs that monitor trends in species abundance do not meet all of these needs (Nichols, this proceedings), and a more effective monitoring program is needed. A national program that includes monitoring of demographic parameters can potentially meet all 3 criteria.

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Detecting Problems Early

Monitoring demographic parameters allows early detection of population problems. Local population size is affected by local demographic parameters, emigration, and immigration. Because immigration rates can vary spatially, monitoring trends in population size alone can not differentiate healthy and unhealthy populations (in a healthy population, local recruitment equals or exceeds annual mortality). Environmental perturbations may negatively affect reproduction or survival, but local population size might still be maintained by immigration from other populations, with the result that local environmental problems may not be reflected in population trends until problems become severe. Alternatively, identifying populations in which local demographic parameters are insufficient to maintain local population size would allow us to identify populations at risk of decline before drastic declines occur.

Identifying Critical Habitat Requirements

Monitoring demographic parameters also provides the opportunity to measure specific habitat features that influence population health. Habitat features that correlate with local demographic parameters are more appropriate targets for management than those that correlate with abundance (Martin 1992a), because immigration contributes to local abundance but is influenced by nonlocal processes. Identifying and managing for habitat features that influence demographic parameters is the best approach for maintaining healthy populations of species.

Identifying Causes of Declines

Finally, monitoring demographic parameters provides information on the causes of population declines. For example, Peregrine Falcon populations were declining in the 1950s due to unknown causes (Hickey 1969). Monitoring reproductive success revealed abnormally low hatching success. Research on the causes of low hatching success ultimately led to the discovery that chemicals in the environment were causing females to produce abnormally thin egg shells (Peakall and others 1975; Peakall 1976). Monitoring population size alone never would have revealed the ultimate cause of Peregrine Falcon population declines. Only through monitoring reproductive success was the cause determined; this knowledge was necessary for effective recovery.

Monitoring demographic parameters meets our 3 criteria for an effective national monitoring program, but which demographic parameters should we monitor? Nesting success and productivity are particularly appropriate because they are relatively easy to estimate (compared to annual survival), provide sensitive barometers of population health, help identify causes of population declines, and allow measurement of specific habitat features associated with local population health. Moreover, variation in reproductive success greatly influences population trends (Temple and Cary 1988; Martin 1993b).

Monitoring avian nesting productivity as a tool to identify and remedy population problems requires a broad geographic scope. This is best accomplished through collaborative partnerships among independent scientists using similar methods. However, bringing scientists across the country together to focus on studies of avian nesting productivity using standardized methods requires an organized effort. The Breeding Biology Research and Monitoring Database (BBIRD) Program was initiated in 1992 to meet this need. BBIRD uses standardized sampling protocols to gather data on nesting success, breeding productivity, and habitat requirements of coexisting nongame birds. BBIRD provides managers with information on habitat requirements and estimates of nesting success and productivity at local, regional, and national scales. BBIRD is a cooperative project with sites across the continent; core sites are located in large forest blocks to minimize the influence of habitat degradation and to provide baseline data on life-history traits within healthy ecosystems. This paper gives a general overview of the BBIRD program, including history, program objectives, methodology, and results produced, and highlights the unique contribution that the program can make toward developing a national conservation plan for nongame birds.

History

BBIRD is organized through the Division of Cooperative Research of the Biological Resources Division of the United States Geological Service, but depends on partnerships with other agencies. Each site is administered by an independent principal investigator to maintain high data quality and facilitate rapid identification, publication, and dissemination of important results from local sites. Data from all sites are merged and maintained in a central repository at the Montana Cooperative Wildlife Research Unit to allow overview analyses of trends and patterns across sites, and to allow individual investigators to query the database to compare their results with other sites.

The BBIRD program was initiated in 1992 with funding from the National Biological Service's Global Change Program for a 4-year feasibility study. Initial funding was for 8 BBIRD sites, and the objectives of the feasibility study were to:

- Develop standardized national sampling protocols for monitoring demographic and associated habitat parameters of nongame birds.
- Determine the feasibility of coordinating a national program for monitoring avian breeding productivity.
- Determine whether sufficient scientific interest and partnerships could be generated to provide additional and continued funding for program expansion.
- Estimate variance in reproductive parameters to determine sample sizes needed to make comparisons across habitats, management treatments, or environmental gradients.
- Develop a national database and computing center to house data and disseminate results.

After 4 years, the BBIRD program has been extremely successful, and has gone beyond the objectives of the feasibility study. We have worked closely with program participants to establish nationally recognized sampling protocols and guidelines (Martin and Geupel 1993b; Martin and others 1997). The BBIRD Field Protocols (Martin and others 1997) is a 64-page illustrated document with detailed procedures for plot selection, marking plots, finding and monitoring nests, conducting point counts, measuring vegetation. calculating nesting success, and submitting data. BBIRD Field Protocols help others design and implement large-scale manipulative and mensurative experiments to investigate how breeding birds are affected by different treatments. The Field Protocols are requested by approximately 200 managers and researchers annually, and provide a benchmark for approaches to nesting productivity studies. Field Protocols are now available on the BBIRD home page (http//pica.wru.umt.edu/bbird), and users are able to download several word processor-compatible versions.

We have demonstrated the feasibility of a national program for monitoring nesting productivity through rapid growth, participation, and research products. Participants have collected data on more than 25,000 nests from 76 BBIRD sites in 28 states, including data on ≥20 nests for 102 species (table 1). Substantial data for many species already are available from multiple BBIRD sites, which allows comparisons of nesting productivity across sites (table 1). Most data are from BRIRD sites in eastern hardwood forests; more sites are needed to expand coverage and scope of inference. More than 100 partners have provided funding for one or more BBIRD sites, including federal. state, and local government agencies, universities, nongovernmental conservation organizations, industry, and private foundations. Funding exceeds 2 million dollars annually for all sites combined. An annual meeting is well attended, and offers a unique forum for collaboration and data-sharing. One-half day is devoted to presentation of research results by participants, and 1.5 days are devoted to discussing sampling and analytical issues and suggesting new directions. Annual minutes of the meeting are distributed to all BBIRD participants.

BBIRD studies have been very productive in both research and education. In only 5 years, products resulting from BBIRD nesting productivity studies include 23 papers in peer-reviewed journals, 5 book chapters, 11 technical reports/monographs, and 11 completed graduate theses/dissertations (see BBIRD home page). These published results of data from individual BBIRD studies demonstrate that sample sizes are sufiicient to gain valuable research results at each site and to make valuable comparisons among habitats, management treatments, and environmental gradients (eg. Martin 1993a; Donovan and others 1995b; Robinson and others 1995b; Hejl and Paige 1994; Petit and Petit 2000).

AH monitoring programs should address potential biases of the techniques used. We have begun to address one potential bias of estimating nesting productivity from our nest monitoring program. Within a species, individuals may vary in the caution with which they approach their nest. If nests of less-cautious individuals are more likely to be found by both nest searchers and predators, we might underestimate true nesting productivity. By recording a behavioral index based on the caution with which each individual approaches its nest, and comparing nesting success and habitat features between cautious and less-cautious indi-

Table 1--Number of nests currently in the BBIRD database for species in which ≥20 nests were found at ≥ 1 BBIRD site. 1992-1996.

Species	Total no. nests	No. sites with ≥20 nests
Broad-winged Hawk	21	1
Wild Turkey	25	0
Mourning Dove	140	1
Yellow-billed Cuckoo	114	3
Whip-poor-will	28	0
Ruby-throated Hummingbird	32	0
Northern Flicker	476	3
Yellow-bellied Sapsucker	208	1
Williamson's Sapsucker	252	1
Red-naped Sapsucker	284	4
Red-bellied Woodpecker	32	0
Downy Woodpecker	100	1
Hairy Woodpecker	137	1
Acorn Woodpecker	45	1
Eastern Wood-pewee	51	1
Western Wood-pewee	274	4
Eastern Phoebe	99	1
Eastern Kingblrd	33	1
Least Flycatcher	496	3
Acadian Flycatcher	2637	24
Dusky Flycatcher	168	2
Cordilleran Flycatcher	372	1
Willow Flycatcher	40	1
Violet-green Swallow	54	1
Scrub Jay	49	1
Blue Jay	35	0
Stellar's Jay	22	1
Black-billed Magpie	29	1
American Crow	22	0
Carolina Chickadee	43	1
Black-capped Chickadee	146	1
Mountain Chickadee	435	4
Chestnut-backed Chtckadee	33	1
Plain Titmouse	41	1
Tufted Titmouse	22	0
Wrentit	82	1
Bushtit	112	1
White-breasted Nuthatch	131	1
Red-breasted Nuthatch	464	4
Pygmy Nuthatch	346	1
Brown Creeper	202	3
House Wren	799	3
Carolina Wren	36	1
Winter Wren	109	1
Ruby-crowned Kinglet	30	1
Blue-gray Gnatcatcher	176	2
Eastern Bluebird	61	1
Western Bluebird	101	2
Wood Thrush	1734	19
Veery	192	3
Swainson's Thrush	53	1
Hermit Thrush	543	3
Bicknell's Thrush	21	0
American Robin	1019	5
Gray Catbird	91	1
Cedar Waxwing	136	2
European Starling	38	1
White-eyed Vireo	87	1
Sollitary Vireo	254	4
Red-eyed Vireo	1092	10
Warbling Vireo	455	3

(con.)

Table 1 (Con.)

Species	Total no. nests	No. sites with ≥20 nests
Prothonotary Warbler	23	0
Orange-crowned Warbler	438	1
Virginia's Warbler	239	1
Black-thr. Blue Warbler	84	1
Black-thr. Green Warbler	44	1
Blackpoll Warbler	63	1
MacGillivray's Warbler	113	2
Yellow-rumped Warbler	230	2
Black-and-white Warbler	129	2
Yellow Warbler	1120	2
Kentucky Warbler	158	4
Hooded Warbler	635	10
Worm-eating Warbler	392	6
Pine Warbler	79	1
Prairie Warbler	112	1
Louisiana Waterthrush	33	0
Ovenbird	966	11
Common Yellowthroat	59	1
American Redstart	203	3
Red-faced Warbler	260	1
Yellow-breasted Chat	224	2
Scarlet Tanager	168	2
Western Tanager	235	2
Summer Tanager	39	1
Northern Cardinal	448	3
Rose-breasted Grosbeak	97	1
Black-headed Grosbeak	194	3
Indigo Bunting	520	4
Green-tailed Towhee	340	2
Spotted Towhee	94	1
Eastern Towhee	30	1
Song Sparrow	279	3
Chipping Sparrow	127	2
White-crowned Sparrow	41	1
Lincoln's Sparrow	20	1
Fox Sparrow	39	1
Field Sparrow	88	1
Dark-eyed Junco	639	5
Red-winged Blackbird	44	1
Bullock's Oriole	62	1
American Goldfinch	23	1

viduals, we will be able to evaluate the magnitude of this potential bias.

We have established a national database and computing center at the University of Montana. The computing center includes a work station and networking software, and the data are stored in a relational database. A full-time program manager works with participants to submit their data in proper format, merges incoming data files, and handles data requests.

Program Objectives

After successfully meeting the goals of the 4-year feasibility study, we revised the program objectives based on initial results and national conservation needs. Current BBIRD objectives are to:

- Provide baseline data on nesting productivity of species in minimally disturbed environments.
- Develop models of habitat needs for healthy populations of coexisting species.
- Use models to assess suitability of habitat conditions for sustaining bird diversity under varying land management and disturbance regimes.
- Examine distributional and demographic responses to temporal and spatial climate changes to project long-term responses to global climate change.
- Identify species' breeding habitat requirements.
- Use habitat information to recommend specific management solutions to maximize probability of reversing declining population trends prior to species listing under the Endangered Species Act.

BBIRD Methodology

BBIRD replicates intensive local studies of avian nesting productivity at sites across North America. Nests of all or focal bird species are located and monitored to provide productivity data on coexisting species. BBIRD sites are either funded or volunteer sites. Funded sites follow BBIRD protocols (Martin and others **1997)** completely. Volunteer participants use BBIRD protocols to the greatest extent possible. The minimum requirement for participation in the program by volunteers is data on nesting productivity and sources of nesting mortality. However, measurement of vegetation associated with nest sites also is a critical element and is strongly encouraged. Point counts **are** included whenever possible to provide estimates of local trends in species abundance.

Plot Location and Establishment

Each BBIRD site includes replicate plots, the size and number of which vary depending on local objectives and productivity of the habitat. A sufficient number of nest plots should be established so that field personnel find at least **20** nests per year, in a single treatment/habitat type, of each of the most common local species. In eastern hardwood forest this is typically about eight **35-50** ha plots, while in productive western riparian sites, eight **10-20** ha sites might be sufficient. These are only guidelines. The success with which BBIRD participants find nests varies, because: Species vary in nesting density and the ease with which their nests are located; field workers vary in nest-finding ability; and habitats vary in accessibility and species diversity (Hejl and Holmes, this proceedings). Densely vegetated habitats with low nesting densities may require greater numbers of plots or additional nest searchers. Investigators initiating new BBIRD sites need to ensure that they have enough plots and trained personnel to find suitable numbers of nests to address their local study objectives.

Nest Location and Monitoring

Nest searching and monitoring protocols follow methods outlined in Martin and Geupel (1993b) and Martin and others (1997). Plots are searched for nests every **2** days, and individual nests checked every 3-4 days. Each BBIRD site typically has 4-10 volunteers, technicians, and graduate students working in the field each summer. Each full-time technician can effectively monitor 2 nest plots, visiting each plot every other day. Some cooperators choose to focus their effort on a few common "focal" species when locating and monitoring nests (Hejl and Holmes, this proceedings). Focusing on focal species allows a cooperator to address a specific question of local interest using a few representative species for which almost all active nests within the study plots can be located and monitored intensively.

Vegetation Measures at Nests and Nonuse Sites

Vegetation sampling methods are currently established for forest and grassland habitats. Forest vegetation sampling is similar to methods described by Martin and Roper (1988) arid Martin (1993b) with some modifications (Martin and others 1997). Habitat features are measured within 5- and 11.3-m radius circular vegetation plots centered on each nest and a nonuse site adjacent to each nest. Vegetation is measured at nonuse sites to determine which patch (5 and 11.3-m scale) characteristics influence nest site selection (BBIRD participants decided to discontinue measuring vegetation at nonuse sites at the 1996 annual cooperators' meeting). Shrub and sapling stems are counted by species, and ground cover and litter depth are estimated in the 5-m radius plot. Trees are counted by species, and canopy cover and height are estimated in the 11.3-m radius plot. The number of stems of each tree species is counted for various size classes.

Territory Maps of Nest Plots

Some BBIRD participants create territory maps for each species. Nest searchers visit nest plots every other day throughout the breeding season and hence can effectively make territory maps of each plot. Territory maps provide measures of species abundance, and allow participants to estimate proportion of territories for which nests were found for each species. These data also can be used to estimate pairing success of territorial males.

Point Count Surveys of Nest Plots

Point count surveys are conducted to index spatial and temporal differences in population size. We use 10 minute, 50-m fixed-radius point counts. All birds detected beyond 50 m are also recorded to provide total number detected for each species. BBIRD sites typically includes-12 point count plots within each nest-search plot. Each point is separated by 200 m and point counts are surveyed 3 times per season.

Vegetation at Point Count Survey Plots

Vegetation is measured at 4 subplots within each 50-m radius point count plot. Each subplot consists of a 5- and 11.3-m radius circle identical to vegetation circles on nest plots.

Results

With this standardized methodology and program design. BBIRD data can provide answers to a variety of important questions that are essential for designing effective conservation efforts. The sampling design of the program allows us to make both between- and within-site comparisons. Consequently, results from the BBIRD program can provide important information for managers at local, regional, and national levels (Johnson, this proceedings; Nichols, this proceedings). Because of the standardized methodology, comparisons across multiple BBIRD sites allow examination of broad landscape-scale conservation questions that previously were impossible to address with scientists working independently at single sites using different methodologies. For example, examining the effect of forest fragmentation on bird populations requires a large number of replicate plots in both fragmented and non-fragmented landscapes distributed across a large geographic region. By incorporating data across sites using similar methods into a meta-analysis (Gurevitch and Hedges 1993; Johnson, this proceedings), BBIRD cooperators can begin to address these large-scale questions. Indeed, comparison across sites has provided the best test of the effects of forest fragmentation on avian nesting productivity (Robinson and others 1995b). Replication of studies in space and time is considered far more important than replication within a study for examining the effect of a management treatment (Hawkins 1986; Johnson, this proceedings). Robinson and others' (1995b) analysis is a good example of the important questions that can be addressed by regional comparisons among a large number of replicate sites.

At a regional scale, BBIRD data can be used to identify potential "source" and "sink" populations (Pulliam 1988) by comparing estimates of nesting success and productivity among sites. Areas or habitats with comparatively high nesting productivity can be targeted for preservation efforts, while areas or habitats with low nesting productivity can be targeted for more active conservation and management efforts to increase regional population health. Identifying and preserving healthy populations and employing proactive management strategies in areas with unhealthy populations are essential steps for making efficient use of limited resources in developing and implementing effective regional conservation plans.

In addition to providing national and regional results, the BBIRD program also has a within-site component. Most monitoring programs (e.g., BBS, MAPS) require pooling data across a wide diversity of sites to provide statistical inference. BBIRD is unique in that individual sites also can provide strong statistical~inference to evaluate effects of local management actions, Consequently, the program can address national and local goals simultaneously. Within many sites, investigators can make statistically valid comparisons of differences in demographic parameters across years, species, environmental gradients, habitats. management practices, or treatments (e.g., Cooper and others, this proceedings). Indeed, local experiments to investigate functional relationships between population parameters and environmental variables are essential for effective management, and this approach is far superior to correlative retrospective analyses (Nichols, this proceedings). These local studies will help us understand the environmental factors influencing variation in breeding success and population health across a species range. Local objectives of individual BBIRD sites include:

- Examining the effects of forest fragmentation on population health by measuring variation in nesting success. Investigators are examining the effect of distance to clearcut edge and the amount of forest cover in the surrounding landscape on the probability of nest predation and parasitism.
- Examining the effects of silvicultural treatments on abundance and nesting productivity of forest bird communities.
- Examining the effects of climate on nesting productivity. Comparisons across years within several sites have demonstrated that clutch size, nesting success, and probability of renesting can vary with climate.
- Examining habitat suitability and population dynamics of selected focal species of local management or conservation concern.
- Examining the habitat factors influencing the probability of nest parasitism by brown-headed cowbirds.

These are just a few examples of the local objectives being addressed by BBIRD studies. This local component to the BBIRD program produces research results that help local and regional managers make decisions that might help mitigate the effects of local land-use practices on avian populations. Thus, partners contributing to a BBIRD site are not only contributing to a national monitoring program, but can also obtain information needed to improve local management efforts.

In summary, the BBIRD program has both a national and local component, and serves both a monitoring and research role in developing short- and long-term management plans. Consequently, the BBIRD program is designed to serve a vital role in aiding avian conservation in North America. As the BBIRD program continues to grow, the wealth of data at both local and national scales undoubtedly will enhance our ability to effectively manage and conserve avian populations in North America.