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TRACKING THE NESTING SUCCESS OF NORTH AMERICA'S BREEDING BIRDS THROUGH PUBLIC PARTICIPATION IN NESTWATCH

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Abstract. Funded by the National Science Foundation (NSF) and developed in collaboration with the Smithsonian Migratory Bird Center, NestWatch is a citizen science project that engages birdwatchers of all skill levels to repeatedly monitor bird nests, collect breeding data, and submit their nest records online where they can be accessed and studied by scientists and the public alike. The target audiences for NestWatch—beginners, nest box monitors, and veteran nest searchers—were purposefully chosen to increase the participant base and the number of species for which we would receive ample data for analysis. NestWatch accepts data from all nesting birds in North America thereby allowing us to detect changes in reproductive timing and fledging success across a range of species and geographic areas. Observations gathered across multiple landscapes, including privately held lands, which are difficult to sample otherwise, also contribute importantly to the database, increasing our potential to identify new threats and address impacts of large-scale changes like global climate change, urbanization, and changing land use patterns on birds.

Key Words: Citizen Science, NestWatch, monitoring, public participation, breeding birds.

SEGUIMIENTO DEL ÉXITO DE ANIDACIÓN DE AVES QUE SE REPRODUCEN EN AMÉRICA DEL NORTE, MEDIANTE PARTICIPACIÓN PÚBLICA EN NESTWATCH

Resumen. Financiado por la Fundación Nacional de la Ciencia (NSF) y desarrollado en colaboración con el Centro de Aves Migratorias Smithsonita, NestWatch es un proyecto científico ciudadano que involucra a observadores de aves de todos los niveles, quienes periódicamente monitorean nidos de aves, acopian y registran datos de cría o reproducción y presentan registros de nidificación en línea. Dichos datos pueden ser accedidos y estudiados tanto por científicos como por el público en general. El público al cual NestWatch se dirige—principiantes, monitores de cajas de nidificación y buscadores de nidos ya experimentados—fue intencionadamente elegido con el fin de aumentar la base de participantes y el número de especies para la cual recibiríamos una extensa base de datos a analizar. NestWatch acepta datos de todas las aves que anidan en América del Norte, lo que nos permite detectar cambios en la época reproductiva y el éxito de emplumamiento, de una amplia gama de especies y zonas geográficas. Las observaciones recogidas en diversos paisajes incluyendo tierras privadas -que de otro modo serían difíciles de muestrear-, también contribuyen de manera importante a la base de datos. Esto aumenta nuestro potencial para identificar nuevas amenazas y abordar los impactos de los cambios de mayor escala, como el cambio climático global, la urbanización y la incidencia en las aves, de los cambiantes patrones en el uso de la tierra.

INTRODUCTION

As fragmentation of natural landscapes continues to accelerate, birds are nesting with increasing frequency in marginal, human-modified habitats such as backyards, fragmented wood lots, golf courses, and roadways (Bowman and Woolfenden 2002). Nearly three-quarters of all forests in the U.S. are privately owned (USDA 1988) and ~90% of the nearly 1100 species of plants and animals listed as endangered or threatened under the Endangered Species Act are found on private lands (Brown and Shogren 1998). When compared to federal lands, population declines tend to be more pronounced for species residing on private lands (Shogren 1998).

How do we account for the presence, abundance, distribution, and management of birds on private property? State breeding bird atlases (www.pwrc.usgs.gov/bba/), the Breeding Bird Survey (www.pwrc.usgs.gov/bbs), banding stations, eBird (www.ebird.org/content/

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ebird), and other large-scale monitoring programs provide information on bird occurrences across time and space, allowing us to quantify bird distributions and relative abundance in these areas. However, surprisingly little is known about how birds use human-modified landscapes and how these landscapes influence the survival and reproductive success of birds residing within them.

Because access to private land is a major obstacle for researchers, creating a mechanism for gathering data from volunteer or amateur birders can help to fill the information gap for private lands, especially in residential landscapes. In 1996 the Cornell Lab of Ornithology (CLO) began using the term "Citizen Science"—the organized engagement of the public in scientific research—to promote citizen-based monitoring at scales impossible to achieve with even the largest professional collaborative teams (Bonney 1996). CLO offers a range of citizen science projects meant to appeal to a wide variety of audiences across various landscapes throughout the year (Allen and Cooper 2006, Cooper et al. 2007). Each shares the common goals of research, education, and conservation. (www.birds.cornell.edu/LabPrograms/CitSci).

Citizen science is often praised for its ability to help participants learn science content and gain understanding of the scientific process (Crane et al. 1994, Trumball et al. 2000, Bonney 2004, Brossard et al. 2005, Krasny and Bonney 2005, Phillips et al. 2006), but it has just recently begun to gain acceptance as a method for answering biologically-relevant, large-scale, scientific questions (Bhattacharjee 2005). Engaging amateurs in professional research has aided the democratization of science by allowing anyone to make frequent and measurable contributions to the body of professional ornithological knowledge (Greenwood 2007). These measurable contributions are evident in the scores of peer-reviewed articles using volunteer-generated data contributed to Cornell's citizen science projects (Hochachka et al. 1999, Rosenberg et al. 1999, Hochachka and Dhondt 2000, Hames et al. 2002, Dhondt et al. 2002, Winkler et al. 2004, Cooper et al. 2005a, Cooper et al. 2005b, Cooper et al. 2006).

The need for large, continent-wide databases tracking survival and reproductive success of a wide range of species is increasing (Desante and Burton 1995). While survival estimates require intensive banding of nesting birds, work typically done by professionals, NestWatch (www.nestwatch.org), CLO's newest citizen science project, is designed to study the relationship between environmental change and avian nesting success through repeated monitoring of nests. NestWatch represents a major advance towards creating a unified nest-monitoring scheme to assess reproductive success across a breeding bird's range. As declining reproductive success is often precursor to avian population declines (Carson 1962), NestWatch data can also be used to detect important demographic shifts in relation to landscape and climate change.

NestWatch has been developed with a broad array of audiences in mind, from backyard birders and nest-box monitors to school groups and public land managers, in order to achieve coverage in diverse habitats across the urban-to-rural gradient. The focus of this paper is to illustrate the utility of the NestWatch program as a means to address research questions across broad spatial and temporal scales as well as to demonstrate how three very different audience groups—beginners, nest-box monitors, and veteran nest searchers—can contribute measurably to the scientific goals of NestWatch.

METHODS

Nestwatch Protocol

Although NestWatch officially launched in 2008, it contains more than 85 000 nest records from an earlier program and its protocol for monitoring nests is based on the historic Cornell Nest Record Card program. This data set dates back to 1965 (Pettingill 1966) and contains more than 330 000 nest records from 600 species of North American breeding birds. In turn, the Cornell Nest Record Card protocol was based on the British Trust for Ornithology's Nest Record Scheme (NRS), dating back to 1939 and whose collection consists of nearly 1.3 million cards from 232 species (Crick et al. 2003). These protocols ask volunteers to make multiple visits to nests on a regular basis and use standard data forms to record what they observe during each visit throughout the nesting cycle. Online data entry tracks these repeated visits, allowing researchers to generate Mayfield estimates of egg and nestling daily survival rates (Mayfield 1975).

Specifically, NestWatch volunteers record species, year, unique nest site names, and location of each nest. Locations can be entered as a street address, an existing nest location, as a latitude and longitude, or by pinpointing the site using a high resolution Google maps application (www.maps.google.com). A description of the nest site substrate is required and volunteers can also enter information about surrounding habitat, elevation, nest height, and cavity orientation and width. The breeding parameters recorded include: date and time of each nest visit, numbers of eggs, live young, and

dead young for host and brood parasite species, as well as standardized codes to describe adult activity, nest maintenance activity, and the developmental stages of nests and young. In addition, volunteers are encouraged to provide a summary for each nest attempt, which includes information for the host species' estimated first egg, hatch and fledge dates, maximum clutch size, and numbers of unhatched eggs, live young, and fledged birds, as well as the total number of visits made to the nest by the monitor.

Although the NestWatch protocol is flexible, volunteers are strongly encouraged to monitor nests at least once, but preferably twice per week (Phillips et al. 2007). Participants are also given the opportunity to provide anecdotal evidence for why they believe a nest was successful or failed. Volunteers enter their field observations online as the season progresses or at the end of the season. The online database has several built-in error checks, (for example, clutch size must be greater than or equal to number of live young and fledged young), and further site-specific geographic filters are currently under development.

AUDIENCE DRIVEN RESEARCH

Beginners

NestWatch targets three groups of volunteers whose involvement and skill level are extremely varied. Beginners—which may include individuals that classify themselves as "backyard birders"—are completely new to nest monitoring, have a strong inclination to learn about birds, and generally monitor just a few conveniently located nests near home. In order to encourage the goal of keeping "common birds common" (Rich et al. 2004), beginners are encouraged to focus their efforts on the 25 NestWatch focal species, which were chosen because of their relatively large populations sizes (Table 1) and their tendency to nest in human-modified habitats across the urban-suburban-rural gradient. These common birds are easy for beginners to identify and are quite tolerant of frequent nest checks. Because many of the focal species exist throughout urban, suburban, and rural landscapes, they are ideal for examining how factors such as predation, land use changes, cowbird parasitism, and climate change, vary across the urban-to-rural gradient.

TABLE 1. Estimated population sizes of NestWatch focal species in the continental US and Canada. Estimates are rounded to the nearest 0.1 million. Adapted from Rich et al. 2004.

Species	U.S. and Canada population estimate (millions)
American Kestrel	4.4
Eastern Phoebe	16.0
Says Phoebe	3.4
Blue Jay	22.0
Western Scrub-Jay	2.7
Tree Swallow	20.0
Violet-green Swallow	8.7
Barn Swallow	51.0
Carolina Chickadee	18.0
Black-capped Chickadee	34.0
House Wren	19.0
Eastern Bluebird	8.0
Western Bluebird	1.2
Mountain Bluebird	5.2
American Robin	307.0
Gray Catbird	10.0
Northern Mockingbird	45.0
Song Sparrow	53.0
Northern Cardinal	82.0
Red-winged Blackbird	193.0
Brown-headed Cowbird	51.0
House Finch	16.6
Lesser Goldfinch	16.0
American Goldfinch	24.0

Nest-Box Monitors

Nest-box monitors have already been influential in research and conservation of cavity nesting birds. For nearly four decades the Eastern Bluebird (*Sialia sialis*) has been the poster child of nest-box monitoring programs leading to significant increases in relative abundance throughout its breeding range (Sauer et al. 2008). Nest-box monitors continue to play an important role in providing nest sites for cavity-limited species. Research benefits are evident from Cooper et al.'s (2006) analysis of data from nest-box monitors which showed significant latitudinal and temporal variation in clutch size and hatching failure (Fig. 1). Data collected from citizen scientists have corroborated other studies demonstrating that clutch size tends to decrease from north to south and declines over the course of the season, regardless of latitude (Dhondt et al. 2002).

Nest-box monitors also make it possible to carry out small isolated experimental or manipulative studies, such as a recent study involving the placement of time and temperature data loggers inside nest boxes to analyze Eastern Bluebird incubation behavior (Fig. 2; Cooper et al. 2005a). Large-scale studies of seasonal or latitudinal variation require vast amounts of data throughout a species' breeding range and across many years, making citizen science a valuable method of data collection for tracking the effects of environmental variability and, ultimately, environmental change.

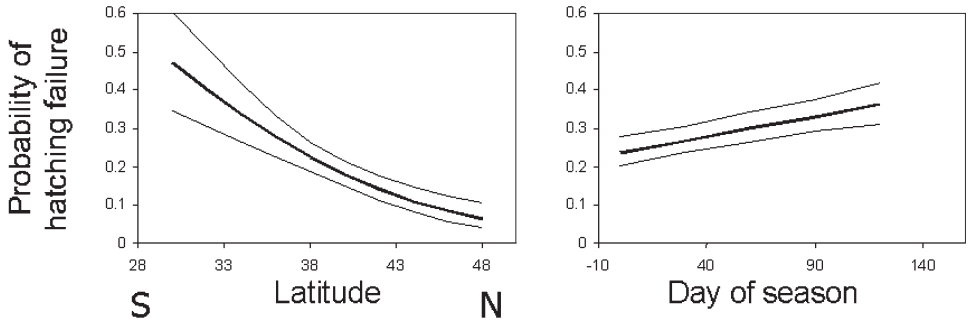

FIGURE 1. Data collected from nest-box monitors reveals significant differences in egg failure with respect to clutch size, season, and latitudinal range of Eastern Bluebirds. Probability of egg failure increases with day of season and decreasing latitudes. Lighter lines represent 95% confidence intervals. Source: Cooper et al. (2006), reprinted with permission from *Ibis*.

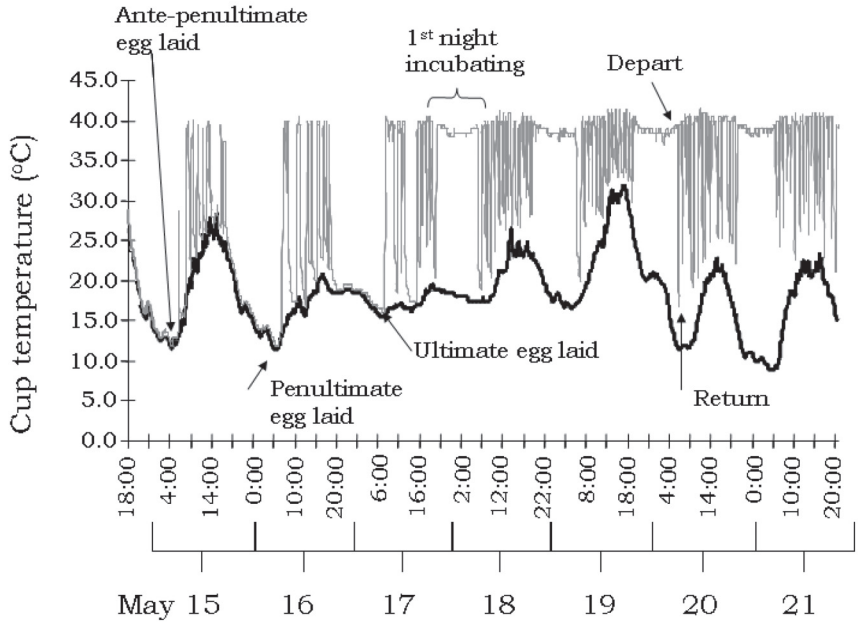

FIGURE 2. Dime-sized data recorders placed inside nest boxes and nest cups, record time and temperature and illustrate fluctuations of on and off bouts during incubation by female Eastern Bluebirds. Source: Cooper et al. (2005), reprinted with permission from *Ecology*.

Veteran Nest Searchers

Another group of NestWatch participants who play a significant role in breeding bird conservation are veteran nest searchers. Many people in this group are professional biologists, public land managers, or individuals who have been actively monitoring nests for many years and have contributed site specific data on a regular basis to Cornell's Nest Record Card program. These data have been used in approximately 130 papers including peer-reviewed journals and *The Birds of North America* species accounts [personal communication, Jim Lowe]. In addition to providing historic baseline data on geographic and seasonal patterns of life history traits (James and Shugart 1974, McCrimmon and Bart 1978, McNair 1985, Young 1994), the Nest Record Cards have been used in conjunction with abundance and distribution data to estimate time-specific daily nest survival rates (Bart and Robson 1982), or the proportion of nests that did not fail on a given day of the nesting cycle while nests are under observation.

Experienced nest searchers also have the expertise to effectively monitor nests of rare or secretive birds and can provide crucial information about their breeding biology (England and Laudenslayer 1993, Conway et al. 1994, Eddleman and Conway 1998). This information, particularly when gathered on private lands, may prove critical to conservation and management practices. Even better would be recruitment of experienced nest searchers into a constant effort protocol, where citizens devote a standard amount of time to nest searching and also search within a standardized area. Such surveys, if coordinated across a broad region, would provide valuable data on both the density of nests and the success of nests for species of concern towards identifying causal factors in declines, such as lowered nesting rates, reproductive failure, or reduced nestling survival. This expansion of the NestWatch protocol for experienced nest searchers is comparable to the strategy employed by BBIRD, a nest monitoring program with similar goals that was active through the Montana Cooperative Wildlife Research Unit from 1997 until 2002 (www.umt.edu/bbird/).

Recently, the utility of using nest records to understand effects of global climate change on avian reproduction has become more pronounced. For example, Dunn and Winkler (1999) analyzed 30 years of nest records and found a significant advancement in egg-laying dates of Tree Swallows (*Tachycineta bicolor*) correlated with increased air temperatures. The nest records were used in a subsequent analysis that examined long-term changes in the advancement of first egg dates and the relationship of environmental temperatures to clutch size and hatching success (Winkler et al. 2002). Although the analysis showed no relationship between clutch size and advancement of lay date it demonstrates the potential for NestWatch data to be used to examine avian response to large-scale environmental factors such as climate change.

DISCUSSION

As in any large scale effort to collect data, the NestWatch data are not without limitations. Currently, our data are geographically skewed to the Northeast. Future efforts will seek to recruit more members from areas that are underrepresented such as Canada and the southwestern United States. Eventually we hope to expand the project to include all of Mexico, Central America, South America, and the Caribbean. Plans are also underway to embed more sophisticated error checking tools into the online database to help minimize reporting errors, including data filters that report when species are out of range geographically, temporally, and in terms of the duration of the nesting period. We realize that we must account for the lack of a standardized sampling protocol across observers and between seasons as well as the serious bias imposed by variation in nest detectability among species, habitats, and regions.

Two things would increase the rigor of the NestWatch program and broaden its utility as a research tool. First, as discussed above, implementing a protocol that would ask a subset of citizen researchers to select a specific, defined area and search for nests exhaustively at least twice per month, would add critical information on nest density, which would allow researchers to obtain more accurate measures of reproductive success as it varies with habitat. Second, allowing researchers to enter banding data would permit NestWatch to capture a broad array of data from long-term studies of marked populations allowing for full demographic analysis.

Validation studies also would be helpful in assessing the accuracy of NestWatch data. Validation could be achieved with focused, intensive field studies of key species in order to test assumptions prior to analyzing NestWatch data. For example, gathering data on habitat-specific territory size for a particular species could allow researchers to test the validity of statistical assumptions of independence and choose nests with appropriate inter-nest distances. In addition to locally intensive observational studies, experiments hold promise for understanding the mechanistic underpinnings of patterns seen with citizen science data, suggesting that there is considerable potential for coupling Masters or Ph.D. research at the population level with analysis of large spatial-temporal patterns using NestWatch.

Our community of volunteers, whether contributing data from a backyard, a nest-box trail or an atlas grid, provide the critical data needed to understand factors limiting breeding success of birds across the continent. These factors include predation, competition, land use changes, cowbird parasitism, and climate change, all of which vary across the rural-to-urban landscape gradient. As climate change continues at an ever-hastening pace, avian responses such as earlier egg-laying dates, changes in optimal clutch size or hatching success, changes in reproductive success tied to range shifts, or even a mismatch between peak reproduction and availability of food for growing chicks, will be closely monitored by NestWatch. With huge sample sizes, careful

selection of questions, and an appropriate match of data to question, NestWatch is an important addition to the arsenal of tools available for monitoring birds across North America. When combined with other large databases such as those housing landscape and weather data, NestWatch may well provide an accurate picture of population processes critical to conservation issues at relevant and previously unattainable spatial scales.

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