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USING THE MAPS AND MOSI PROGRAMS TO MONITOR LANDBIRDS AND INFORM CONSERVATION

James F. Saracco,[1] David F. DeSante, M. Philip Nott, and Danielle R. Kaschube

The Institute for Bird Populations, P.O. Box 1346, Point Reyes Station, California 94956-1346, USA

Abstract. Mist-netting and banding networks can complement count-based monitoring and provide focus for research and conservation of migratory landbirds. Here we describe two banding networks, one that operates during the breeding season, the Monitoring Avian Productivity and Survivorship (MAPS) program, and one that operates during the overwintering period, the Monitoreo de Sobrevivencia Invernal (MoSI) program. We provide an example, using data for Swainson's Thrush (Catharus ustulatus), of how data from these networks can be used to infer spatial patterns in adult apparent survival rates (survival) and understand linkages between breeding and wintering populations. We estimated survival of Swainson's Thrush from MAPS data at the scale of Bird Conservation Regions (BCRs). Survival was highest in the Northern Rockies and Atlantic Northern Forest BCRs and lowest in the Northwestern Interior Forest and Boreal Taiga Plains BCRs. We used wing chord to study migratory connectivity. Spatial patterning in wing chord suggested links between northerly portions of the breeding range and northern Rocky Mountains and birds overwintering farthest south. This pattern is consistent with the literature and illustrates the utility of using a simple metric measured at banding stations to understand migratory connectivity. Although our example analysis for Swainson's Thrush highlights the utility of these banding programs for providing focus for research and conservation, it also highlights the need for growth of these programs to fill geographic gaps in the distribution of banding stations and to target habitats and species of high conservation priority.

Key Words: bird banding, bird monitoring, *Catharus ustulatus*, migratory connectivity, mist netting, survival, Swainson's Thrush.

UTILIZANDO LOS PROGRAMAS MAPS Y MOSI PARA MONITOREAR AVES TERRESTRES E INFORMAR SOBRE CONSERVACIÓN

Resumen. Las redes de estaciones de trampeo y anillamiento pueden complementar el monitoreo basado en conteos y permiten encauzar la investigación y la conservación de aves terrestres migratorias. Aquí describimos dos redes de estaciones de anillamiento, una que opera durante la época reproductiva, el programa de Monitoreo de Productividad y Supervivencia de Aves (MAPS, por sus siglas en inglés), y otro que opera durante el periodo invernal, el programa de Monitoreo de Sobrevivencia Invernal (MoSI). Proporcionamos un ejemplo, empleando información sobre el zorzal de Swainson (Catharus ustulatus), de cómo los datos de estas redes pueden ser utilizados para inferir patrones espaciales de tasas de supervivencia aparente (supervivencia) y entender los vínculos entre las poblaciones reproductoras e invernantes. Estimamos la supervivencia del zorzal de Swainson a partir de datos de MAPS a nivel de las Regiones de Conservación de Aves (BCR, por sus siglas en inglés). La supervivencia fue mayor en las BCR del Norte de las Rocallosas y la de los Bosques del Atlántico Norte, y menor en la de los Bosques del Interior del Noroeste y la de los Llanos de la Taiga Boreal. Utilizamos la cuerda alar para estudiar la conectividad migratoria. Los patrones espaciales de la cuerda alar sugieren vinculación entre las porciones más norteñas del área de reproducción y el norte de las Montañas Rocallosas, con las aves que invernan más al sur. Este patrón es consistente con la literatura e ilustra la utilidad de usar una variable simple medida en las estaciones de anillamiento, para entender la conectividad migratoria. A pesar de que nuestro análisis-ejemplo para el zorzal de Swainson enfatiza la utilidad de estos programas de anillamiento para enfocar la investigación y la conservación, también resalta la necesidad de ampliar estos programas para cubrir brechas geográficas en la distribución de las estaciones de anillamiento, y encauzar esfuerzos sobre hábitats y especies de gran prioridad para la conservación.

INTRODUCTION

Broad-scale landbird monitoring in North America is largely count-based and directed at monitoring relative abundance and trends (Bart 2005). Such data are invaluable for identifying conservation targets and priorities (e.g., Rich et al. 2004), but are less useful for directing research,

[1] E-mail: jsaracco@birdpop.org

management, and conservation (DeSante et al. 2005a). Standardized mist-netting and banding programs can complement count-based monitoring and provide focus for conservation. In particular, constant-effort capture data and capture-recapture data from these programs can be used to provide indices or estimates of vital rates (survival, productivity, recruitment). Such data can be critical for identifying proximate (demographic) and ultimate (environmental) causes of population changes (Nott et al. 2002, Saracco et al. 2008). Additionally, measurements and biological samples collected from birds across a network of mist-netting stations can be used to better understand patterns of migratory connectivity (e.g., Kelly et al. 2005, Boulet and Norris 2006).

Although broad-scale mist-netting networks offer many opportunities to improve broad-scale avian monitoring in North America, their establishment and implementation remains challenging. Operation of individual stations requires intensive effort and time commitment compared to more extensive count programs. Additionally, many such stations must be operated for many years to provide useful data on spatial and temporal variation in demographic parameters. Many professional biologists and volunteers must be recruited and trained every year to ensure that lapses in station operation do not occur at these banding stations (Burton and DeSante 1999). Despite these challenges, The Institute for Bird Populations (IBP), via hundreds of partnerships established with governmental agencies, bird observatories, non-profit organizations, educational institutions, and individual bird banders, has been largely successful at establishing and implementing standardized mist-netting-based avian monitoring programs in North America and the northern Neotropics. Here we briefly describe two networks coordinated by IBP, the Monitoring Avian Productivity and Survivorship (MAPS) and Monitoreo de Sobrevivencia Invernal (MoSI) programs, and provide an example, using data for Swainson's Thrush (*Catharus ustulatus*), of how data from these networks can be used to identify spatial patterns in survival rates and link breeding and wintering populations.

IBP-COORDINATED MIST-NETTING PROGRAMS

The flagship of the mist-netting efforts coordinated by IBP is the Monitoring Avian Productivity and Survivorship (MAPS) program (DeSante et al. 1995, 2004). The MAPS program uses constant-effort mist-netting and capture-recapture data collected during the breeding season (see DeSante et al. 2008a for methodological detail) to provide estimates of adult apparent survival rates and indices of productivity for >180 species of landbird that breed in the United States and Canada (DeSante and Kaschube 2007). More than 1,000 stations have been operated as part of the MAPS program since establishment of the program in 1989 (Fig. 1; ~500 stations are operated each summer), and many MAPS stations (~25%) have been operated for ≥10 years. About 20% of MAPS stations are operated on public lands (primarily federal) by interns recruited and trained by IBP; the remaining stations are operated by independent researchers and bird banders on both private and public landholdings.

Because Neotropical migrant species spend over half their year outside of the United States and Canada, the Monitoreo de Sobrevivencia Invernal (MoSI) program was established in winter of 2002–03 (DeSante et al. 2005b). This represents a critical complement to the MAPS program in providing data on the vital rates and body condition of Nearctic–Neotropical migratory birds during the non-breeding season. The MoSI program, now having completed six seasons, has involved at least 58 partners from 14 countries, and at least 127 MoSI banding stations have been operated by these partners during at least one winter season (Fig. 1). Many MoSI stations have been established and operated in Important Bird Areas and other sites that are state or national protected areas. A sister program to MoSI, Monitoring Avian Winter Survival (MAWS), was established on four military bases in the southeastern United States as a four-year pilot project in winter 2003–04. Several independent MAWS station operators have also contributed data to the MAWS program. MoSI and MAWS utilize a common field protocol (DeSante et al. 2007), and share common goals, including the identification of spatial patterns in winter and between-year apparent survival rates and body condition of overwintering birds and linking this spatial variation to habitat types or characteristics.

Case Study: Swainson's Thrush Survival and Connectivity

Data from the MAPS, MoSI, and MAWS programs can be used individually and in combination (as well as combined with data from other monitoring programs) to inform management and conservation and to direct research. A central goal of these programs is to identify spatial patterns in vital rates. These spatial patterns

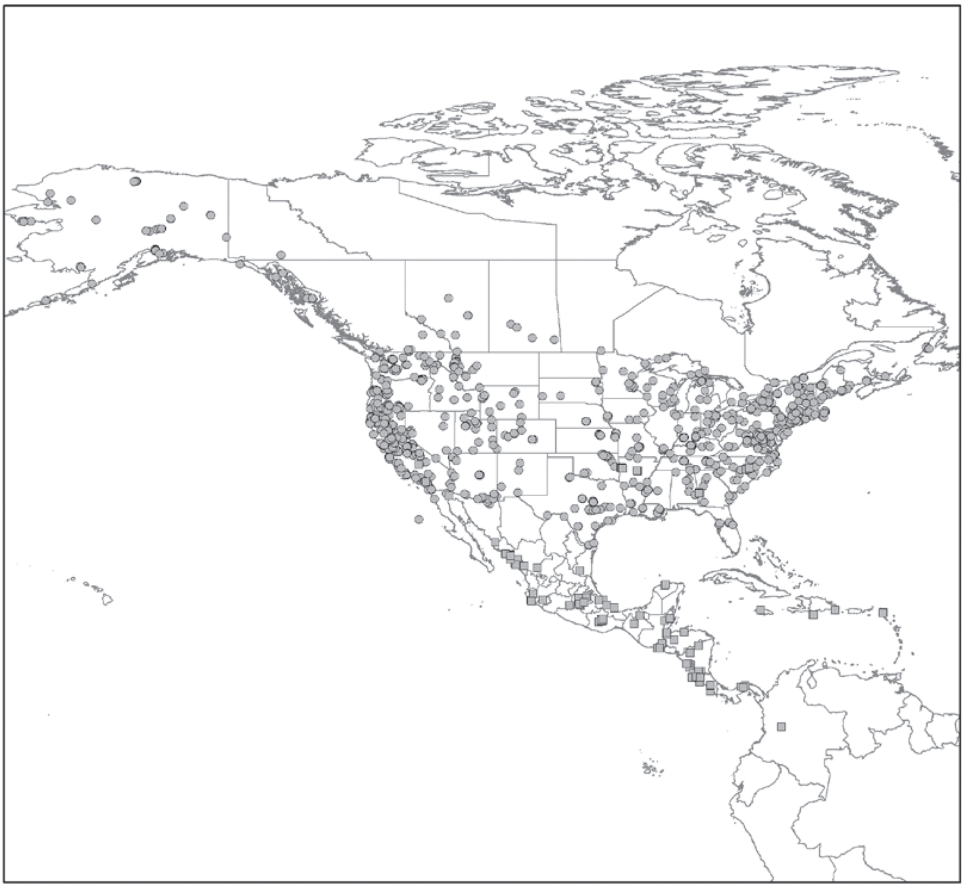

FIGURE 1. Distribution of 1,017 Monitoring Avian Productivity and Survivorship (MAPS) stations operated during ≥1 season between 1989 and 2007 (circles), 144 Monitoreo de Sobrevivencia Invernal (MoSI) and Monitoring Avian Winter Survival (MAWS) stations operated between winters of 2002–03 and 2006–07 (squares).

can highlight areas with especially high or low values of particular vital rates and show where deficient vital rates may be leading to population declines (DeSante et al. 2001, Saracco et al. 2008).

As an example, we consider here time-constant estimates of adult apparent survival rate for Swainson's Thrush (*Catharus ustulatus*) derived from 1992-2003 MAPS data from 10 Bird Conservation Regions (http://www.nabci-us.org/aboutnabci/bcrdescrip.pdf; Table 1, Fig. 2). Estimates were derived from the *ad hoc* Robust Design Cormack-Jolly-Seber model (Nott and DeSante 2002, Hines et al. 2003) using program TMSURVIV (http://www.mbr-pwrc.usgs.gov/software.html). We only included data from stations that operated ≥4 consecutive years and at which the species was a usual breeder (i.e., breeds there during at least 50% of the years in the study period) using the longest consecutive segment of data whenever a year was missed. For stations that stopped operating prior to 2003, records from the last year of operation were marked as lost on capture.

Apparent survival rates of Swainson's Thrushes were highest in the Northern Rockies and Atlantic Northern Forest BCRs and lowest in the Northwestern Interior Forest and Boreal Taiga Plains BCRs (Table 1; Fig. 2). The spatial pattern in survival appears to reflect, in part, separation of the various subspecies. For example, the low survival of the Northwestern Interior Forest and Boreal Taiga Plains birds may largely represent the subspecies *C. u. incanus* of the olive-backed Swainsoni group (Mack and Yong 2000). The high survival of the Northern Rockies and Atlantic Northern Forest, in contrast, primarily represent the *C. u. swainsonii* race.

Survival rates of migratory birds may largely reflect conditions experienced during migration and wintering periods. Indeed, the very low survival of Swainson's Thrush in the Sierra Nevada

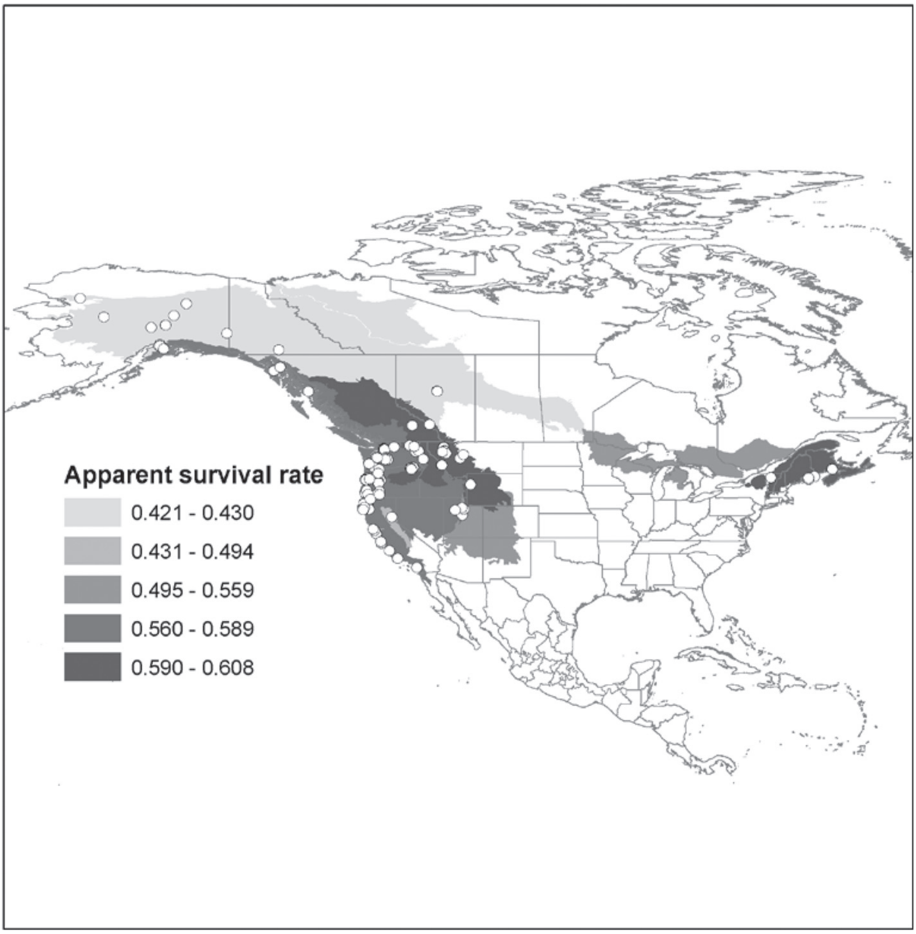

FIGURE 2. Time-constant adult apparent survival-rate estimates derived from 1992–2003 Monitoring Avian Productivity and Survivorship (MAPS) data for Swainson's Thrush (*Catharus ustulatus*) at the scale of Bird Conservation Regions (see Table 1 for detail). MAPS stations used in the analysis are indicated by open circles.

TABLE 1. Time-constant adult apparent survival-rate estimates ($\hat{\phi}$), recapture probability estimates ($\hat{p}$) and estimates of the proportion of newly marked birds that are resident ($\hat{\tau}$) for Swainson's Thrush (*Catharus ustulatus*) and their standard errors (SE) in 10 Bird Conservation Regions. Estimates were derived from the *ad hoc* Robust Design Cormack-Jolly-Seber model (Nott and DeSante 2002, Hines et al. 2003) applied to 1992–2003 Monitoring Avian Productivity and Survivorship (MAPS) data using program TMSURVIV (http://www.mbr-pwrc.usgs.gov/software.html).

Bird Conservation Region	Nsta[1]	Nind[2]	$\hat{\phi}$	(SE)	$\hat{p}$	(SE)	$\hat{\tau}$	(SE)
Northern Rockies	24	2006	0.605	(0.015)	0.515	(0.021)	0.440	(0.029)
Boreal Hardwood Transition	1	83	0.559	(0.076)	0.635	(0.103)	0.609	(0.170)
Atlantic Northern Forest	6	124	0.608	(0.062)	0.643	(0.080)	0.619	(0.129)
Sierra Nevada	1	33	0.494	(0.119)	0.546	(0.181)	1.000	(0.455)
Southern Rockies/Colorado Plateau	3	210	0.550	(0.051)	0.377	(0.065)	0.932	(0.194)
Coastal California	9	2317	0.586	(0.020)	0.620	(0.028)	0.163	(0.015)
Northwestern Interior Forest	11	536	0.421	(0.036)	0.537	(0.061)	0.568	(0.094)
Northern Pacific Rainforest	45	5693	0.589	(0.008)	0.668	(0.012)	0.377	(0.015)
Boreal Taiga Plains	2	91	0.430	(0.112)	0.655	(0.181)	0.331	(0.156)
Great Basin	12	1093	0.589	(0.017)	0.630	(0.024)	0.550	(0.041)

[1] Number of stations included in the analysis. Stations separated by < 1 km are considered as a single station.
[2] Number of individuals included in the analysis.

BCR (although based on data from only a single station) is interesting in light of the precipitous decline the species has experienced in the Sierra, which has been attributed by Marshall (1988) to habitat loss on the winter grounds. Thus, identifying spatial pattern in survival is just one step toward focusing research and conservation. Another important step involves identifying linkages between breeding and wintering areas. Most attempts at studying migratory connectivity have been based on stable isotope and genetic data (e.g., Kelly et al. 2005, Boulet and Norris 2006); however, morphometric measurements collected at banding stations can also contribute to resolving connectivity issues. Because the distributions of subspecies of Swainson's Thrush are relatively well-known and genetic and isotope studies have previously revealed general patterns of migratory connectivity (Kelly et al. 2005), it can serve as a test case for the use of morphometric data to study linkages between breeding and wintering populations.

We used unflattened wing chord (measured to the nearest 1 mm), a metric that is typically measured as a part of normal banding station operation, to examine morphometric differentiation in mean Swainson's Thrush wing chord at the scale of 1-degree blocks across the spatial extents of the MAPS and MoSI networks. We only included blocks for which ≥5 individuals were measured. For the MAPS data we only included adult birds (second-year and after-second year); sexes were pooled. To highlight the spatial pattern, and to interpolate predicted mean wing chord across the portions of the breeding and wintering ranges encompassed by the MAPS and MoSI networks, we applied ordinary kriging to each data set using the Geostatistical Analyst toolbox in the ArcGIS software package (Ver. 9.2, Environmental Systems Research Institute, Redlands, CA). We used statistics in the model validation component of this toolbox (e.g., mean prediction errors, root mean square error) to compare various models (we considered trend surface polynomials, anisotropy in theoretical semivariograms, and several theoretical semivariogram models); we present here models that represented the best fits of those considered.

We found clear spatial pattern in wing chord during the breeding (May–August) and wintering (November–March) seasons (Fig. 3). The distribution of wing chord and predicted wing chord from MAPS data show the longest-winged birds to breed in the farthest northern portions of the breeding range and throughout the northern Rocky Mountains. These birds include subspecies of the swainsoni group known to winter primarily in South America (Mack and Yong 2000). This was corroborated by our finding that the longest-winged birds in the MoSI program occurred farther south, particularly at the most southerly two stations sampled in Colombia. We found the shortest winged birds in the breeding season to occur along the west coast (*ustulatus* group), particularly California, and, based on our winter wing-chord, these birds may largely overwinter in Mexico, particularly along the west coast. Again, this linkage is fairly well established in the literature (Mack and Yong 2000, Kelly et al. 2005); however, we show here that a simple metric measured at banding stations can lend additional insight to the issue of connectivity. We find similar spatial patterning for other species for which less is know about spatial patterning of populations (unpubl. data).

OPPORTUNITIES FOR IMPROVEMENT AND GROWTH

Our Swainson's Thrush example highlights both the potential for using broad-scale mist-netting data to focus research and conservation as well as its current limitations given gaps in the distribution of banding stations. For example, most of the range of Swainson's Thrush across the boreal forest zone is virtually unrepresented by MAPS stations. Granted, roads and human populations are relatively sparse in this region; however, accessible lands do exist there, and we suggest that every opportunity should be extended to fill these gaps in this network, particularly given recent conservation focus on the boreal forest. Similarly, our survival map for Swainson's Thrush suggest high variation in survival across the northern range of this species, yet little is known as to whether, and to what extent, these birds occupy different regions or habitats on their South American wintering grounds. Additional banding data, and analysis of blood or feather samples from these areas could shed light on geographic or habitat differentiation in this species in the southerly portions of its winter range. Finally, because MoSI stations are operated during repeated visits throughout the winter period, they can also be used to shed light on the timing and extent of movements of subspecies and distinct subpopulations during the overwintering period.

We suggest that the utility of networks of mist-netting station that track the annual life cycle of bird populations, such as MAPS and IBP's winter banding efforts MoSI and MAWS, can be maximized by focusing growth in underrepresented regions and on species and habitats of high conservation concern. This is especially

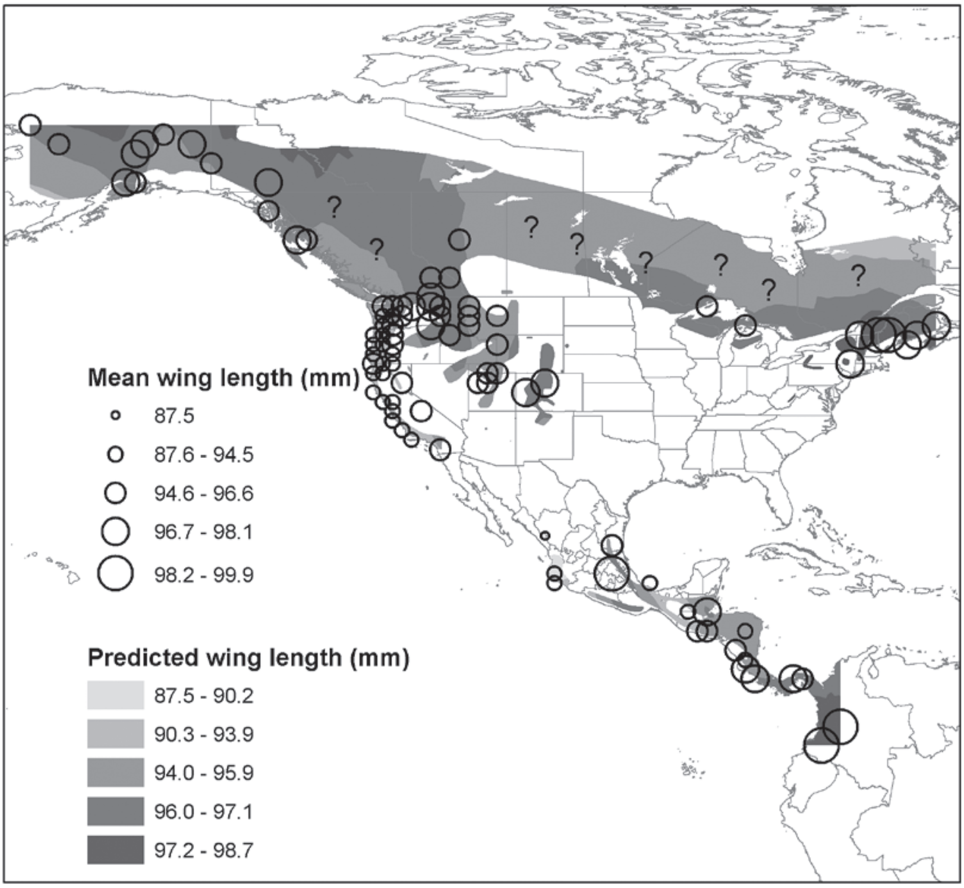

FIGURE 3. Mean wing length (graduated open circles) for Swainson's Thrush at Monitoring Avian Productivity and Survivorship (MAPS) stations during the breeding season (May–August) of 1992–2003 and at Monitoreo de Sobrevivencia Invernal (MoSI) stations during winter (November–March) of 2002–03 through 2007–08 (aggregated at the scale of one-degree blocks). Only blocks for which ≥5 individuals were measured are shown. Contour intervals show predicted wing lengths based on ordinary kriging applied to the one-degree-block MAPS and MoSI data. Predictive surfaces were clipped by breeding and winter range maps of Ridgely et al. (2007; note that several MAPS and MoSI stations fell outside of that range) and do not extend beyond the outermost banding stations. Question marks highlight vast areas without data.

important in the context of measuring species' response to climate change in the next few decades. Towards guiding this growth, we have completed evaluations of the effectiveness of the MAPS program in sampling species and habitats of conservation interest in U.S. Fish and Wildlife Service Regions 1 and 5 (Pyle et al. 2005, DeSante et al. 2008b). We urge international cooperation in the planning and realization of the growth of these programs to enhance the role of mist-netting networks in continental and hemispheric partnerships in bird conservation.

Clearly, as demonstrated by the Swainson's Thrush case study, the potential of such monitoring efforts is great because we show that with coordinated effort, participation by diverse agencies and organizations, and a common set of protocols and goals, demographic monitoring can provide critical data for directing bird conservation efforts. Challenges for the future relevance and utility of these programs include

a) targeted program growth to more effectively sample species and habitats of high conservation priority, throughout breeding and non-breeding ranges,
b) targeted program growth to monitor the effectiveness of avian conservation efforts,
c) development of sub-networks directed at monitoring avian demographics in climate-sensitive regions such as tree-line habitats and arid brushlands,

d) integration of sampling with broad-scale count-based monitoring programs (e.g., the North American Breeding Bird Survey), and
e) the continued development of analytical methods that can more fully exploit the richness of spatially-explicit demographic data.

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