MoSI (Monitoreo de Sobrevivencia Invernal): Assessing Habitat-Specific Overwintering Survival of Neotropical Migratory Landbirds[1]

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Abstract

Recent evidence suggests that population declines in many Neotropical-wintering migratory landbird species are caused by habitat loss and degradation on their wintering grounds. Such habitat loss and degradation can lower overwintering survival rates and cause surviving birds to leave their wintering grounds in poor physical condition, leading to high mortality during spring migration and low breeding productivity. Large-scale, long-term data on winter demographic parameters of these species and linkages between those parameters and winter habitat characteristics are urgently needed to understand the population dynamics of these migratory landbirds and guide management and conservation efforts for them. We established the MoSI (Monitoreo de Sobrevivencia Invernal) Program to fill this data gap. The objectives of MoSI are: (1) to assess habitat-, age-, and sex-specific overwintering survival rates and late winter physical condition for a suite of target species in a variety of winter habitats by applying state-of-the-art mark-recapture models to data collected from a network of standardized mist-netting and bird-banding stations throughout Mexico, Central America, and the Caribbean; (2) to use these data to formulate management plans for these species on their winter grounds; and (3) to use the MoSI network to facilitate feather collection for DNA and stable isotope analyses that aim to link breeding and wintering populations of these species. We have initiated a five-year pilot project aimed at evaluating, enhancing, and expanding the MoSI Program, and have created partnerships with 20 organizations and individuals in Mexico, Central America, and the Caribbean who operated 29 MoSI stations during the winter of 2002-03, the first year of this pilot project. We suggest that a successful MoSI Program can provide useful information on winter demographic parameters of resident, as well as migratory, Neotropical landbird species, and can be expanded northward into southern U.S. to address these same issues in temperate-wintering migratory species.

Introduction: Background and Extent of the Problem

Analyses of data from the North American Breeding Bird Survey (BBS) indicate that populations of many species of Neotropical-wintering migratory birds (hereafter, NTMBs) have declined over the past three decades (Robbins et al. 1989, Terborgh 1989, Peterjohn and Sauer 1993, Pardiek and Sauer 2000). In response to these declines, major conservation efforts such as the Neotropical Migratory Bird Conservation Initiative, Partners in Flight (PIF); the North American Bird Conservation Initiative (NABCI); and the Neotropical Migratory Bird Conservation Act (NMBCA) were established and funded. Nevertheless, these conservation efforts have been hindered by a lack of information concerning the causes of declines (DeSante 1992, 1995, Peterjohn et al. 1995, DeSante et al. 2001). For example, the BBS and similar monitoring programs provide indices of population abundance, yet the link between habitat quality and abundance can be misleading due to source-sink dynamics (Van Horne 1983, Pulliam 1988, Donovan et al. 1995).

In contrast to population abundance, vital rates (productivity, recruitment, survivorship, emigration, immigration) respond directly, and usually without substan-

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tial time lags, to environmental stressors or management actions (Temple and Wiens 1989, DeSante and George 1994). Thus, estimation of avian vital rates provides critical information to population managers (DeSante and Rosenberg 1998) and should be an integral component of all avian monitoring and management efforts (DeSante et al. this volume). In the case of NTMBs, estimates of avian vital rates can be used to help determine whether population declines are related to low productivity on the breeding grounds, high mortality during migration or winter, or both (Sherry and Holmes 1995). More generally, these estimates can be incorporated into predictive population models to assess potential effects of various land use practices on population viability (Noon and Sauer 1992) or predict effects of global climate change on bird populations (Nott et al. 2002, Parmesan and Yohe 2003).

In order to complement the BBS and lend insight into causes of NTMB population changes, The Institute for Bird Populations (IBP) created the Monitoring Avian Productivity and Survivorship (MAPS) Program in 1989 (DeSante et al. 1995). MAPS is a cooperative effort among public agencies, private organizations, and individual bird banders in the U.S. and Canada to operate a network of over 500 standardized, constant-effort mist-netting and bird-banding stations during the breeding season. The principal goal of MAPS is to monitor the vital rates and population dynamics of over 120 species of resident and migratory landbirds (DeSante and O'Grady 2000). In addition to monitoring, MAPS is organized to address specific research and management goals. Research goals include the identification and description of: (1) temporal and spatial patterns in the vital rates of target species (DeSante 2000), (2) relationships between vital rates and population trends and ecological characteristics of target species (DeSante et al. 1999), and (3) relationships between vital rates and habitat and weather variables (Nott 2002). Management goals include: (1) the identification of proximate demographic cause(s) of population change (DeSante et al. 2001), (2) the formulation of management guidelines and conservation strategies to reverse population declines (Nott et al. 2003), and (3) the evaluation of the effectiveness of management actions through an adaptive management framework.

Recent analyses of MAPS data show that low adult survival appears to be the proximate demographic cause of population decline for a number of NTMBs (DeSante et al. 2001). In the Neotropics north of the equator (where the majority of these birds winter), high mortality may occur toward the end of the winter period when, due to the onset of the dry season, food resources are often scarce and intra- and inter-specific competition is high. Habitat loss or degradation in such a competitive environment could result in dramatically lowered survival rates. Alternatively, diminished late winter resources could increase mortality during the ensuing spring migration, when birds must cross hostile or unfavorable habitats, often under adverse weather conditions (Sillett and Holmes 2002). Either way, it is likely that low survival during the non-breeding season is an important factor affecting population declines of many NTMBs.

Another important result from the MAPS program suggests that conditions on the wintering grounds at the end of the overwintering period can play a major role in determining avian reproductive success on the breeding grounds (Nott et al. 2002). Again, the extent of this effect on productivity likely varies as a function of habitat quality on the wintering grounds. These findings agree with work that suggests winter habitat quality affects the physical condition and spring departure schedules of American Redstarts, resulting in variable arrival dates and physical condition on temperate breeding grounds (Marra et al. 1998). Both studies provide evidence of an important link between events affecting adult birds on the wintering grounds and subsequent life cycle events, and both suggest that winter habitat may limit populations.

Patterns of winter habitat use have been shown to differ between age- and sex-classes for many NTMB species (e.g., Conway et al. 1995, Wunderle 1995, Sherry and Holmes 1996, Marra et al. 1998, Murphy et al. 2001, Latta and Faaborg 2002). Such habitat segregation could translate into differences between the physical conditions and survival rates of different ages and sexes during the non-breeding season. This would be expected in cases where dominant males actively exclude first-year (i.e., sub-adults) and female birds from optimal habitats (Marra and Holmes 2001). Nevertheless, few data exist to shed light on this prediction. Understanding sex- and age-related differences in habitat use and survival is necessary before a complete picture of the factors affecting population dynamics can emerge. Recent advances in aging and sexing landbirds makes such a goal attainable for many NTMBs (Pyle 1997).

A growing body of evidence thus suggests that populations of many NTMBs may be limited by factors during the non-breeding season. Nevertheless, data on the overwintering ecology of most of these species is severely limited. A variety of local-scale studies have shown that many NTMBs use a wide array of habitats in the tropics; even species thought to prefer relatively mature or undisturbed primary forest can be found in substantial numbers in secondary forest, forest edge, and other disturbed habitats (e.g., Greenberg 1992). Patterns of winter abundance in different habitats, however, can be a misleading indicator of habitat quality (Marra and Holmes 2001). In order to determine the true value of different winter habitats, estimates of sex-, age-, and habitat-specific overwintering survival rates and indices of late winter physical condition are needed. These parameters have been studied for a few species on a local scale. In order to draw inferences for a larger suite of species, and to determine how these parameters vary as a function of space and habitat, a standardized, spatially-extensive monitoring effort is required.

Solution to the Problem: The Establishment and Operation of the MoSI (Monitoreo de Sobrevivencia Invernal = Monitoring Overwintering Survival) Program

1. Overview of the MoSI Program

We suggest that the first step toward reversing population declines of NTMBs that are related to loss or degradation of winter habitat is to determine, for each species, the habitat characteristics that provide for adequate overwintering survival and good physical condition at the end of the winter season. This goal was identified by many presenters at the Third International Partners in Flight Conference in March 2002 (Ralph and Rich this volume), and at the 13th Annual Meeting of the Society for Caribbean Ornithology in July 2001 (Latta et al. 2003), as a critical need for the development of winter management strategies for NTMBs. We suggest that the optimal way to achieve this goal is to determine habitat-, age-, and sex-specific overwintering survival rates from mark-recapture data, and indices of late winter physical condition from data on body mass relative to wing length. We suggest further that this critical information can best be obtained by the establishment and operation of a network of standardized mist-netting and bird-banding stations throughout Mexico, Central America, and the Caribbean. With the initiation of the MoSI Program in 2002, we have begun to establish just such a network.

The MoSI program is patterned after the MAPS program in that it: (1) has clear monitoring goals based on firmly established needs, (2) provides direct links between monitoring data and research and management goals, (3) provides critical information at both regional and local spatial scales, (4) is comprised of a network of stations each utilizing the same standardized protocol, (5) provides the means for electronic data submission and verification by cooperators, (6) utilizes state-of-the-art analytical models for making inferences, (7) utilizes central data repositories and identifies individuals and organizations responsible for timely analyses of data and publication of results, (8) provides frequent and substantive feedback to cooperators, and (9) will undergo peer review after an appropriate five-year pilot period.

As with the MAPS program, MoSI addresses monitoring, research, and management objectives. The *monitoring goals of MoSI* are to provide estimates of habitat-, age-, and (when possible) sex-specific annual and seasonal (overwintering) survival rates, population sizes, and population trends for a suite of about 20 target species, as well as indices of late winter body condition. *Research goals of MoSI* include: (1) the statistical modeling of estimates of survival and indices of physical condition as functions of site-specific and landscape-level winter habitat characteristics and weather variables, (2) the linking of these winter population parameters with breeding season vital rates and population trends, and (3) the development of predictive population models to assess population viability of NTMB species under various scenarios of future habitat or climate change. The *management goals of MoSI* are to apply knowledge of the linkages between winter habitat and population parameters in such a manner as to (1) formulate generalized management strategies and specific management actions for the target species to reverse population declines and maintain stable or increasing populations, and (2) evaluate the effectiveness of any implemented management actions. The design of the MoSI program allows for many levels of data aggregation and analysis, and we anticipate the formulation of management strategies that will address issues at a variety of spatial scales, ranging from the regional (country, state, Bird Conservation Region, physiographic strata) to the local (park, preserve, or other local area) scale.

Accordingly, in partnership with 20 organizations and individuals in Mexico, Central America, and the Caribbean (*Appendix 1*), The Institute for Bird Populations has initiated a five-year pilot project to evaluate, enhance, and expand the MoSI Program. Primarily through the volunteer efforts of these 20 organizations and individuals, the first year of this pilot project has already been completed and 29 MoSI stations were established and operated during the winter of 2002-03. This number was limited by the lack of broad-scale funding, the lack of a MoSI coordinator for the Caribbean region prior to the 2002-03 winter field season, and the program's very recent establishment. We suggest that, given adequate funding, the MoSI network will grow rapidly over the next three winters to the point where about 150 stations will be operated during each of the last two years (2005-06 and 2006-07) of the five-year pilot project. We project that these 150 stations will be dispersed throughout six MoSI regions as follows: three in Mexico (Pacific lowlands, highlands, Atlantic lowlands), two in Central America (lowlands, highlands), and one in the Caribbean, with about 25 stations in each MoSI region.

In order to provide focus to the MoSI pilot project, MoSI stations are currently sited to address a discrete list of target species (*Appendix 2*). These species were selected according to three criteria: (1) MAPS data have shown that they can be captured with ground-level mist nets in sufficient numbers to provide adequately precise estimates of annual survival rates; (2) they have been identified as priority species in one or more Bird Conservation Regions (and typically have declining 20-year BBS population trends), or they are non-declining species for which survival rates can be compared to those for the declining species; and (3) they provide for an adequate representation of declining and non-declining species over each of the six regions defined above.

Three coordinators, one each in Mexico, Central America, and the Caribbean, provide local coordination of the MoSI Program. Responsibilities of the three MoSI coordinators include: (1) helping to facilitate the recruitment and training of potential MoSI cooperators; (2) registering and maintaining the registry of MoSI stations within their region; (3) distributing MoSI materials, including manuals, data sheets, and electronic data entry, verification, editing, submission, and analysis programs; (4) receiving and archiving MoSI data from the cooperators; (5) disseminating regional annual reports on the results of the Program; and (6) sharing data with other researchers and organizations. Communication and sharing of information among cooperators is aided by an annual regional workshop and training session held in each of the three major areas. The Institute for Bird Populations provides assistance to the three coordinators in program development, program enhancement (creation of manuals and computer programs for data collection, verification, editing, and analysis), data analysis, and drafting of results.

2. The MoSI Field Protocol

The MoSI program is designed to be as inclusive as possible, and its overall goal – to maximize the numbers of captures of target species – is broad enough that it can accommodate several variations of the basic protocol. For all protocol variations, we suggest that every effort be made to run nets in a constant-effort manner and to apply the same protocol in all years of operation. Consistency of operation, although not required for mark-recapture analyses, can aid in mark-recapture modeling. We appreciate, however, that changes can often be necessary as funding levels or research objectives change.

The basic MoSI field protocol calls for five monthly ”pulses” of mist net operation on a 20-ha study area (the MoSI station) established in a habitat of interest where at least one MoSI target species can be captured in substantial numbers. Each pulse of mist netting consists of operating about 16 nets for two or (preferably) three consecutive (or near consecutive) days, yielding 10 or (preferably) 15 days of netting during the five-month (November through March) winter period. In general, pulses should be conducted as close as possible to the midpoints of each of the five monthly periods, and at least three weeks should elapse between successive pulses. This time gap should minimize net-avoidance resulting from more frequent net operation and better allow modeling of monthly survival rates.

MoSI cooperators that are unable to operate MoSI stations for five pulses should make every effort to run stations for at least three (preferably four) pulses. If three- or four-pulse protocols are followed, we suggest that nets be run for three days on each pulse (for a total of 9 or 12 netting days). If nets are run for four pulses, we recommend that the missing pulse be either December or February. If December is missed, we suggest that the November pulse be run after November 15. Likewise, if February is missed, we suggest that the March pulse be run before March 16. If nets are operated for only three pulses, we suggest that they be operated in November, January, and March. As for the four-pulse protocol, the November pulse should occur after November 15 and the March pulse before March 16.

Although less desirable, it may be possible to contribute to the MoSI program by running nets for only two pulses during the winter season. If only two pulses can be completed, we suggest that one of them be in March (before March 16). In addition, if only two pulses can be completed, we suggest that the size of the study area be increased to 40 ha, that it be divided into two 20-ha subplots, and that up to 16 nets be operated for two or (preferably) three days on each subplot in each pulse (to produce 8 or 12 netting days). In general, two days of operation on each subplot in each pulse would be preferable to three only if either (1) large numbers of birds are captured on the first day and capture rates drop so drastically on the second day that a third day of netting in the subplot would not be useful; or (2) logistic considerations limit the operation of the station.

Finally, it may be possible to include data in the MoSI Program from stations that operate even more frequently than one pulse per month (e.g., one pulse every two weeks or once every 10 days). In such cases, all data from the month would be pooled as if they were part of a single pulse. Before utilizing this approach, further investigation of possible biases that might be produced in the estimation of monthly survival and/or recapture rates will likely be necessary.

All mist nets used in the MoSI program should, if possible, be 12-m-long, 4-tier, tethered nets. Depending upon the local target species, these nets should have either a 30- or 36-mm mesh (36-mm if the major target species is *Catharus* thrush-sized or larger; otherwise 30-mm). One good strategy for placing the nets is to scatter them singly and relatively uniformly over the central 12 ha of the 20-ha station (or subplot) at locations where substantial numbers of birds can be captured. An alternate strategy is to place them along at least two lines that are at least 150 m apart and that traverse the station (or subplot). All nets on a given station (or subplot) should be operated during each day of operation of that station (or subplot). Although we recommend operating 16 nets per station (or subplot), the actual number of nets run should be the maximum that can be operated by available personnel without endangering the lives or welfare of the birds captured.

If possible, MoSI stations should be operated for all daylight hours on each day of operation. If high temperatures, lack of shade, or other logistic considerations prevent nets from being operated for all daylight hours, they should be operated for at least the first 4-6 morning hours. In general, the three (or two) days of operation should be as close to consecutive as possible, although we realize that inclement weather and unforeseen circumstances may make operation for three consecutive days problematic. For two-pulse stations that are divided into two 20-ha subplots, the three (or two) days of operation on the second subplot should follow immediately after the three (or two) days of operation on the first subplot.

Nets should be opened and closed and (if possible) checked in the same order on each day of operation and net check. Opening, closing, and net check times should be recorded to the nearest ten minutes. All birds captured should be identified to species, age (hatching-year/second-year vs. after-hatching-year/after-second-year, where '/' signifies the December 31/January 1 annual age change in all individuals), and (if possible) sex. Unmarked birds should be banded with a uniquely numbered leg band. The body mass of each bird captured should be determined to 0.1 g using a portable battery-operated electronic balance, and its unflattened wing chord should be measured to the nearest mm. Two tail feathers and 2-3 breast feathers should be plucked from each individual for DNA and stable isotope analyses, which are critical for linking breeding and wintering ranges of populations of NTMBs. Finally, all species seen or heard on the study plot during the course of the mist-netting effort each day (even if not captured) should be recorded in such a way as to determine the probable residency status of each species (e.g., using methods similar to those used in breeding bird atlas projects). A standardized protocol for assessing habitat structure and pattern is currently being created and will be available for the 2004-05 season.

Individual color banding and resighting, although labor intensive, can provide an excellent means for improving the precision of survival-rate estimates because, with sufficient effort, resighting probabilities can be substantially higher than recapture probabilities. We suggest that color banding/resighting effort be targeted on one or two (possibly three) focal species and be conducted in conjunction with, or immediately after, the operation of the stations during each pulse. Individuals of focal species should be banded with two or three plastic color bands and one numbered metal band. Resighting color-banded birds is best accomplished by: (a) creating a detailed map of the MoSI station, (b) systematically searching the MoSI station for individuals of the focal species, (c) closely observing all such individuals with binoculars and (if possible) following them for up to 15 minutes, and (d) recording, on species-specific daily station maps, the color-band combination, age and sex (if possible), and exact locations where each individual of the focal species was captured and subsequently re-sighted. A master summary map for each species can be created and updated at the end of each pulse and used in the next pulse to guide efforts to relocate individual birds.

We emphasize that the protocol presented here is in its pilot stage and we welcome suggestions for improvement. Data from the first pilot year of the program come primarily from stations operating only two pulses per winter and the revised protocol presented here arose from preliminary analysis of those data as well as five years of data from Cuba (Siegel et al. 2004). All field protocols will continue to be reviewed after data from each of the first three years of the pilot project have been received, will be modified as appropriate after each of these years, and will be disseminated in the MoSI Manual (DeSante et al. 2003), currently being translated into Spanish.

3. Analysis of MoSI data

All MoSI data are subjected to rigorous data verification procedures that identify and resolve both: (a) within-record discrepancies between age or sex determinations and supplemental data, such as degree of skull pneumatization, molt limits, and feather wear; and (b) between-record discrepancies in species, age, or sex determinations for a given band number. The means for cooperators to provide electronic verification, editing, and submission of their MoSI data is currently being developed through a modification of MAPSPROG, the MAPS data verification program.

Data collected within the suggested MoSI protocol guidelines will permit determination of seasonal indices of body condition and estimation of both annual and overwintering survival rates, population sizes, and population trends. State-of-the-art methods are employed in the analysis of MoSI data. Modified Cormack-Jolly-Seber (CJS) mark recapture models (Pollock et al. 1990, Lebreton et al. 1992), that employ a between-pulse transient modification to account for the negative bias of transient individuals on estimates of survival rates (Pradel et al. 1997), are used to estimate survival and recapture probabilities. Initial estimates of overwintering survival rates (i.e., monthly survival raised to the fourth power, constrained to be constant over all months) will be available after the winter of 2003-04.

At the end of the five-year pilot project, estimates of overwintering survival, oversummering survival (i.e., survival from March to November, which includes mortality during both the spring and fall migration periods), and annual survival (estimated either from March to March or from November to November), as well as recapture (or resighting) probabilities will be modeled as functions of time (year), geographic location, habitat characteristics, age, and (when possible) sex using Program MARK (White and Burnham 1999). Model selection methods based on Akaike's Information Criteria (AIC) (Burnham and Anderson 1998) will be used to assess evidence for sex-, age-, year-, location-, and habitat-related differences in survival and recapture probabilities. Models in each candidate set will be ranked by second-order AIC differences and adjusted by the $\hat{c}$ obtained from bootstrap goodness-of-fit tests to ensure conservative model selection (Cooch and White 2002). The relative likelihood of each model in each candidate set will be estimated with $QAIC_C$ weights, and model-averaging procedures will be used to provide the best estimates of survival and recapture (or resighting) probabilities from all models in a candidate set. This method of multi-model inference will enable us to use the entire set of candidate models to judge the importance of a parameter to survival rate, rather than basing conclusions on a single best-fit model (Burnham and Anderson 1998).

Discussion

The most important goal of the MoSI program over the next two years is to recruit local ornithologists to establish and operate new MoSI stations. To this end, we have identified regional coordinators in Mexico and Central America to organize regional workshops and training programs, recruit and coordinate the activities of MoSI cooperators, distribute MoSI materials to them, and provide, through their sponsoring organizations, regional repositories for MoSI data. These regional coordinators are *Claudia Romo de Vivar Alvarez*, Laboratorio de Ornitologia de CIB, Universidad Autonoma del Estado de Morelos, Cuernavaca, for Mexico; and *Salvadora Morales*, Alianza para las Areas Silvestres (ALAS), Masaya, Nicaragua, for Central America, who was aided by *Alexis Cerezo*, Fundación para el Ecodesarrollo y la Conservacio (FUNDAECO), Ciudad de Guatemala, Guatemala. Discussions are currently underway to identify a regional coordinator for the Caribbean. The existence and efforts of these regional coordinators have been critical for the initial success of MoSI. Indeed, they were responsible for organizing and facilitating the MoSI workshops and training programs held in Mexico and Nicaragua during October 2002, and for recruiting the 19 cooperating organizations and individuals that established and operated 26 MoSI stations in Mexico and Central America during the winter of 2002-03. Moreover, the regional coordinators serve to ensure that control of the program resides in the hands of the people of each region, and that researchers throughout the region will have access to the data.

The five-year MoSI pilot project will generate substantial capacity-building among partners in Mexico, Central America, and the Caribbean, by providing them with: (1) access to critical equipment (e.g., mist nets); (2) USGS/BRD subpermits and bands for migratory birds provided through the Master Station banding permit of The Institute for Bird Populations; (3) training in advanced ageing and sexing techniques and in the MoSI mist-netting protocol; (4) information and tools (e.g., manuals and computer programs) for collecting, verifying, editing, and analyzing mist-netting and mark-recapture data; (5) a means for obtaining and sharing critical data on demographic parameters of migratory landbirds that can only be obtained from a large-scale program; and (6) a network of cooperators and an established program that adds a measure of legitimacy to individual small-scale efforts. In addition, MoSI station operators are encouraged to invite the participation of local residents interested in birds. The information gained from MoSI stations can be used to help educate local residents (including children and school groups) on the importance of conserving quality habitat for Neotropical migrant and resident birds. The presence of MoSI stations and of ornithologists interested in conserving Neotropical birds will contribute to promoting a conservation ethic among area residents.

The MoSI Program will contribute greatly toward creation of a major network of ornithological stations throughout the Neotropics to promote the conservation of both migratory and resident birds. Indeed, a result of the October 2002 Mexico MoSI workshop was the formal creation "El Grupo de MoSI de Mexico." Two of the first goals it identified were to promote the establishment of a repository for survival data on resident bird species in Mexico and the establishment of a national Mexican bird banding program to distribute uniquely numbered bands for resident species in Mexico. Sustainability of the MoSI Program (in Mexico at least) is being enhanced by efforts to include the program as a critical monitoring, research, and management tool in the bird conservation plans and demonstration projects being developed by NABCI for select Important Bird Areas in Mexico. To this end, the establishment of MoSI stations along important habitat gradients is currently being considered as an integral part of the bird conservation efforts at both the El Triunfo Biosphere Reserve (through a NABCI workshop held in Chiapas in January 2003) and the El Cielo Biosphere Reserve (through the efforts of the Texas Parks and Wildlife Department). Sustainability of the program elsewhere in Central America is being enhanced by efforts to include MoSI as an important aspect of the monitoring programs that are being developed for use in national parks and protected areas in Middle America through Park Flight, a consortium between the National Park Service, National Park Foundation, National Fish and Wildlife Foundation, USAID, and American Airlines. In addition, discussions are underway between IBP and the American Bird Conservancy to include MoSI stations as a means for monitoring the effectiveness of the GEF Silvipasture Project being led by CATIE in Costa Rica.

The MoSI program also provides a means for promoting further cooperation between United States and Canadian bird banders and Latin America ornithologists. For example, a project could be envisioned whereby banders from the United States cooperate with ornithologists from Mexico and Central America to operate MoSI stations along gradients of managed habitat (e.g., cover and species composition of shade trees for coffee growing) to document the effect of these practices on overwintering survival of NTMBs. The existence of the MoSI Program will facilitate the establishment of such cooperative ventures. Indeed, over 20 individual bird banders or prospective bird banders have contacted IBP and enquired about the possibility of helping at on-going MoSI stations in the Neotropics. In addition, the MoSI protocol may well turn out to be useful for assessing overwintering survival and late-winter physical condition of temperate-wintering, as well as Neotropical-wintering, migratory landbirds. If this proves to be the case, the MoSI Program should be expanded northward with new MoSI stations targeting the many declining species of sparrows wintering throughout the southern United States.

In conclusion, the MoSI Program promises to forge major partnerships among researchers, ornithologists, and institutions in Mexico, Central America, the Caribbean, and United States, and provides opportunities for sharing crucial data on overwintering survival of NTMBs (as well as permanent resident species). These data will be used to guide and evaluate management plans for modifying and preserving critical habitat in an effort to positively affect vital rates (e.g., survivorship) of these species so as to reverse their population declines. Finally, MoSI provides a means to collect a spatially extensive sample of feathers from target species on their Neotropical wintering grounds for DNA, stable isotope, and trace element analyses. Such samples are critically needed to link breeding and wintering ranges for populations of NTMBs. As of this writing, IBP and both the MAPS and MoSI Programs have developed cooperative agreements with the UCLA Neotropical Migrant Conservation Genetics Project, headed by Dr. Thomas E. Smith, for the analysis and archiving of feather samples collected from these cooperative mist-netting efforts.

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Literature Cited

Burnham, K. P., and D. R. Anderson. 1998. **Model Selection and Inference: a Practical Information Theoretic Approach.** New York, NY: Springer-Verlag.

Cooch, E., and K. P. Burnham. 2002. **Program MARK, Analysis of Data from Marked Individuals: "A Gentle Introduction,"** 2nd edition. www.phidot.org/software/mark/docs/book/.

Conway, C. J., G. V. N. Powell, and J. D. Nichols. 1995. **Overwinter survival of neotropical migratory birds in early-successional and mature tropical forests.** Conservation Biology 9(4): 855-864.

DeSante, D. F. 1992. **Monitoring Avian Productivity and Survivorship (MAPS): a sharp, rather than blunt, tool for monitoring and assessing landbird populations.** In: D. C. McCullough and R. H. Barrett, editors. Wildlife 2001: Populations. London, UK: Elsevier Applied Science; 511-521.

DeSante, D. F. 1995. **Suggestions for future directions for studies of marked migratory landbirds from the perspective of a practitioner in population management and conservation.** Journal of Applied Statistics 22: 949-965.

DeSante, D. F. 2000. **Patterns of productivity and survivorship from the MAPS Program.** In: R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, editors. Strategies for Bird Conservation: the Partners in Flight Planning Process. Proceedings of the Third Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: Rocky Mountains Research Station, Forest Service, U.S. Department of Agriculture; 166-177.

DeSante, D. F., K. M. Burton, J. F. Saracco, and B. L. Walker. 1995. **Productivity indices and survival rate estimates from MAPS, a continent-wide programme of constant-effort mist netting in North America.** Journal of Applied Statistics 22: 935-947.

DeSante, D. F., and T. L. George. 1994**. Population trends in the landbirds of western North America.** In: J. R. Jehl, Jr. and N. K. Johnson, editors. A Century of Avifaunal Change in Western North America. Studies in Avian Biology 15: 173-190

DeSante, D. F. and D. R. O'Grady. 2000. **The Monitoring Avian Productivity and Survivorship (MAPS) Program 1997 and 1998 Report.** Bird Populations 5: 49-101.

DeSante, D. F., D. R. O'Grady, and P. Pyle. 1999. **Measure of productivity and survival derived from standardized mist-netting are consistent with observed population changes.** Bird Study 46 (suppl.): S178-188.

DeSante, D. F., M. P. Nott, and D. R. Kaschube. This volume. **Monitoring, modeling, and management: why base avian management on vital rates and how should it be done?**

DeSante, D. F., M. P. Nott, and D. R. O'Grady. 2001**. Identifying the proximate demographic cause(s) of population change by modeling spatial variation in productivity, survivorship, and population trends.** Ardea 89 (special issue): 185-207.

DeSante, D. F., and D. K. Rosenberg. 1998. **What do we need to monitor in order to manage landbirds?** In: J. M. Marzluff, and R. Sallabanks, editors. Avian Conservation: Research and Management. Washington, DC: Island Press; 93-106.

DeSante, D. F., J. F. Saracco, C.R. deVivar Alvarez, and S. Morales. 2003. **2003-04 MoSI Manual: Instructions for establishing and operating bird-banding stations as part of the MoSI (Monitoreo de Sobrevivencia Invernal) Program.** Point Reyes Station, CA; The Institute for Bird Populations; 27 p.

Donovan, T. M., F. R. Thompson III, J. Faaborg, and J. R. Probst. 1995. **Reproductive success of migratory birds in habitat sources and sinks.** Conservation Biology 9: 1380-1395.

Greenberg, R. 1992. **Forest migrants in non-forest habitats on the Yucatan peninsula**. In: J. M Hagan. and D. W. Johnston, eds. Ecology and Conservation of Neotropical Migrant Landbirds. Washington, DC: Smithsonian Institution Press; 273-286.

Latta, S. C., A. Tossas, A. Sutton, H. Gonzalez, P. B. Hamel, and D. DeSante. 2003. **Research, monitoring, and conservation of Neotropical migratory land birds in the West Indies: a report to the Society for the Conservation and Study of Caribbean Birds (SCSCB) by the Neotropical Migratory Bird Working Group of the SCSCB.** Journal of Caribbean Ornithology 16:1-19.

Latta, S. C., and J. Faaborg. 2002. **Demographic and population responses of Cape May Warblers wintering in multiple habitats.** Ecology 83: 2502-2515.

Lebreton, J. D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. **Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies.** Ecological Monographs 62: 67-118.

Marra, P. P., K. A. Hobson, and R. T. Holmes. 1998**. Linking winter and summer events in a migratory bird by using stable-carbon isotopes.** Science 282: 1884-1886.

Marra, P. P., and R. L. Holberton. 1998. **Corticosterone levels as indicators of habitat quality: effects of habitat segregation in a migratory bird during the non-breeding season.** Oecologia 116: 284-292.

Murphy, M. T., A. Pierce, J. Shoen, K. L. Murphy, J. A. Campbell, and D. A. Hamilton. 2001. **Population structure and habitat use by overwintering neotropical migrants on a remote oceanic island.** Biological Conservation 102: 333-345.

Noon, B. R., and J. R. Sauer. 1992. **Population models for passerine birds: structure, parameterization, and analysis.** In: D. C. McCullough and R. H. Barrett, editors. Wildlife 2001: Populations. London, UK: Elsevier Applied Science; 441-464.

Nott, M. P. 2002. **Climate, weather, and landscape effects on landbird survival and reproductive success in Texas.** Unpublished report to the U.S. Department of Defense Legacy Resource Management Program, Adjutant General's Department of Texas, and USGS/BRD Patuxent Wildlife Research Center. Point Reyes Station, CA: The Institute for Bird Populations; 29 p.

Nott, M. P., D. F. DeSante, and N. Michel. 2003. **Management strategies for reversing declines in landbirds of conservation concern on military installations: a landscape-scale analysis of MAPS data.** Unpubl. report to the U.S. Department of Defense Legacy Resource Management Program. Point Reyes Station, CA: The Institute for Bird Populations; 357 p.

Nott, M. P., D. F. DeSante, R. B. Siegel, and P. Pyle. 2002. **Influences of the El Niño/Southern Oscillation and the North Atlantic Oscillation on avian productivity in forests of the Pacific Northwest of North America**. Global Ecology and Biogeography 11: 333-342.

Pardiek, K. L., and J. R. Sauer. 2000. **The 1995-1999 summary of the North American Breeding Bird Survey.** Bird Populations 5: 30-48.

Parmesan, C., and G. Yohe. 2003. **A globally coherent fingerprint of climate change impacts across natural systems.** Nature 421: 37-42.

Peterjohn, B. G. and J. R. Sauer. 1993. **North American Breeding Bird Survey, Annual Summary 1990-2001.** Bird Populations 1: 52-63.

Peterjohn, B. G., J. R. Sauer, and C. S. Robbins. 1995. **Population trends from the North American Breeding Bird Survey.** In: T. E. Martin and D. M. Finch, editors, Ecology and Management of Neotropical Migratory Birds. New York, NY: Oxford University Press; 3-39.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. **Statistical inference for capture-recapture experiments.** Wildlife Monographs, No. 107.

Pradel, R., J. E. Hines, J. D. Lebreton, and J. D. Nichols. 1997. **Capture-recapture survival models taking account of transients.** Biometrics 53: 60-72.

Pulliam, H. R. 1988. **Sources, sinks, and population regulation**. American Naturalist 132: 652-661.

Pyle, P. 1997. **Identification Guide to North American Birds, Part 1**. Bolinas, CA: Slate Creek Press.

Ralph, C. J., and T. D. Rich. This volume. **Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference 2002.**

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. **Population declines in North American birds that migrate to the neotropics.** Proceedings of the National Academy of Sciences. (USA) 86: 7658-7662.

Sherry, T. W., and R. T. Holmes. 1995. **Summer versus winter limitation of populations: conceptual issues and evidence.** In: T. E. Martin and D. M. Finch, editors. Ecology and Management of Neotropical Migratory Birds. New York, NY: Oxford University Press, 85-120.

Sherry, T. W., and R. T. Holmes. 1996. **Winter habitat quality, population limitation, and conservation of neotropical-nearctic migrant birds.** Ecology 77: 36-48.

Siegel, R. B., R. L. Wilkerson, D. F. DeSante, D. R. Kaschube, and T. S. Sillett. 2004. **Survival rates of landbirds on U.S. Naval Station Guantanamo Bay, Cuba**. Unpublished report to the U. S. Department of Defense Legacy Resource Management Program. Point Reyes Station, CA: The Institute for Bird Populations; 128 p.

Sillett, T. S. and R. T. Holmes. 2002. **Variation in survivorship of a migratory songbird throughout its annual cycle**. Journal of Animal Ecology 71: 296-308.

Temple, S. A., and J. A. Wiens. 1989. **Bird populations and environmental changes: can birds be bio-indicators?** American Birds 43: 260-270.

Terborgh, J. 1989. **Where Have All the Birds Gone? Essays on the Biology and Conservation of Birds that Migrate to the American Tropics.** Princeton, NJ: Princeton University Press.

Van Horne, B. 1983. **Density as a misleading indicator of habitat quality.** Journal of Wildlife Management.47: 893-901.

White, G. C., and K. P. Burnham. 1999. **Program Mark: survival estimation from populations of marked animals.** Bird Study 46(suppl.): 120-138.

Wunderle, J. M. 1995. **Population characteristics of Black-throated Blue Warblers wintering in three sites on Puerto Rico.** Auk 112: 931-946.

Appendix 1— *Twenty partners that have established 28 MoSI stations during 2002-03 (or 2001-02). Unless stated differently, all stations began operation in November or December, 2002.*

A. Mexico

1. *Manuel Grosselet - Independent researcher*
   Stations:
   101 - "Parque Nacional Huatulco, Cacaluta" Oaxaca, Mexico (started November 2001)
   201 - "Llano Grande," Oaxaca, Mexico (started November, 2001)
   210 - "Etla Viguera," Oaxaca, Mexico
2. *Jardín Botánico de Santo Domingo*
   Station:
   202 - "Jardín Botánico de Santo Domingo," Oaxaca, Mexico (started November, 2001)
3. *Ornitorrinco*
   Stations:
   102 - "Bosque de Maple," Jalisco, Mexico
   103 - "Meso," Jalisco, Mexico
4. *University of Michigan*
   Station:
   104 - "Finca Irlanda," Chiapas, Mexico
5. *Pronatura Noroeste Mar de Cortes*
   Stations:
   105 - "Patolandia," Sinaloa, Mexico
   106 - "Pichiuila," Sinaloa, Mexico
6. *Laboratorio de Zoología, Fez-Iztacala-UNAM, Mexico*
   Station:
   203 - "Parque Estatal Sierra de Nanchititla," Mexico, Mexico
7. *Parque Ecología de la Ciudad de Mexico*
   Station:
   204 - "Cortafuegos de Corena," D.F., Mexico
8. *Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Molelos*
   Station:
   205 - "San Andres de la Cal," Morelos, Mexico
9. *Ramiro Aragon - Independent researcher*
   Station:
   206 - "El Capamento," Oaxaca, Mexico
10. *Instituto de Biología, UNAM, Ciudad Universitaria, D.F.*
   Station:
   207 - "Carricitos," D.F., Mexico
11. *Instituto de Biología, UNAM Departamento de Zoología, Colección de Nacional de Aves*
   Station:
   208 - "Jardín Botánico, UNAM," Morelos, Mexico
12. *Universidad Autonoma de Guerrero*
   Station:
   209 - "Parque Ecologico Estatal Omiltemi," Guerrero, Mexico (started February, 2002)

B. Central America

Guatemala

13. *Fundación para el Ecodesarrollo y la Conservacion (FUNDAECO)*
   Stations:
   405 - "Las Torres," Izabal, Guatemala
   406 - "Navajoa," Izabal, Guatemala (started February, 2002)
   407 - "Punta de Manabique," Izabal, Guatemala (started February, 2002)

Honduras

14. *Universidad Nacional Autónoma de Honduras*
   Station:
   408 - "Panacam," Cortes, Honduras (started February, 2002)

Nicaragua

15. *FUNDACIÓN COCIBOLCA*
   Stations:
   401 - "Reserva Natural Volcán Mombacho - Cafetál de Sombra," Nicaragua
   402 - "Reserva Natural Volcán Mombacho - Bosque Nuboso," Nicaragua
16. *Fundación Amigos del Río San Juan (FUNDAR)*
   Station:
   403 - "Refugio de vida silvestre los Guatuzos," Rio San Juan, Nicaragua
17. *Centro de Acción y Apoyo al Desarrollo Rural (CENADE)*
   Station:
   404 - "Chocoyero - El Brujo," Managua, Nicaragua
18. *FUNDENIC - Fundación Nicaraguense para el Desarrollo Sostenible SOS*
   Stations:
   501 - "Bosque Jaguar," Nicaragua
   502 - "Coffee Plantations Jaguar," Nicaragua

Panama

19. *Sociedad Audubon de Panama (SAP)*
   Station:
   409 - "Campo Chagres, Parque Nacional Chagres," Panama (to start November, 2003)

C. Caribbean

20. *Environmental Protection in the Caribbean (EPIC)*
   Stations:
   601 - "St. Martin Dry Forest," Netherlands Antilles (started January, 2001)
   602 - "St. Martin Thorn Scrub," Netherlands Antilles
   603 - "St. Martin Mangroves," Netherlands Antilles

Appendix 2— *Target species for the first two years (2002-03 and 2003-04) of the five-year MoSI Pilot Project***.**

			Mexico			Central America		
Species [1]		**20-year BBS population trend** [2]	**Pacific Lowland**	**Highland**	**Atlantic Lowland**	**Lowland**	**Highland**	**Caribbean**
Willow Flycatcher	*Empidonax traillii*	Neg.**	✓			✓		
Least Flycatcher	*E. minimus*	Neg.**	✓	✘	✓	✓	✘	
White-eyed Vireo	*Vireo griseus*	Pos.			✓	✓		
Warbling Vireo	*V. gilvus*	Pos.**	✓	✓	✘	✓	✓	
Swainson's Thrush	*Catharus ustulatus*	Neg.**	✓	✓	✓	✓	✓	
Wood Thrush	*Hylocichla mustelina*	Neg.**			✓	✓		
Gray Catbird	*Dumetella carolinensis*	Pos.			✓	✓		✘
Orange-crowned Warbler	*Vermivora celata*	Neg.*	✓	✓	✘			
Magnolia Warbler	*Dendroica magnolia*	Pos.	✘		✓	✓		
Cape May Warbler	*D. tigrina*	Neg.						✓
Black-throated Blue Warbler	*D. caerulescens*	Pos.**						✓
Prairie Warbler	*D. discolor*	Neg.**						✓
American Redstart	*Setophaga ruticilla*	Neg.	✓		✓	✓		✓
Ovenbird	*Seiurus aurocapilla*	Pos.	✓		✓	✓		✓
Kentucky Warbler	*Oporornis formosus*	Neg.**			✓	✓		
Mourning Warbler	*O. philadelphia*	Neg.**				✓	✓	
MacGillivray's Warbler	*O. tolmiei*	Neg.		✓			✓	
Hooded Warbler	*Wilsonia citrina*	Pos.*			✓	✓		
Wilson's Warbler	*W. pusilla*	Neg.**	✓	✓	✘	✓	✓	
Indigo Bunting	*Passerina cyanea*	Neg.**	✓		✓	✓		✓
Painted Bunting	*Passerina ciris*	Neg.	✓		✓	✓		✘

[1] Additional potential target species of a fully realized MoSI Program: Yellow-bellied Flycatcher (*E. flaviventris*), Dusky Flycatcher (*E. oberholseri*), "Western" Flycatcher (*E. difficilis/ occidentalis)*, Bell's Vireo (*V. bellii)*, House Wren (*Troglodytes aedon)*, Ruby-crowned Kinglet (*Regulus calendula)*, Blue-gray Gnatcatcher (*Polioptila caerulea)*, Tennessee Warbler (*V. peregrine)*, Nashville Warbler (*V. ruficapilla)*, Yellow Warbler (*D. petechia)*, Chestnut-sided Warbler (*D. pennsylvanica)*, Yellow-rumped Warbler (*D. coronata)* , Palm Warbler (*D. palmarum)*, Black-and-white Warbler (*Mniotilta varia)*, Prothonotary Warbler (*Protonotaria citrea)*, Worm-eating Warbler (*Helmitheros vermivorus)*, Northern Waterthrush (*Seiurus noveboracensis)*, Common Yellowthroat (*Geothlypis trichis)*, Yellow-breasted Chat (*Icteria virens)*, Brewer's Sparrow (*Spizella breweri)*

[2] Trends and their significance from Pardiek and Sauer (2000).

* $0.05 \leq P < 0.10$

** $P < 0.05$

✓ regular and relatively common

✘ irregular or uncommon