Assessing Winter Habitat Quality for Migratory Landbirds

A Report on Five Winters (2002-03 through 2006-07) of the Monitoreo de Sobrevivencia Invernal (MoSI) Program

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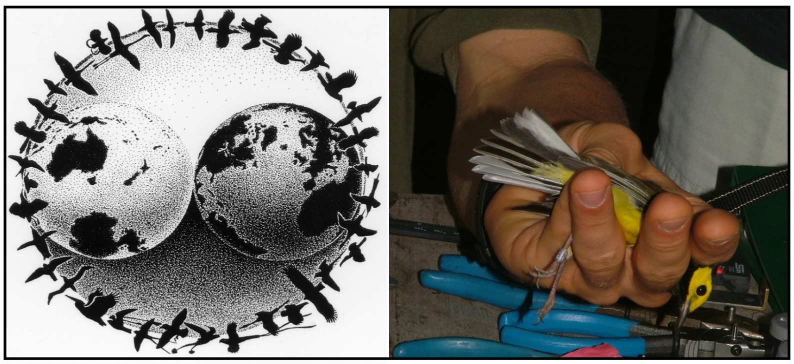

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Executive Summary

In an unprecedented international effort to provide broad-scale data on Neotropical migratory bird (NTMB) winter habitat quality and to link wintering and breeding population parameters, The Institute for Bird Populations (IBP) and partners across the northern Neotropics established the Monitoreo de Sobrevivencia Invernal (MoSI) program in 2002. MoSI consists of a spatially extensive network of mist-netting and bird-banding stations in Mexico, Central America, and the Caribbean. MoSI utilizes a standardized field protocol and state-of-the-art analytical techniques to make inferences at multiple spatial and temporal scales. Broad objectives of MoSI are to assess NTMB winter habitat quality and develop management and conservation plans for target NTMB species on their wintering grounds. Habitat quality is assessed by identifying variation in monthly winter apparent survival rate (site persistence), between-winter apparent survival rate, and physical condition (body weight adjusted for body size) and relating this variation to habitat type or habitat characteristics.

Here we summarize data collected as part of the MoSI program between the winters of 2002-03 and 2006-07. We report specifically on progress toward, or realization of, goals established by our 2005 NMBCA-funded project, *Habitat-Management Strategies that Enhance Overwintering Survival of Migratory Landbirds***.** These goals included: (1) expansion of the MoSI program to 80 stations operated during the winters of 2005-06 and 2006-07; (2) mapping habitats and collecting vegetation data at MoSI stations; (3) obtaining remote-sensed landscape habitat data at stations; (4) modeling apparent survival and body condition as functions of habitat; and (5) formulation of habitat-management strategies. We consider one composite characteristic of (remote-sensed) landscape-scale habitat, leaf area index (LAI), in detail. LAI reflects both structural elements of vegetation (cover and volume) and primary production; it can be highly variable within and among seasons and years. As such, we test the importance of late-winter LAI and the difference in LAI between early and late winter at the scale of 1-km^2 grid cells in affecting body condition and apparent survival of NTMBs at MoSI stations.

At least 127 MoSI stations were operated in 14 countries as part of the MoSI program. A broad array of habitats were sampled, including dry forest, scrub, pine-oak forest, cloud forest, lowland rain forest, and agricultural habitats. Of 52 MoSI stations believed to have been operated during the 2004-05 winter season, we received and verified data from 42 (81%). Our push to expand the MoSI program following 2004-05 led to as many as 82 and 78 stations being operated in 2005-06 and 2006-07, respectively. We received and verified data from 64 (78%) of the 2005-06 stations and from 60 (77%) of the 2006-07 stations. We received data from 76 stations for at least one of the two seasons (nearly achieving the goal of 80 stations). Observed program growth was substantial, representing a 43-52% increase from the (minimum of) 42 stations operated in 2004-05.

We banded 21,674 individuals of 145 NTMB species (including short-distance and long-distance migrants that overwinter [at least partially] in the Neotropics). Of these, we recorded 3,736 pulse-unique recaptures. (Totals do not include shorebirds or hummingbirds, which are not banded at most MoSI stations.) Eight hundred ninety-five station-pulses of effort were recorded during the pilot MoSI program. The five most commonly banded species were Orange-crowned Warbler (1,610 individuals), Tennessee Warbler (1,252 individuals), Wilson's Warbler (1,155 individuals), Prothonotary Warbler (986 individuals), and Wood Thrush (950 individuals; Appendix 2). The most widespread species included: Black-and-white Warbler (74 stations), Ovenbird (73 stations), Wilson's Warbler (67 stations), Swainson's Thrush (55 stations), and Wood Thrush (47 stations; Appendix 2). We recorded the largest numbers of between-pulse

recaptures for Prothonotary Warbler (414), Northern Waterthrush (357), Yellow Warbler (263), Ovenbird (222), and Wilson's Warbler (199).

We received habitat maps and vegetation descriptions from 40 stations operated in 2005-06 or 2006-07. Locally-measured canopy cover was positively correlated with LAI data. Spatial, temporal, and LAI variables accounted for 2-44% of the variation in body condition (weight/wing chord) for 34 NTMB species. Considering just LAI variables, 20 species showed significant relationships between body condition and either late-season LAI (13 species) or difference in LAI between early and late winter (16 species). Thirteen of the 16 species showing body condition responses to LAI difference had lower body condition at sites with larger declines in LAI. We found little evidence of changes in body weight for individuals captured in multiple banding pulses within a winter related to LAI. We estimated station-specific apparent survival rates for six focal species. Three species showed evidence of effects of late-winter LAI on apparent survival: Wood Thrush, Prothonotary Warbler, and Wilson's Warbler. Wood Thrush winter apparent survival was negatively related to late-winter LAI over the set of stations considered in the survival analysis. However, comparison of late-winter LAI values at sites where Wood Thrush were banded but never recaptured between pulses to sites where site fidelity or site persistence was documented, showed that overall late-season LAI values were generally much *lower* at sites where recaptures were never recorded. A nearly identical (even stronger) pattern was found for Ovenbird. Prothonotary Warbler and Wilson's Warbler showed positive relationships between monthly apparent winter survival and late-winter LAI. Three species showed evidence of negative effects of declines in LAI between early and late winter on apparent survival rates: Orange-crowned Warbler, Prothonotary Warbler, and Northern Waterthrush. One high-elevation site for which LAI increased substantially over the winter was an exception to this pattern. Capture rates of Orange-crowned Warblers at this site increased exponentially in late winter, suggesting that it may serve as an important refuge for this species in late winter, when most other sites in the region have experienced significant desiccation.

Results of the 5-yr NMBCA-supported MoSI pilot project show that, through cooperative international participation in broad-scale monitoring, important insights can be achieved into factors that affect winter habitat quality for NTMBs. Until the initiation of this effort, our understanding of the winter ecology of NTMBs has largely been based on intensive efforts focused on single species or sites. We show here that two metrics – body condition and apparent survival rate assessed on multiple species – can vary tremendously from site-to-site and from year-to-year, and that by identifying patterns in this variation we can gain insight into habitat quality. Moreover, for many species, these metrics likely provide more reliable indicators of habitat quality than are provided by other commonly used metrics, such as presence/absence or relative density, which have been shown to often provide misleading indicators of habitat quality.

Our results suggest that, in general, advancement of the dry season over the winter months, as reflected in changes in remote-sensed LAI data, can adversely impact habitat quality for many NTMB species, particularly in winter deciduous habitats and other water-limited regions. Appropriate management actions for NTMB species in such regions include the enhancement and protection of areas that are resilient to drought, such as riparian zones, mangroves, and other wetlands. The identification, protection, and enhancement of local habitats that actually *increase* in greenness throughout the winter in these water-limited regions and can serve as late-winter refugia is another critical management recommendation derived from this study. Indeed, if multiple sites are used regularly throughout the winter in a systematic manner by individual birds in such regions, then a much broader scale approach to winter bird habitat conservation will be required. Such an approach will necessitate the management and conservation of multiple habitats across large spatial extents or elevation gradients. Identification of key conservation areas will clearly require a coordinated network of monitoring sites, such as that represented by the MoSI Program. This network should include key long-term MoSI stations and new stations that target specific habitats or habitat gradients.

Despite evidence of late-season LAI or LAI difference affecting body condition for many species, these habitat effects generally were not important in explaining differences in body weight of individual birds captured on multiple occasions in a season. We suspect that dominant birds (e.g., males, older birds) may be able to successfully defend winter territories and secure sufficient resources to maintain body condition and persist at a site through extended periods of diminished resources, and that subordinate birds (e.g., females, young birds) may be more severely affected by changes in habitat quality over the winter period. Additional monitoring data and modeling could shed light on this hypothesis by enabling identification of age- and sex-specific responses of body condition and survival to habitat.

In wetter regions of the northern Neotropics, late-winter desiccation may not currently be a serious issue; the preferential establishment of protected areas in such regions is an obvious and important management recommendation. However, climate models predict significant declines in winter rainfall over most of the region in the coming decades. The manner in which increased drought will affect the winter population dynamics and trends of NTMBs will need to be better understood to effectively conserve their populations in the face of impending climate change.

Our results also show, however, that even in these wetter habitats, some species, including Wood Thrush and Ovenbird, need relatively high levels of LAI to show any winter site persistence at all. For other species, such as Prothonotary and Wilson's warblers that show some site-persistence at relatively low levels of LAI, winter apparent survival rates increased with increasing LAI. For Wood Thrush, however, at very high levels of LAI, apparent survival decreased with increasing LAI, suggesting that some amount of patchiness (e.g., gaps, edges) may be necessary for optimal habitat quality.

Clearly, we are excited by our discovery of the effectiveness of remote-sensed LAI data for providing a useful, albeit coarse, tool for assessing winter habitat quality for NTMB species and for identifying potential areas for their conservation. However, the identification of local scale structural and perhaps floristic habitat metrics that are better linked to remote-sensed habitat data, such as LAI, will be critical for providing specific recommendations to resource management agencies regarding on-the-ground management actions to enhance the quality of winter habitat and the conservation of these NTMB species. When such linkages are established between remote-sensed LAI data and site-specific habitat metrics, the full power of this newly discovered tool may be realized.

Finally, the MoSI program has also been successful on many other fronts. For example, MoSI has contributed thousands of feather samples for genetic and stable isotope analyses of migratory connectivity, and wing-chord data from MoSI are also lending insight into links between breeding and wintering populations. Additionally, MoSI has generated substantial capacity building amongst partners through funding, provision of materials, and training workshops (16 in six countries), enabling cooperators to partner with other projects and to initiate year-round bird monitoring efforts. Support for continuation of key MoSI stations, collection of additional local-scale habitat data, and the continued development of the MoSI network are needed to ensure the informed management of winter habitats for declining NTMB species, especially in these times of accelerating climate change.

Introduction

Populations of many species of Neotropical migratory birds (NTMBs) have declined in recent decades (Robbins et al. 1989, Terborgh 1989, Peterjohn and Sauer 1993, Pardieck and Sauer 2000, Sauer et al. 2008). These declines have led to the establishment and funding of 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). Yet, conservation of NTMBs continues to be hindered because of uncertainty regarding causes of population declines. Processes operating during the non-breeding season may be particularly important, yet data from the wintering grounds of NTMBs, particularly data that link wintering and breeding population parameters, are currently few (Marra et al. 1998, Nott et al. 2002). The dearth of data on the winter ecology of NTMBs is particularly disturbing because most natural habitats in the northern Neotropics (where most of these species overwinter) are considered "vulnerable, threatened, or endangered" due to direct human impacts (Olson and Dinerstein 1998).

In an unprecedented international effort to provide broad-scale data on NTMB winter habitat quality and to link wintering and breeding population parameters, The Institute for Bird Populations (IBP) and partners across the northern Neotropics established the Monitoreo de Sobrevivencia Invernal (MoSI) program in 2002 (DeSante et al. 2005). MoSI consists of a spatially extensive network of mist-netting and bird-banding stations in Mexico, Central America, and the Caribbean. MoSI utilizes a standardized field protocol and state-of-the-art analytical techniques to make inferences at multiple spatial and temporal scales. Broad objectives of MoSI are to assess NTMB winter habitat quality and develop management and conservation plans for target NTMB species on their wintering grounds. Habitat quality is assessed by identifying variation in monthly winter apparent survival rates (site persistence), between-winter apparent survival rates, and physical condition (body weight adjusted for body size) and relating this variation to habitat type or habitat characteristics.

Earlier results from the MoSI program demonstrated a positive relationship between MoSI monthly winter site persistence rates and long-term breeding population trends for 12 species of forest-inhabiting NTMBs (Saracco et al. 2004). This result implicates processes operating on the wintering grounds as a major driving force effecting population changes. Birds forced to leave home ranges during winter in search for better habitat may suffer increased risk of mortality (Rappole et al. 1989) or a reduction of physical condition (Latta and Faaborg 2002) leading to high mortality in late winter or during spring migration (Sillett and Holmes 2002). In addition, birds unable to find high quality overwintering habitat could arrive late or in poor physical condition on their breeding grounds leading to low recruitment into the breeding population or low reproductive success (Marra et al. 1998, Nott et al. 2002). Despite uncertainties in the exact mechanism(s) involved, it is clear that migratory bird conservation and management in the Neotropics must consider factors that affect the ability of birds to persist at sites through the winter season.

Here we summarize data collected as part of the MoSI program between the winters of 2002-03 and 2006-07. We report specifically on progress toward, or realization of, goals established by our 2005 NMBCA-funded project, *Habitat-Management Strategies that Enhance Overwintering Survival of Migratory Landbirds*. These goals included: (1) expansion of the MoSI program to 80 stations operated during the winters of 2005-06 and 2006-07; (2) mapping habitats and collecting vegetation data at MoSI stations; (3) obtaining remote-sensed landscape habitat data at stations; (4) modeling apparent survival and body condition as functions of habitat; and (5) formulation of habitat conservation and management strategies.

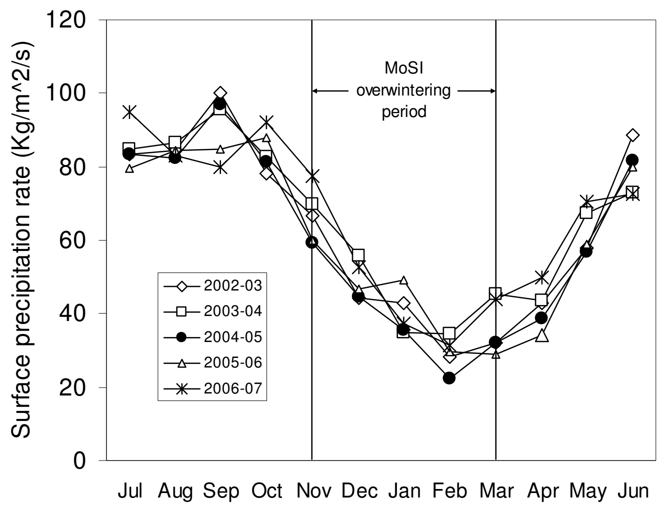

Figure 1. Seasonal pattern of precipitation across the northern Neotropics (5-25° N, -60 – -110° W) during 5 years of the MoSI pilot project. Data are from the NCEP/NCAR Reanalysis Project (http://www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl).

The overwintering period for NTMBs spans the transition from wet to (peak) dry seasons in the northern Neotropics (Fig. 1). It has been suggested that this transition, when severe, can seriously impact NTMB habitat quality (e.g., Parrish and Sherry 1994). In order to test the generality of this assertion, we consider one composite characteristic of (remote-sensed) landscape-scale habitat, leaf area index (LAI), in detail. LAI reflects both structural elements of vegetation (cover and volume) and primary production; it can be highly variable across space as well as within and among seasons and years (Myneni et al. 2007). As such, we test the importance of late-season LAI and the difference in LAI between early and late winter at the scale of 1-km^2 grid cells in affecting body condition and apparent survival of NTMBs at MoSI stations.

Methods

We utilized standardized field protocols established by the MoSI program. Details of these methods can be found in the MoSI Manual (DeSante et al. 2007). Here we provide a brief description.

Study Areas

Each MoSI station consisted of a study area of approximately 20 ha. These stations were broadly distributed across Mexico, Central America, and the Caribbean (Fig. 2). A variety of habitats were sampled including dry forest, scrub (mattoral), pine-oak forest, cloud forest, lowland rain forest, and agricultural habitats (primarily coffee plantation; Appendix 1).

Banding Data

Birds were mist-netted and banded within the central 12 ha of each MoSI station during 2-5 monthly "pulses" of field work between November and March of five winter seasons (2002-03, 2003-04, 2004-05, 2005-06, and 2006-07). Each pulse consisted of 1 (one station) to 3 days of station operation. All NTMBs captured were identified to species, age, and (if possible) sex, and, if unbanded, were marked with uniquely numbered, USGS-Bird Banding Laboratory (BBL) metal leg bands; band numbers of recaptured birds were carefully recorded. Age determinations were based largely on molt limits (or lack thereof) and plumage characteristics (Pyle 1997). Ancillary data were recorded and sometimes used for age determinations. These included: extent of skull pneumaticizication, body and flight feather molt, and extent of primary-feather wear. We measured the unflattened wing chord (to the nearest 1 mm), body weight (to 0.1 g), and fat score (based on a scale that ranged from 0 [no fat] to 5 [continuous bulging fat]) of each captured bird. Date, time of capture, and net number were also recorded for all captures. Two tail feathers were plucked from many individuals for use in the Neotropical Migrant Conservation Genetics Project (NMCGP) of the University of California, Los Angeles (headed by Dr. Thomas E. Smith) for DNA and stable isotope analyses.

All banding data were run through a series of verification programs. These programs flagged suspicious codes and records to help ensure that: (1) codes and values were valid; (2) date values in banding and effort files matched; (3) species, age, and sex determinations agreed with associated ancillary data (molt limits and plumage characteristics, degree of skull pneumaticization, extent of body and flight-feather molt, primary-feather wear); (4) no unusual or duplicate band numbers or unusual band sizes were included in the database; and (5) species, age, and sex determinations were consistent for each band number among pulses and years. Discrepancies or suspicious data identified by these programs were examined and corrected if necessary. Wing chord, body weight, station of capture, date, and pertinent notes were used as supplementary information for correction of errors in species, age, and sex determinations. We also examined distributions of wing chord and weight data and removed extreme outliers from consideration in body condition analyses (see below).

Habitat Data

Habitats were mapped (whenever multiple habitat types existed) and vegetation structure and species composition was assessed at each station. (Note that habitat maps and descriptions

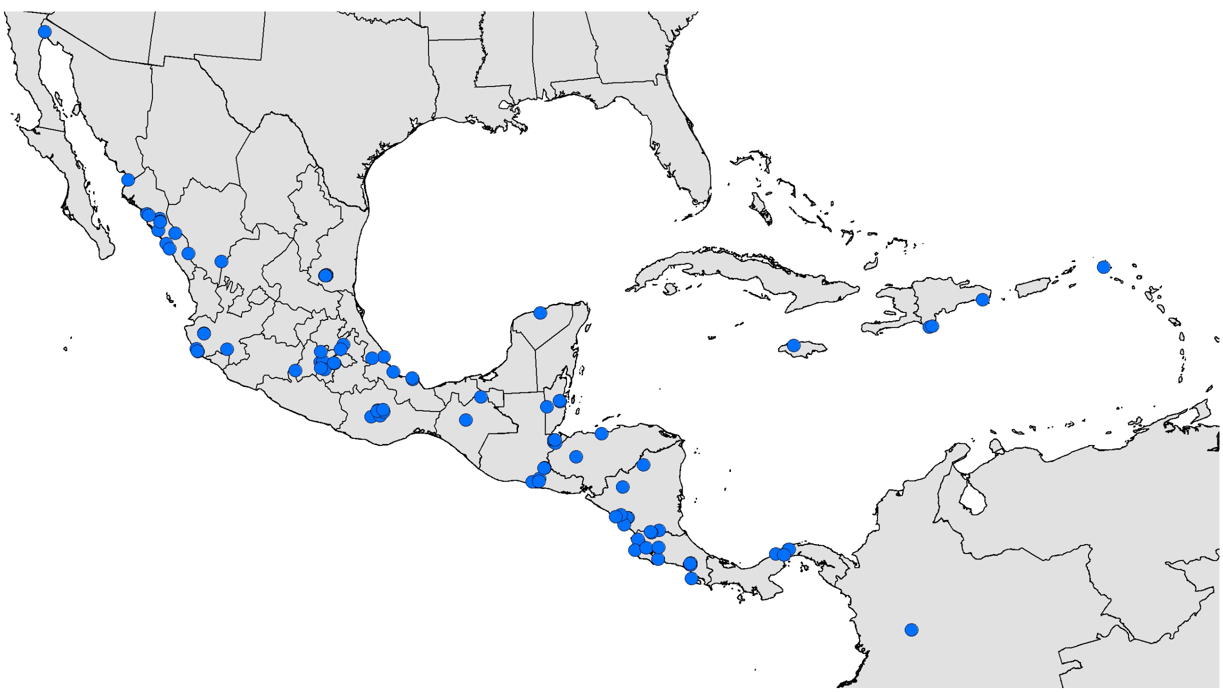

Figure 2. Distribution of 118 MoSI stations operated as part of the Monitoreo de Sobrevivencia Invernal (MoSI) program between 2002-03 and 2006-2007. (See Appendix 1 for a list of stations and operation details. Appendix 1 includes nine additional stations for which we do not have geographic coordinates).

were received for just 41 stations. See Results for detail.) Proportions of stations covered by each major habitat type were estimated from station maps. Percent cover within each of four vegetation layers (ground, shrub, subcanopy, canopy) for each station and major habitat type was estimated using 11 cover classes (%): < 5, 5-15, 15-25, 25-35, 35-45, 45-55, 55-65, 65-75, 75-85, 85-95, >95. Average height of each vegetation layer was visually estimated. The number of snags in two layers (subcanopy and canopy) was indexed for each station and habitat type using three categories: < 5 snags, 5-15 snags, or > 15 snags. Dominant species, successional stage and/or age of each habitat, moisture regime and percent coverage of water, homogeneity of cover, edge characteristics, and natural- or human-caused disturbances and management history were also recorded. For each station and vegetation layer, we computed weighted-average percent coverages (using midpoints of cover classes and weights equal to the proportions of each major habitat type present) and a weighted-average index of snag abundance. In addition to the local-scale habitat data, we obtained satellite-derived leaf area index (LAI) values derived from 1-km^2 scale Moderate Resolution Imaging Spectroradiometer (MODIS) data as processed and made available by the Boston University Climate and Vegetation Research Group (Knyazikhin et al. 1998a, b). LAI (one-sided areal coverage of leaves per unit ground area) is a function of both structural habitat elements and primary production; it can be highly variable within and among seasons and years, even in the relatively seasonally stable humid tropics (Myneni et al. 2007). We obtained monthly-averaged values of LAI for Mar-Dec. 2003-2006; data image files were processed using ENVI software. From these files, we extracted mean values for Nov.-Dec. (early winter) and Feb.-Mar. (late winter) for each station and calculated the mean difference in LAI between these two time periods (early winter – late winter) to quantify seasonal variation in LAI. To better understand the link between LAI and local habitat structure, we regressed LAI (both early and late winter) on cover estimates from 4 vegetation layers. We also calculated mean early-winter and late-winter LAI for all 1-km blocks in the Neotropical region using the raster calculator tool in the Spatial Analyst Toolbox of ArcGIS.

Data Analyses

Body condition.—We performed two sets of multiple regression analyses to assess temporal, spatial, and habitat related variation in body condition. In the first set (Analysis 1), we used an index of body condition, weight/wing chord (Latta and Faaborg 2002), as the response variable. We considered individual captures as replicates. We limited the second set of analyses (Analysis 2) to pairs of sequential captures of individuals; for these, we used change in body weight (weight at second capture – weight at first capture) scaled by time between captures (month to nearest 0.03 mo.) as our response variable. The complete set of explanatory variables considered in each set of analyses is listed in Table 1. Because local habitat data were available for a relatively small subset of stations, we limited habitat variables considered in analyses to those derived from the LAI data. We hypothesized that if LAI affected body condition (albeit indirectly), it would most likely be manifested during late winter when resources were likely low at many stations and would likely be most severely manifested when differences between early and late winter were greatest. Thus, we considered two LAI variables: late-winter LAI (lai.fm) and the difference between early-winter and late-winter LAI (lai.diff). We conducted Analysis 1 for 33 NTMB species that were well-represented in the MoSI data base (all had > 150 captures with both body weight and wing chord data; actual sample sizes, however, were slightly lower in two cases due to elimination of extreme outliers). For Analysis 2, we considered nine species with > 50 pairs of captures. We did not consider annual differences (i.e., year effects) in Analysis 2 as smaller sample sizes limited the number of variables that could be reasonably tested simultaneously (a year effect would add 3-4 dummy variables). We also expected less annual variation than within-winter (day) or time-of-day (time) effects. For both sets of analyses we used a backward stepwise procedure with a *P*(leave) = 0.05. Although explanatory variables were correlated to varying extents for all species, we chose to present analyses conducted on these original variables rather than present results from analyses conducted on composite variables (e.g., from principal component analysis) because of the relative ease of interpretation (different composite variables would need to be used for each species). Results from regressions on principal components yielded qualitatively similar results in most cases. All principal components and regression analyses were conducted using JMP for Windows v. 7.0.1 (SAS Institute, Cary, NC).

Survival.—We estimated monthly winter and between-winter apparent survival rates (ϕ_w and ϕ_s, respectively) by fitting Cormack-Jolly-Seber (CJS) models (Pollock et al.1990) to capture-recapture data for six of the best represented species in the MoSI data base (all had > 700 captures and > 150 between-pulse recaptures). We ran models in program MARK (White and Burnham 1999) from R ver. 2.6.1 (R Development Core Team 2007) using the RMark package (Laake and Rexstad 2008). "Winter apparent survival rate", ϕ_w, is the probability of a marked (banded) bird surviving and remaining at the station where it was banded between monthly (30-day) netting pulses. "Between-winter apparent survival rate", ϕ_s, is the probability (scaled to a monthly interval) of a marked bird surviving and returning to the station where it was banded between winters. The 'nuisance parameter', recapture probability (*p*) is also estimated for each model; it refers to the probability of a marked bird being recaptured at a station, given that it survived and remained at the station (or returned, in the case of between-winter survival) between pulses. A minimum of three capture sessions (pulses) is required to estimate both recapture probability and apparent survival rate for one of the time periods. Although intervals

Table 1. Explanatory variables used in body condition multiple regression analyses.

Explanatory variable	Definition	Response variable: Body condition (weight/wing)	Response variable: Δ weight (g/mo.)
<u>Temporal effects</u>			
winter season	categorical variable indicating MoSI winter season ('03' = 2002-03 winter,'04' = 2003-04 winter, etc.)	×	
day	day of MoSI season	×	
time	capture time (hr, to nearest 0.17 hr)	×	
day.init	Day of MoSI season when initially captured		×
time.dif	Difference in capture times between dates of capture (hrs)		×
<u>Spatial effects</u>			
lat	Latitude (decimal degrees)	×	×
long	Longitude (decimal degrees)	×	×
log(elev)	$\log_{10}$(elevation) (m)	×	×
<u>Habitat effects</u>			
lai.fm	Mean 2004-2006 leaf area index (LAI) for late winter (Feb.-Mar.)	×	×
lai.diff	Mean difference in LAI between early winter (Nov.-Dec. 2003-05) and late winter (Feb.-Mar. 2004-06)	×	×

between pulses varied somewhat among stations and from year-to-year, we assume here equal monthly intervals between (within-) winter pulses and 8 months between winters. We set $p = 0$ for stations whenever banding pulses were missed for a station.

For each of the six species, we only included data for a station in the analysis if it (1) operated for ≥ 2 years (to allow estimation of both ϕ_w and ϕ_s), (2) had ≥ 5 individuals banded/yr, and (3) had ≥ 5 between-pulse recaptures. Including data from stations with fewer data added little information (i.e., results were qualitatively similar) and resulted in many inestimable parameters. We considered as many as 66 models testing for spatial and habitat related differences in apparent survival rates. We did not consider temporal effects on survival (annual or monthly), as data were generally too sparse to consider that level of detail (at least at the scale of stations). For all species and models, we assumed differences between overwintering, ϕ_w, and between-winter, ϕ_s, survival (season effect). We considered models with 'transient effects' as well as standard CJS models (no transient effect). Transient models followed the parameterization of Pradel (1996). Under this parameterization, survival for the first interval after banding is modeled separately from survival between subsequent time intervals. Survival-rate estimates for the first interval after banding were always lower than survival-rate estimates for subsequent periods; however, spatial, temporal, and habitat-related patterns were consistent between transient (first interval) and non-transient (subsequent intervals) estimates. We only report non-transient survival-rate estimates here. For each model type (transient or non-transient), we considered sets of covariates describing spatial and habitat effects. Spatial models included three covariates (with intercepts and slope parameters estimated separately for seasonal and transient survival effects): latitude, longitude, and the interaction between latitude and longitude. We included all spatial effects in models simultaneously to limit the number of models considered. We also considered models that allowed for elevation effects ($\log_{10}$[elev]). We did not consider spatial or elevation effects for two of the six species, Prothonotary Warbler and Northern Waterthrush, as all stations except one (of those included in analyses) for both species were in northwestern Costa Rica and at low elevation. Habitat models included those with late-winter LAI as a covariate (lai.fm) and models that included the difference between early-winter and late-winter LAI as a covariate (lai.diff). We considered all combinations of models that included each of these explanatory variables (or set of variables in the case of spatial [lat-long] effects) as additive effects with season (ϕ_w and ϕ_s) and/or transience (i.e., non-transient v. transient) or as additive effects with interactions with season and transient effects.

We used model selection methods based on Akaike's Information Criterion (AIC) (Burnham & Anderson 1998) to compare models. Models were ranked by second-order AIC_c differences (Burnham & Anderson 1998). We tested for goodness-of-fit using the bootstrap test in program MARK (100 bootstrap samples per species). These tests indicated that data were 'underdispersed' for all species ($0.56 < \hat{c} < 0.94$), suggesting sparsity of data and (likely) dominance of relatively few individuals in determining model structure. Rather than adjust $\hat{c}$ for model selection purposes (as is prescribed when data are overdispersed), we followed the advise of Cooch and White (2002) and kept $\hat{c}$ set at its default value of 1.00. This helped to ensure conservative model selection. Relative likelihoods of each model (given the model set) were then estimated for each species from AIC_C weights, w_i (Burnham & Anderson 1998). Statistical support for particular explanatory variables (e.g., lai.fm) was assessed by summing w_i values across all models that included that variable. We estimated apparent survival and recapture probabilities (and standard errors, SEs) for each species and station using model averaging based on w_i's from all models in candidate model sets. This method of multi-model inference enabled us to base inference on the entire model set rather than on a single "best-fit" model. To further examine relationships between LAI, spatial gradients, and habitat quality, we compared lai.fm (late-winter LAI), lai.diff, latitude, and longitude between stations for which site persistence (or between-year site fidelity) was recorded (i.e., ≥ 1 between-pulse recapture) and stations where no recaptures were recorded using weighted one-way ANOVAs with weights equal to the number of pulses of operation.

Results

MoSI program expansion

A summary of 127 MoSI stations operated as part of the MoSI program between 2002 and 2007 is presented in Appendix 1 (only stations from which we have received data are included). These stations were operated within 14 countries (although a few of the stations operated in the Caribbean region were only operated for 1-2 pulses). Of 52 MoSI stations that we believe to have been operated during the 2004-05 winter season, we received and verified data from 42 (81%). Our push to expand the MoSI program following the 2004-05 season led to as many as 82 and 78 stations being operated in 2005-06 and 2006-07, respectively. We have received and verified data from 64 (78%) of the 2005-06 stations and from 60 (77%) of the 2006-07 stations (Appendix 1). Although short of our proposed 80 stations per season, we did receive data from 76 stations for at least one of the two seasons. Regardless of meeting our expansion goal, observed (data received) program growth was substantial, representing a 43-52% increase from the (minimum of) 42 stations operated in 2004-05.

Banding summary

We banded 21,674 individuals of 145 NTMB species (including short-distance and long-distance migrants that overwinter [at least partially] in the Neotropics) at 127 MoSI stations between winter 2002-03 and 2006-07. Of these, we recorded 3,736 pulse-unique recaptures. (Totals do not include shorebirds or hummingbirds, which are not banded at most MoSI stations.) Eight hundred ninety-five station-pulses of effort were recorded during the five-year MoSI program. The five most commonly banded species were Orange-crowned Warbler (1,610 individuals), Tennessee Warbler (1,252 individuals), Wilson's Warbler (1,155 individuals), Prothonotary Warbler (986 individuals), and Wood Thrush (950 individuals; Appendix 2). The most widespread species included: Black-and-white Warbler (74 stations), Ovenbird (73 stations), Wilson's Warbler (67 stations), Swainson's Thrush (55 stations), and Wood Thrush (47 stations; Appendix 2). We recorded the largest numbers of between-pulse recaptures for Prothonotary Warbler (414), Northern Waterthrush (357), Yellow Warbler (263), Ovenbird (222), and Wilson's Warbler (199).

Habitat data

We received habitat maps and vegetation descriptions from 40 stations operated in 2005-06 or 2006-07. Structural habitat elements varied substantially among stations (Appendix 3). Remote-sensed leaf area index (LAI) values partly reflected locally-measured habitat variables. For example, LAI was strongly correlated with estimated canopy cover (Fig. 3). Maps of early- and late-winter LAI across the northern Neotropics and the difference in LAI between early and late winter highlight the broad-scale pattern of high LAI throughout the mountains of Mexico and cloud and rain forests of Central America (Fig. 4). By late winter, LAI declines in most places, particularly in western Mexico and areas dominated by tropical deciduous forest. Locally, however, LAI increases through the winter (e.g., high elevation sites, agricultural areas). Even

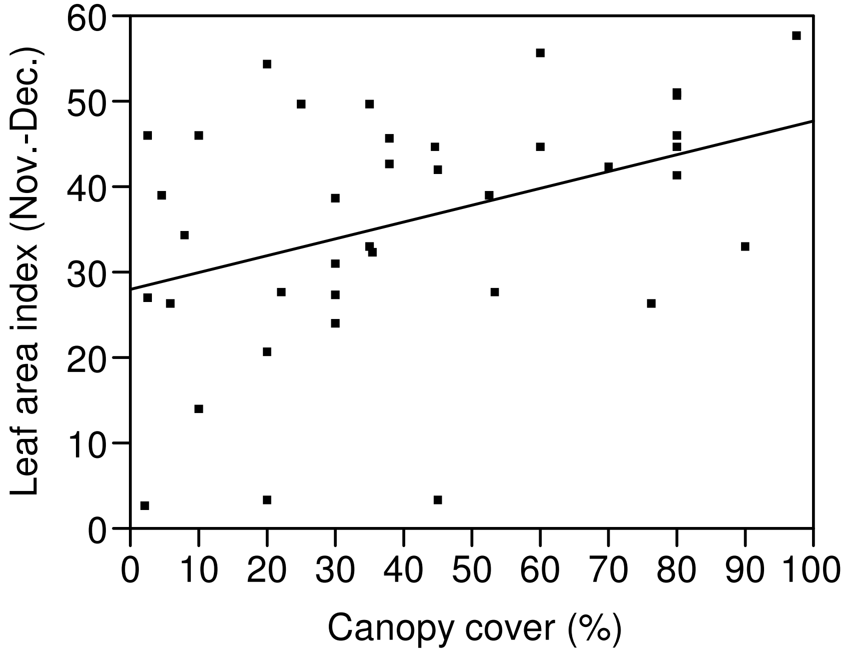

Figure 3. Linear relationship between MODIS-derived 1-km^2 scale leaf area index (LAI) data and canopy cover estimated at 40 MoSI stations. The regression describing this relationship was significant (R^2 = 0.15; $F_{1,38}$ = 6.64, P = 0.01).

within broad habitat types (e.g., evergreen forest or deciduous forest) in a region, LAI and difference in LAI can be highly variable among 1-km^2 blocks (Fig. 4).

Body Condition

Spatial, temporal, and habitat variables accounted for 2-44% of the variation in body condition (weight/wing chord) for the 34 species considered (Table 2). Although most (21) species showed significant differences in body condition among winter seasons, there were no consistent season effects among species (which could simply reflect variation in which stations were run in which winter season). We found significant effects of capture time (time) for 25 species. In all cases, body condition increased as the day progressed. 'Day of season' effects were found for just nine species; body condition increased over the season for seven species and decreased over the season for two species. Twenty-one species showed spatial gradients in body condition in terms of significant latitude or longitude effects. The direction of latitude effects was not consistent among species (body condition positively related to latitude for seven species and negatively related to latitude for seven others). Body condition increased from west to east for most (10 of 14) species that showed longitude effects on body condition. Body condition increased with elevation for nine species and decreased with elevation for four species. Twenty species showed significant relationships between body condition and either late-winter LAI (lai.fm; 13 species) or difference in LAI between early and late winter (lai.diff; 16 species). Six species had higher body condition at higher LAI values, while seven had lower

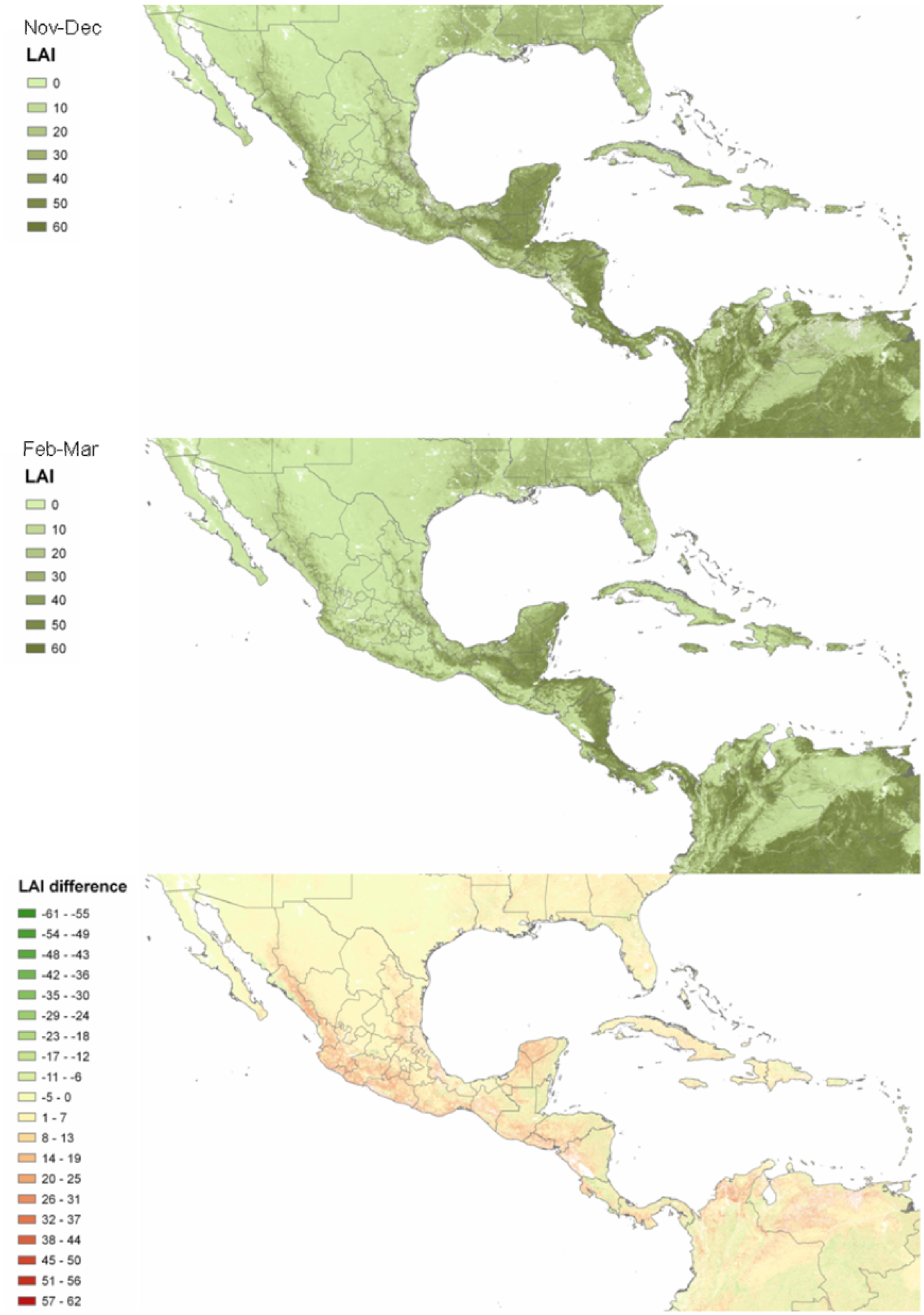

Figure 4. Mean leaf area index (one-sided leaf area per unit ground area; LAI) during early winter (Nov.-Dec.) and late winter (Jan.-Feb.) and mean difference in LAI (early – late) between the two time periods (LAI declines in red areas, increases in green areas) across the northern Neotropics. LAI values were derived from 1-km^2 scale Moderate Resolution Imaging Spectroradiometer (MODIS) data as processed and made available by Boston University Climate and Vegetation Research Group.

body condition at the higher LAI values. Thirteen species showed significant negative relationships with LAI difference (i.e., body condition was lowest at sites with large declines in LAI between early and late winter). Just three species showed significant positive relationships with LAI difference.

Table 2. Results of backward stepwise regressions performed on the response variable 'body condition' (weight/wing chord) derived from MoSI data over five winter seasons, 2002-03, 2003-04, 2004-05, 2005-06, and 2006-07. Explanatory variables are defined in Table 1. Scientific names are listed in Appendix 2. (*: $P < 0.05$; ** = $P < 0.01$; **** = $P < 0.001$; **** = $P < 0.0001$).

				Coefficient¦						
Species	N†	R^2‡	season§	day	time	lat	long	log(elev)	lai.fm	lai.dif
Yellow-bellied Flycatcher	149	0.20			+0.005****				+0.006****	
Western Flycatcher	317	0.20					+0.006****			-0.008****
White-eyed Vireo	199	0.22	07,06>05,04*		+0.004**	+0.004*	-0.008****	-0.007***	+0.008****	
Bell's Vireo	166	0.02	03,06,04>07,05*							
Warbling Vireo	189	0.19	03>04,05,07,06*				+0.006****			
Ruby-crowned Kinglet	487	0.13	05,03>07*				+0.003***	-0.002*	-0.005****	-0.004****
Blue-gray Gnatcatcher	420	0.16	06,05,04>03,07		+0.003****		+0.002**		+0.002*	-0.003****
Swainson's Thrush	878	0.06	06>05,07,04,03****		+0.015***					+0.014***
Hermit Thrush	142	0.12						+0.012****		
Wood Thrush	1098	0.13	03,05>04,07,06**** 04,07>06****	-0.003**	+0.004***	-0.019****	-0.016****	+0.003*		
Gray Catbird	459	0.10	03,04>06,07,05****		+0.005****					
Tennessee Warbler	1067	0.06		+0.003***	+0.001***					
Orange-crowned Warbler	1345	0.14	03,04,07>05,06**** 05>06***	+0.001*	+0.004****	-0.003***		-0.002*	-0.005****	-0.003****
Nashville Warbler	559	0.11	03,05>06,04,07*		+0.003****			+0.002**		-0.001*
Yellow Warbler	778	0.44			+0.001*	+0.006****	+0.012****		+0.002****	+0.003****
Magnolia Warbler	169	0.23	03,06,04>05,07****	+0.003***	+0.002*	+0.002*				-0.005***
Yellow-rumped Warbler	499	0.23	04>07,03,06,05**		+0.002*		+0.010****		-0.006****	-0.004****
Townsend's Warbler	148	0.12	05,03,07,06>04*						-0.009***	-0.008**
Black-and-White Warbler	381	0.11			+0.003****			+0.003****		
Prothonotary Warbler	1355	0.30	07,06>05,03****	+0.005****	+0.004****	-0.001****	+0.001***			
Worm-eating Warbler	300		07,04,06>03,05**** 03>05*	+0.004***	+0.005****				+0.004**	
Ovenbird	842	0.10			+0.004**	+0.003**	+0.009****	+0.005****	-0.005****	
Northern Waterthrush	1088	0.21		-0.002****	+0.003****	+0.002****		+0.002****		-0.002***
Kentucky Warbler	367	0.07			+0.003****	-0.003**		+0.003*		
MacGillivray's Warbler	257	0.22	03,05,04>06,07**** 03>05,04**		+0.006****	-0.007***			-0.011****	-0.004**
Common Yellowthroat	236	0.27			+0.002*	+0.019****	+0.017****	+0.007***		-0.003*
Hooded Warbler	331	0.13		+0.005****	+0.003**			+0.004****		
Wilson's Warbler	1005	0.09	03,04,06,07>05		+0.003****	-0.005**	-0.006***			-0.003****
Yellow-breasted Chat	260	0.11	04,0703>06,05*		+0.009****		+0.006**			
Western Tanager	211	0.22	03,06,04>07,05***				-0.005*		-0.014****	-0.008**
Lincoln's Sparrow	266	0.16	03,04,06,05>07**		+0.006**	-0.009****				
Black-headed Grosbeak	167	0.04				+0.009*				
Indigo Bunting	200	0.12						-0.003*	+0.007****	+0.003***
Painted Bunting	583	0.08	05,04,07,03>06*	+0.009****	+0.007****					

† Number of captures used in analysis
‡ Coefficient of determination (% variance explained by regression model)
§ Inequality symbols indicate winter seasons found to significantly differ. Only the second year of the winter is indicated (e.g., '03' = 2002-03 season).
¦ Standardized regression coefficient. Magnitude of coefficients indicates relative importance in affecting body condition for a particular species. Sign of coefficients indicates direction of relationship.

Regressions describing change in body weight ([body weight$_t$ – body weight$_{t-1}$]/mo.) for individuals captured during multiple pulses within a winter described 8-33% of change in body weight for six of nine species (Table 3). No variables were significant for three species (Swainson's Thrush, Wood Thrush, and Wilson 's Warbler). Difference in capture time was consistently important (significant for five species); later capture times during the second capture occasion resulted in larger gains in body mass (indicated by positive regression coefficients). First capture date was important for two species – in both cases change in body weight was more positive when the date of first capture was later. Spatial effects were found for just one species, Prothonotary Warbler; change in body weight for this species was more positive at lower latitudes; i.e., there was a negative relationship between body weight and latitude). Habitat effects were found for just one species, Yellow Warbler, for which change in body weight was more positive in areas with high late-winter LAI.

Table 3. Results of backward stepwise regressions modeling difference in body weight/mo. as a function of temporal, spatial, and habitat (leaf area index) variables (see Table 1 for variable definitions). Scientific names are listed in Appendix 2.

			Coefficient§						
Species	N†	R^2‡	date	time.dif	lat	long	elev	lai.fm	lai.dif
Swainson's Thrush	51	—							
Wood Thrush	97	—							
Orange-crowned Warbler	58	0.18		+0.15***					
Yellow Warbler	149	0.27		+0.18****				+0.12****	
Prothonotary Warbler	230	0.33	+0.36****	+0.30****	-0.11*				
Ovenbird	114	0.08		+0.32**					
Northern Waterthrush	189	0.16		+0.32****					
Kentucky Warbler	65	0.10	+0.34*						
Wilson's Warbler	71	—							

† Number of captures used in analysis
‡ Coefficient of determination (% variance explained by regression model)
§ Standardized regression coefficient. Magnitude of coefficients indicates relative importance in affecting body condition for a particular species. Sign of coefficients indicates direction of relationship.

Survival

Winter ($\hat{\phi}_w$) and between-winter ($\hat{\phi}_s$) apparent survival rates were variable among species and sites (Table 4). Winter survival-rate estimates were highest (on average) for Ovenbird (0.954) and lowest for Prothonotary Warbler (0.813). Between-year survival-rate estimates, however, tended to be lowest for Ovenbird (mean = 0.900) and highest for Prothonotary Warbler (albeit impossibly so with mean = 0.999; suggesting difficulty of estimating survival near the upper boundary of 1). The pattern of between-winter survival among stations did not always match that of winter apparent survival. We also found strong support for variation in recapture probability among sites for three of the six species (indicated by high $QAIC_c$ weights; Table 5).

We found strong support for the transient model for all species (although support was less strong for Ovenbird; Table 5). We found little support for models with station-specific survival; however, this was undoubtedly due to the large number of parameters required for these models and the relatively sparsity of our data set. Orange-crowned Warbler showed evidence of broad-scale spatial pattern in survival (Table 5); however, because of significant interaction between latitude and longitude, the spatial gradient in survival was not obvious (Fig. 5). Survival for this species was highest in mangrove and dry scrub habitats in the coastal northwest (PATO and PICH in Sinaloa; see Appendix 1 for detail) and in pine-oak forest in the south (CAMP in Oaxaca) and lowest at a station in high elevation fir/pine/matorral habitat on Nevado de Colima (NEVA).

Table 4. Station-scale model-averaged (considering entire set of up to 66 models) estimates of monthly winter apparent survival, ϕ_w, and monthly between-winter apparent survival, ϕ_s (i.e., for resident birds subsequent to the first period after banding), and recapture probability, *p*, for six species sampled by the MoSI program between winter 2002-03 and winter 2006-07. We only considered six of the most commonly captured and recaptured species. Stations were included in analyses if an average of > 5 birds per pulse and > 5 between-pulse recaptures were recorded.

Station code[†]	*Ncap*[‡]	*BPrecap*[§]	$\hat{\phi}_w$	SE	$\hat{\phi}_s$	SE	$\hat{p}$	SE
Wood Thrush								
ARAN	72	11	0.831	0.033	0.958	0.017	0.185	0.028
BN01	120	16	0.789	0.054	0.952	0.027	0.185	0.028
BOSQ	29	7	0.812	0.044	0.961	0.019	0.185	0.028
CAFE	44	8	0.812	0.044	0.961	0.019	0.185	0.028
CARB	41	16	0.832	0.033	0.957	0.017	0.185	0.028
CHOC	48	13	0.838	0.034	0.957	0.017	0.185	0.028
MCHI	44	15	0.845	0.038	0.954	0.021	0.185	0.028
MSB1	59	14	0.861	0.042	0.961	0.021	0.185	0.028
PAPA	18	5	0.817	0.043	0.952	0.020	0.185	0.028
RANC	84	13	0.831	0.033	0.958	0.017	0.185	0.028
RCPC	64	10	0.829	0.068	0.915	0.062	0.185	0.028
Orange-crowned Warbler								
CABU	20	5	0.910	0.073	0.938	0.039	0.098	0.022
CAMP	37	9	0.959	0.036	0.972	0.026	0.097	0.021
NEVA	412	24	0.626	0.128	0.909	0.057	0.092	0.021
PATO	56	5	0.959	0.041	0.947	0.039	0.097	0.022
PICH	281	50	0.941	0.058	0.944	0.032	0.098	0.020
ROCA	112	18	0.867	0.102	0.931	0.033	0.093	0.021
Prothonotary Warbler								
CURU	52	23	0.835	0.036	0.999	0.003	0.252	0.057
ESDV	74	39	0.858	0.044	0.999	0.003	0.192	0.041
ESIG	60	59	0.790	0.034	0.999	0.003	0.348	0.045
ESNA	252	93	0.804	0.023	0.999	0.003	0.134	0.018
ESTA	419	153	0.797	0.025	0.999	0.003	0.130	0.014
PLGR	124	45	0.797	0.025	0.999	0.003	0.142	0.026
Ovenbird								
BN01	33	6	0.956	0.046	0.905	0.027	0.074	0.045
CHOC	99	36	0.958	0.043	0.902	0.023	0.122	0.029
RCPC	16	7	0.958	0.047	0.911	0.031	0.188	0.068
SVIM	42	19	0.953	0.048	0.897	0.025	0.140	0.036
SVLV	23	9	0.954	0.048	0.894	0.028	0.147	0.045
SVMO	18	7	0.954	0.047	0.898	0.025	0.135	0.046
SVNH	38	19	0.936	0.061	0.899	0.029	0.164	0.044
WRC1	19	22	0.956	0.044	0.899	0.030	0.281	0.091
WRC2	29	14	0.956	0.045	0.899	0.030	0.172	0.049
Northern Waterthrush								
CURU	70	30	0.916	0.036	0.931	0.023	0.239	0.023
ESDV	33	25	0.921	0.039	0.927	0.031	0.247	0.031
ESIG	40	33	0.896	0.026	0.941	0.013	0.238	0.021
ESNA	91	46	0.895	0.025	0.940	0.013	0.231	0.022
ESTA	244	183	0.890	0.026	0.942	0.013	0.235	0.019
PICH	66	13	0.906	0.032	0.936	0.016	0.230	0.024
Wilson's Warbler								
CAFE	95	26	0.897	0.058	0.925	0.027	0.154	0.049
CAMP	12	11	0.912	0.043	0.943	0.023	0.383	0.113
JBOT	48	8	0.859	0.071	0.938	0.027	0.134	0.065
PSJB	40	22	0.881	0.054	0.943	0.024	0.378	0.095
ROCA	39	12	0.885	0.048	0.936	0.025	0.197	0.066
SVLV	92	29	0.919	0.044	0.937	0.024	0.118	0.029
SVMO	32	5	0.912	0.046	0.936	0.023	0.069	0.037
SVNH	70	13	0.912	0.056	0.932	0.033	0.056	0.020

[†] See Appendix 1 for station name, location, and operation detail.
[‡] Number of individuals banded.
§ Number of between-pulse recaptures.

Table 5. Model support (summed AIC*c* weights, w_i) for transient effects (trans), spatial effects (station and lat × long), elevation effects [log(elev)], , and landscape scale habitat effects (lai.fm and lai.diff) on monthly apparent survival-rate (ϕ) and recapture probability (*p*) for six focal species over five MoSI seasons 2002-03, 2003-04, 2004-05, 2005-06, and 2006-07. Effects with relatively strong support (w_i > 0.300) are shown in **bold**.

	ϕ						*p*
Species	trans	station	lat × long	log(elev)	lai.fm	lai.diff	station
Wood Thrush	**1.000**	0.002	0.008	0.282	**0.475**	0.092	0.002
Orange-crowned Warbler	**0.746**	0.043	**0.574**	0.013	0.013	**0.334**	0.151
Prothonotary Warbler	**0.987**	0.012	—	—	**0.303**	**0.392**	**1.000**
Ovenbird	**0.550**	0.004	0.097	0.182	0.174	0.221	**0.833**
Northern Waterthrush	**0.989**	0.027	—	—	0.182	**0.453**	0.132
Wilson's Warbler	**0.978**	0.014	0.123	0.091	**0.532**	0.090	**0.999**

Three species showed evidence of effects of late-winter LAI on apparent survival (Table 5). Winter apparent survival declined with increasing LAI for Wood Thrush (although survival could only be estimated within a relatively narrow range of LAI values for this species), while winter apparent survival of Prothonotary Warbler and Wilson's Warbler was positively related to late-winter LAI (Fig. 6 left panels). Between-winter survival for these species did not show a strong pattern in relation to late-winter LAI.

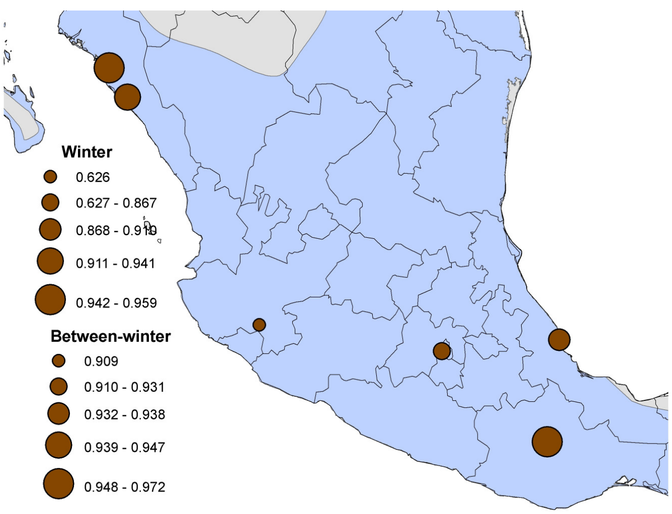

Figure 5. Spatial pattern in apparent monthly survival-rate estimates (winter [$\hat{\phi}_w$] and between-winter [$\hat{\phi}_s$]) for Orange-crowned Warbler at six MoSI stations operated for ≥ 2 winters between 2002-03 and 2006-07 and that had a mean of ≥ 5 individuals banded per winter and ≥ 5 between-pulse recaptures (intervals defined by Jenks' breaks; note that stations falling within each interval were the same for both winter and between-winter survival).

Three species showed evidence of effects of the difference between early- and late-winter LAI on apparent survival rates (Table 5): Orange-crowned Warbler, Prothonotary Warbler, and Northern Waterthrush. With the exception of a single station for Orange-crowned Warbler (NEVA), the trend was for winter apparent survival to decline with larger declines in leaf area (i.e., higher lai.diff values) between early and late winter (Fig. 6 right panels). Between-winter apparent survival for orange-crowned warbler, again with the exception of the NEVA station, also declined with larger declines in leaf area. Northern Waterthrush between-winter apparent survival appeared to increase as declines in leaf area increased, a pattern that contrasted with that observed for winter apparent survival.

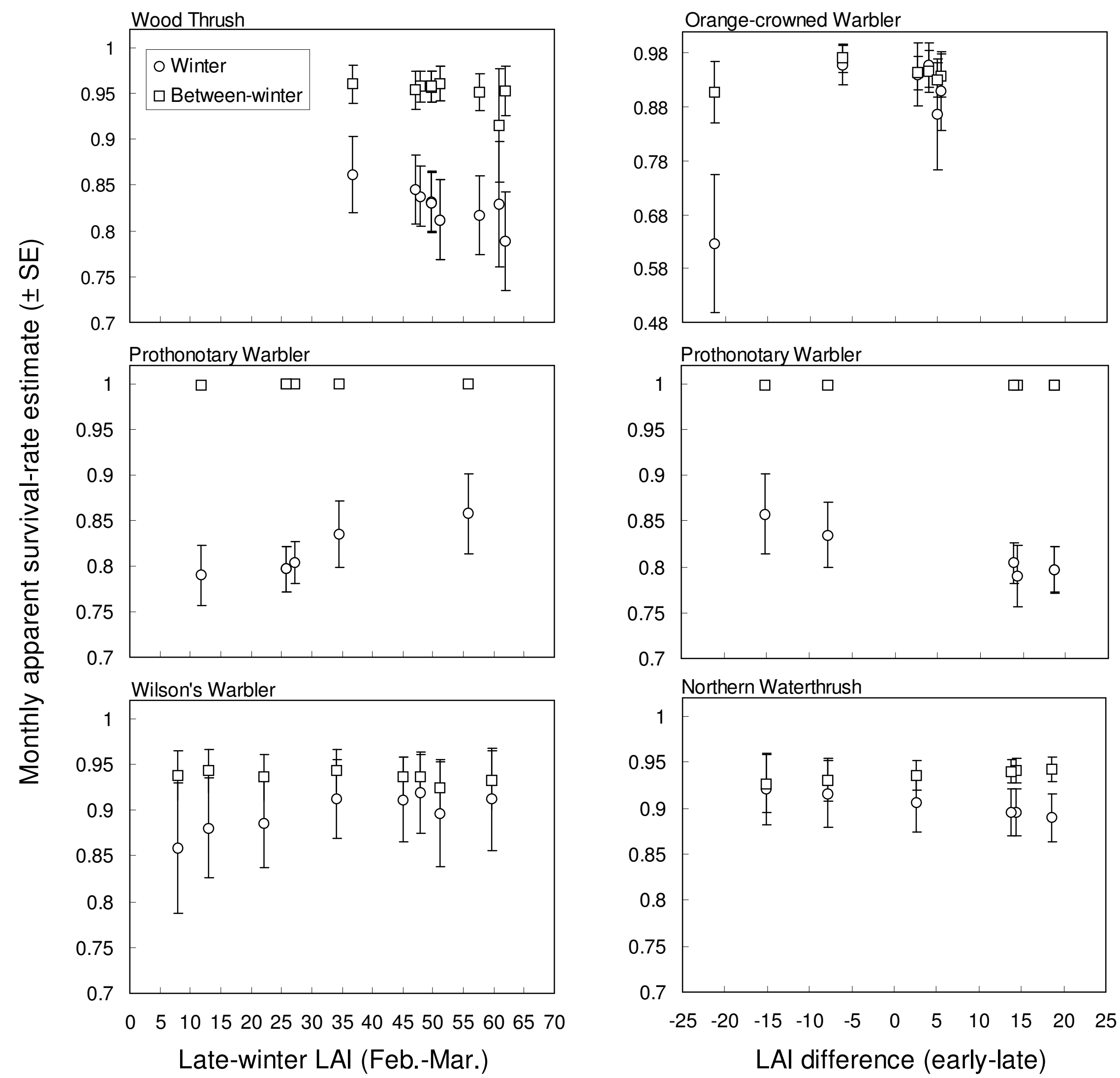

Figure 6. Model-averaged monthly winter apparent survival-rate estimates ($\hat{\phi}_w$) and between-winter apparent survival-rate estimates in relation to LAI variables (late-winter LAI [lai.fm] and LAI difference [lai.diff]) for species showing evidence of a relationship with these variables (see Table 5). Estimates are for individual MoSI stations that were operated for ≥ 2 winters between 2002-03 and 2006-07 with ≥ 5 individuals banded per winter and ≥ 5 between-pulse recaptures.

To investigate possible causes for the low winter apparent survival-rate estimate for Orange-crowned Warbler at the NEVA station, we examined patterns in capture rate for this species over the 2006-07 winter season (the only winter with 5 pulses of data) and the mean change in LAI surrounding this site from early to late winter (Fig. 7). There was an exponential increase in captures at this site in late winter (Fig. 7A; this increase was also evident in the three pulses of data collected there during the 2005-06 season); this increase coincided with an increase in leaf area at this site (and in the nearby landscape) compared to the larger region over which leaf area largely declined (Fig. 7B). No other site showed this large increase in leaf area or any discernable pattern in capture rate over the season.

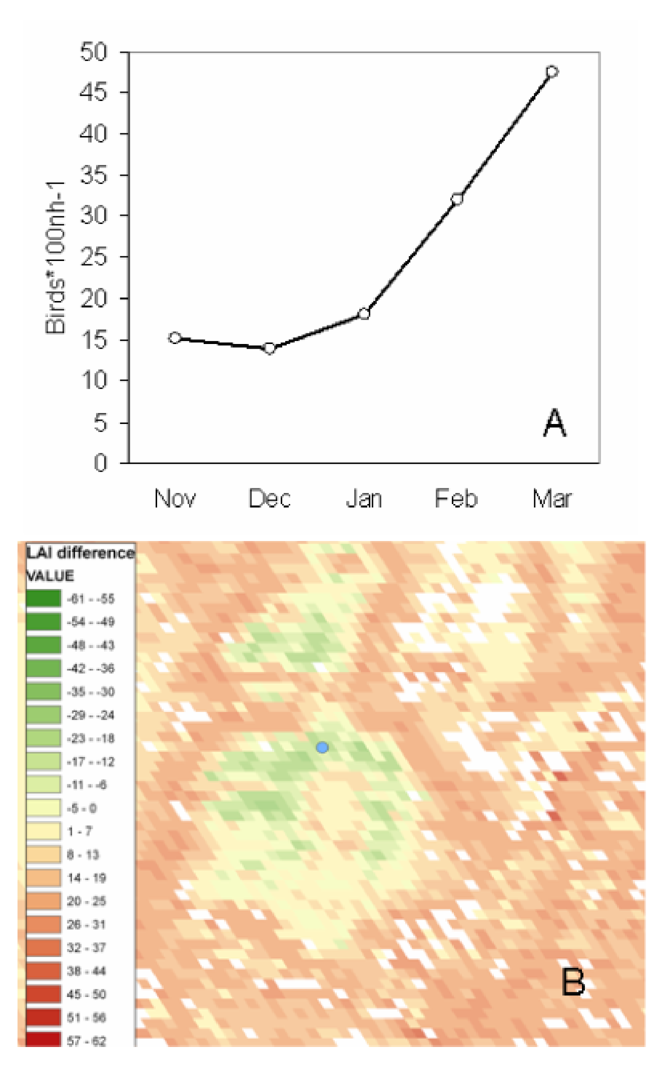

Figure 7. (A) Capture rates over the 2006-07 winter season at the NEVA MoSI station in fir-pine forest in Jalisco, Mexico. (B) Mean difference in leaf area index (LAI) within 1-km^2 blocks between early and late winter at this site (blue dot) and the surrounding landscape.

Two species, Wood Thrush and Ovenbird, showed significant differences in late-winter LAI values between sites where individuals were banded but never recaptured between pulses and sites where site fidelity or site persistence was documented (Fig. 8). In both cases, LAI was higher at sites where recaptures were recorded than at sites where no recaptures were recorded. None of the six species showed significant differences in the difference between early-winter and late-winter LAI between sites with, and sites without, between-pulse recaptures. Although LAI values were correlated with spatial gradients, we did not find evidence of differences in latitude, longitude, or elevation between sites exhibiting site fidelity and sites for which recaptures were not recorded (ANOVA *P*-values >>0.05).

Discussion

Results of the 5-yr NMBCA-supported MoSI pilot project show that through cooperative international participation in broad-scale monitoring, important insights into factors that affect winter habitat quality for Neotropical migratory birds (NTMBs) can be achieved. Until the initiation of this effort, our understanding of the ecology of NTMBs in winter has largely been limited to intensive efforts focused on single species or sites. We show here that two metrics – body condition and apparent survival rates – can vary tremendously from site-to-site and from year-to-year, and that by identifying patterns in this variation we can gain insight into habitat quality. We emphasize that, for many species, these two metrics, body condition and apparent survival rate, likely provide more reliable indicators of habitat quality than are provided by other commonly used metrics, such as presence/absence or relative density, which have been shown to often provide misleading indicators of habitat quality (Van Horne 1983).

Detailed local habitat data were not available for many stations that operated as part of the MoSI pilot program (primarily stations operated prior to the 2004-05 season). Thus, we focused our habitat-modeling efforts on two coarse-scale habitat variables that allowed inclusion of the largest numbers of stations in analyses: late-winter leaf area index (LAI) and difference in LAI between early and late winter. Relationships between LAI and local canopy cover for those stations for which we had local habitat data suggested that LAI accurately reflects habitat characteristics at MoSI stations. An important advance that would increase the utility of remote-sensed indices of habitat such as LAI to land managers would be to identify additional quantitative measurements that link structural (and floristic) vegetation features (on the ground) to LAI values.

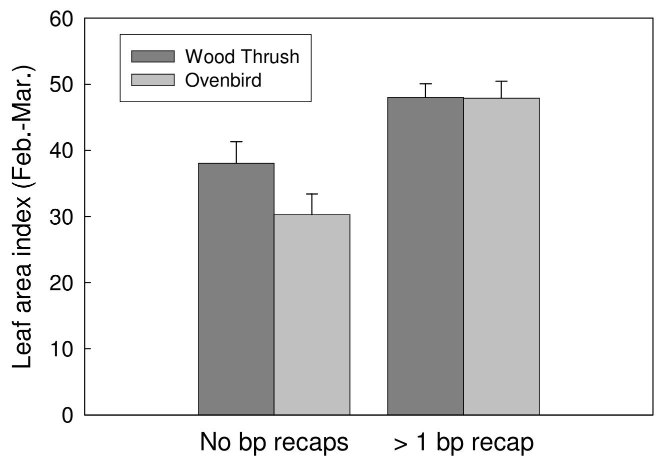

Figure 8. Difference in late-winter leaf area index (1-km^2 late-winter values + SE) between stations where site persistence (within-year) or site-fidelity (between-year) was documented (> 1 between-pulse recapture recorded) and stations where between-pulse recaptures were never recorded for Wood Thrush ($F_{1,45}$ = 6.90, P = 0.01) and Ovenbird ($F_{1,67}$ = 7.13, P < 0.01). Tests were from one-way ANOVAs weighted by no. pulses of operation.

Our results suggest that NTMBs respond to vegetation cover and volume (as reflected in LAI values). Body condition increased for six species and decreased for seven species in relation to increasing late-winter LAI. Although in some cases, the direction of the relationship was logical given typical habitat associations of the species (e.g., species such as Worm-eating Warbler [Hanners and Patton 1998] that are affiliated with forested habitats having higher body condition at higher levels of LAI), in other cases inference regarding the direction of the relationship was not obvious (e.g., open-country/edge species such as Indigo bunting [Payne 2006] having higher body condition at high LAI values). Unintuitive results such as this could simply be a reflection of the range of LAI values sampled by the network of MoSI stations rather than the range of LAI values used by the species. Regardless of the response to specific LAI levels, body condition of most (13/16) species that showed significant relationships with early-to-late-winter LAI difference declined as late-winter LAI declined. Furthermore, two of the three species that showed higher body condition at higher levels of leaf loss (Yellow Warbler and Painted Bunting) were species that also showed a positive relationship with late-winter LAI, suggesting that overall higher leaf area was better for these species. For the third species that showed higher body condition at higher levels of leaf loss, Swainson's Thrush, the relationship seemed to be driven largely by low body condition at one station that gained leaf area over the winter. This station, (SVNH in El Salvador) was a shade coffee plantation, for which increase in leaf area may not have been as reliable an indicator of habitat quality as it may be for more natural habitats.

The body condition results combined with analyses of apparent survival (particularly winter survival) suggest that most migrants are adversely affected (based on body condition and winter apparent survival) by high levels of leaf loss, at least in tropical deciduous forests and other habitats that show severe desiccation over the winter period. Indeed, tropical deciduous forests reach minimum levels of leafing and associated insect flushes late in the dry season (van Shaik et al. 1993). In regions dominated by such habitats, pockets of resource-rich patches that become 'greener' (i.e., for which leaf area increases) over the winter could provide important refugia for overwintering birds. For example, very large numbers of Orange-crowned Warblers were captured at the MoSI station on Nevado de Colima (NEVA) in high elevation fir-pine forest and associated scrub habitats. The low winter apparent survival rate of Orange-crowned Warblers at this site compared to the other five stations for which we estimated survival, suggest low habitat quality. Yet, this site became much greener over the winter period, and this greening appears to have attracted large numbers of birds in late winter when most habitats in the region would have been experiencing peak drought. This capture pattern was unique among MoSI stations for which we have data for this species.

In contrast to tropical deciduous forests and similar water-limited habitats, increases in flowering, fruiting, and insect abundance can occur during the dry season in habitats that are not water-limited (Janzen 1973, Myneni et al. 2007). Although change in leaf area may not be the best predictor of habitat quality for many species in these habitats, some species (e.g., Wood Thrush and Ovenbird) may, however, need relatively high levels of leaf area (LAI ~50 based on Fig. 7) to exhibit site persistence or site fidelity. Some patchiness (e.g., gaps, edges) may still be beneficial, however, as suggested by declines in Wood Thrush winter apparent survival-rate estimates at the highest values of LAI. Finally, although desiccation over the winter period may not currently be an important factor limiting birds that overwinter in wet habitats, climate models predict substantial declines in rainfall across the region over the next century (particularly during the wet season in Central America and dry season in west Mexico; IPCC 2007). A more complete understanding of winter habitat needs of migratory birds in the face of climate change will be critical for their effective conservation. Long-term monitoring aimed at better understanding responses of birds to weather and habitat variation is clearly warranted.

Despite evidence of late-winter LAI or LAI difference affecting body condition for many species, these habitat effects did not appear to be important (with the exception of Yellow Warbler) in explaining differences in body weight of individual birds captured on multiple occasions in a season. It may be that dominant birds that persist at a site for extended periods are able to successfully defend winter territories and secure sufficient resources to maintain body condition through periods of diminished resources (Rappole 1995). Subordinate birds (e.g., females, young birds) may be more severely affected by changes in habitat quality over the winter period. Additional monitoring data and modeling could shed light on this hypothesis by enabling identification of age- and sex-specific responses of body condition and survival to habitat.

In addition to providing insights into NTMB winter habitat quality, the MoSI program has been successful on many other fronts. For example, MoSI has contributed thousands of feather samples for genetic and stable isotope analyses of migratory connectivity, and wing-chord data from MoSI are also lending insight into links between breeding and wintering populations. Additionally, the MoSI program has generated, and will continue to generate, substantial capacity building amongst partners in the northern Neotropics. This capacity building has come directly through funding and provision of materials, as well as through the many training workshops (16 in six countries) that have been provided by IBP since the initiation of the program in 2002. This support has enabled many cooperators to partner with other projects and to initiate year-round monitoring efforts aimed at describing patterns of abundance, productivity, survival, and seasonal movements of resident bird species within the various partnering countries. Despite these successes, gaps in data collection at participating sites (within and between years), as well of the dearth of stations in important areas of wintering ranges of target species, highlight the need for a larger and more consistent funding base to ensure continuation and advancement of the program.

Habitat Conservation and Management Strategies

Our results suggest that for many species of NTMB, site-specific management strategies that protect areas that are either resilient to drought (e.g., riparian zones, mangroves, and other wetlands) or that are in regions of the Neotropics that do not experience significant desiccation over the winter will help conserve NTMBs and reverse trends of declining NTMB species. Conditions that promote winter survival can be managed for in these areas and prioritized for conservation. For example, the relationship that we identified between LAI values and canopy cover at MoSI stations and the mean LAI values for Wood Thrush and Ovenbird needed to ensure site persistence suggest that relatively high levels of forest cover (> 50%) at MoSI stations are needed to ensure site persistence and site fidelity. Yet some patchiness (edge, forest openings) at the station and landscape (1-km^2) scales may still be beneficial (at least for Wood Thrush, as suggested by declines in survival at high late-season LAI values). Additional data will be needed to identify specific structural and floristic characteristics that result in optimal overwintering landscapes for these forest birds.

As we have highlighted in this report, many NTMB species overwinter in regions dominated by habitats that experience desiccation over the wintering period. Although such habitats might provide high quality habitat early in the winter (it is uncertain from analyses presented here that this is the case), the quality of these habitats clearly deteriorates by late winter. A possible viable strategy for birds in these regions may be to move to habitats with ephemeral but abundant resources during late winter (as suggested by the Orange-crowned Warbler example presented here). If this situation (one in which multiple sites are used regularly) proves to be broadly applicable, a much broader scale (i.e., non-site-specific) approach to the conservation of winter bird habitats will be needed. Such an approach would necessitate the conservation of multiple habitats across large spatial extents or elevation gradients. Identification of key conservation areas will clearly require a coordinated network of monitoring sites, such as that represented by the MoSI program. This network should include key long-term MoSI stations, as well as new stations that target specific habitats or habitat gradients. Additionally, identification of local scale habitat metrics that are better linked to remote-sensed habitat data, such as LAI, will be important for providing more specific management recommendations to resource management agencies charged with conserving NTMB species on their wintering grounds.

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Appendix 1. Summary of 127 stations operated as part of the Monitoreo de Sobrevivencia Invernal (MoSI) program during the winters of 2002-03 through 2006-07 for which data have been received and included in this report. Stations are grouped by country and sorted by region[1], latitude, and longitude (from northwest to southeast).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico												
ELDO	El Doctor	Osvel Hinojosa Huerta	Pronatura Noroeste - Sonora	Mesquite forest, salt pine, & salt marsh	3	31.9619/-114.7561	PLM	–	4	–	–	–
NAVO	Navopatia	Adam Hannuksela	Alamos Wildlands	Mature thorn scrub with columnar cactus and deciduous trees/shrubs. Borders mangrove/salt scrub	1	26.4042/-109.2347	PLM	–	–	–	–	5
MOLA	Monte Largo	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Primary forest/thorn forest	1	25.0825/-108.0761	PLM	–	–	2	2	2
PATO	Patolandia	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Xerophytic matorral, mangroves	1	25.0261/-107.9867	PLM	2	2	–	–	–
JOLO	Mojolo Pronatura	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Riparian vegetation, second growth; borders town & low forest	63	24.9373/-107.4397	PLM	–	–	–	–	2
MOJO	Río Humaya	Alfredo Leal Sandoval	Conservación, Investigación y Servicios Ambientales. A. C	Riparian vegetaion, second growth and pasture; borders town and river	44	24.8239/-107.3847	PLM	–	–	–	–	5
BCLN	Jardin Botanico, Culiacán	Lydia Lozano Angulo	Conservación , Investigación y Servicios ambientales A.C.	Botanical garden/ artificial habitats	44	24.8239/-107.3847	PLM	–	–	–	–	5
RCLN	Rio Culiacan	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Gallery and secondary forest	63	24.8097/-107.3914	PLM	–	–	2	–	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
PICH	Pichihuila 2	Samuel Lizarraga Ortega	Independent biologist	Dry scrub, mangrove	1	24.4275/-107.4306	PLM	2	2	–	3	2
COSA	Mineral de Nuestra Senora de l	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Dry forest, gallery forest	600	24.4028/-106.6083	PLM	–	2	–	–	–
CETA	Playa Ceuta	Alfredo Leal Sandoval	Conservación, Investigación y Servicios Ambientales, A. C	Thorn forest/matorral/mangrove near old salt pond & agriculture	0	23.9164/-106.9706	PLM	–	–	–	–	5
DIMA	Estacion Dimas	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Primary and gallery forest near river	5	23.7086/-106.7872	PLM	–	–	2	–	–
PALM	El palmito	Marco Antonio Gonzales Bernal	Pronatura Noroeste Mar de Cortez	Pine-oak and pine forests	1200	23.5861/-105.8436	PLM	–	2	1	3	2
EBC1	Estación Biológica Chamela Uno	Jorge H.Vega Rivera	Instituto de Biología, UNAM	Primary forest	200	19.5083/-105.0417	PLM	–	–	–	4	4
SEME	Ciuxmala 1, Selva Mediana	David Valencia Vilchas	Fundación Ecológica de Cuixmala, A.	Medium and low forest	20	19.4183/-104.9753	PLM	–	–	5	5	5
RIPA	Ciuxmala 2, Riaprian	David Valencia Vilchas	Fundación Ecológica de Cuixmala, A.	Riparian vegetation surrounded by low forest and cereal cultivation	10	19.4086/-104.9608	PLM	–	–	5	5	5
GUEL	Guelavia Marsh	Ramiro Aragon	Independent biologist	Thorn scrub, riparian, and marsh	1650	16.9700/-96.5408	PLM	–	5	–	–	–
BOGA	Jardin Etnobotanico de Oaxaca	Manuel Grosselet	CONANP	Botanical garden	1550	16.9200/-96.9400	PLM	4	5	5	5	5

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
HUAT	Parque Nacional Huatulco, Caca	Manuel Grosselet	CONANP	Dry forest	19	15.7336/-96.1633	PLM	2	–	–	–	–
PHER	Estacion Piedra Herrada	Jorge Nocedal Moreno	Ctr Reg Durango, Inst. de Ecología	Pine-oak forest	2500	23.3872/-104.2464	HIM	–	4	5	–	–
SJPF	San José Primary Forest	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Mature pine-oak forest	1300	23.0475/-99.2231	HIM	–	–	–	3	3
SJSG	San José Secondary Growth	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Patchy second-growth/sweet-gum woodland	1250	23.0444/-99.2172	HIM	–	–	–	3	3
NEVA	Los Barbechos del Floripondio	Alfonzo Langle Flores	Independent Researcher	Fir, pine, matorral	2980	19.6155/-103.6197	HIM	–	–	–	3	5
MAPL	Maple 2	Ana Maria Delgadillo Vasquez	Ases. y Serv. Profes. Ornitorrinco	Maple forest	1900	20.2289/-104.7594	HIM	2	3	3	–	–
MESO	Bosque Mesofilo	Ana Maria Delgadillo Vasquez	Ases. y Serv. Profes. Ornitorrinco	Montane cloud forest	1900	20.2125/-104.7583	HIM	2	3	3	–	–
CANA	Cañada	Elvia Joséfina Jiménez Fernández	Sociedad Mexicana de Ornitologia AC	Pine-oak forest	2600	20.0833/-98.2767	HIM	–	4	–	–	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
TECO	Tecomulco	Elvia Joséfina Jiménez Fernández	Sociedad Mexicana de Ornitologia AC	Disturbed dry forest, xerophytic vegetation (opuntias, agaves), juniper, oak	2550	19.8850/-98.3947	HIM	–	4	–	–	–
ARCO	Parque Estatal Sierra de Tepot	Atahualpa Eduardo de Sucre Medrano	Facultad Estudios Sup-Iztacala-UNAM	Oak forest, crassicaule matorral, and pasture	2500	19.7500/-99.3042	HIM	–	–	3	4	5
RPED	Reserva del Pedregal de San An	Marco Antonio Gurrola Hidalgo	Instituto de Biologia UNAM	Natural matorral within urban zone	2320	19.3131/-99.1786	HIM	–	4	3	3	4
JBOT	Jardin Botanico Exterior, UNAM	Marco Antonio Gurrola Hidalgo	Instituto de Biologia UNAM	Botanical garden, exotic vegetation	2320	19.3083/-99.1883	HIM	2	4	4	4	4
PNDL	Parque Nacional Desierto de lo	Sofia Arenas Castillo	Parque Nacional Desierto de los Leones	Mixed forest (pine, oak y oyamel fir) & oyamel fir forest	3100	19.2833/-99.3000	HIM	–	–	3	3	–
CASA	Cortafuegos de CORENA 2	JorgeAngel Cruz Sánchez	Pronatura A.C.	Xerophytic matorral & oak forest on outskirts of Mexico City	2650	19.2667/-99.2000	HIM	2	–	–	–	–
ZOQ1	Zoquiapan 1	José Luis Alcántara Carbajal	Colegio de Postgraduados - IREGEP	Regenerating Pine-oak forest	3400	19.2592/-98.6681	HIM	–	4	–	–	–
ROCA	Roca volcanica y cañada	José LuisPeña Ramirez	Universidad Autonoma Metropolitana Unidad Xochimilco	Xerophytic matorral & oak forest on outskirts of Mexico City	2650	19.2508/-99.1978	HIM	–	3	4	5	3

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
COCO	Cortafuegos de CORENA	José Luís Peña Ramirez	Universidad Autonoma Metropolitana Unidad Xochimilco	Xerophytic matorral & oak forest on outskirts of Mexico City	2650	19.2333/-99.25	HIM	2	3	–	–	3
LAGU	Laguna Zempoala	Claudia A. Romo de Vivar Alvarez	Lab de Ornitología del CIB-UAEM	Fir-pine forest	2700	19.0286/-99.2783	HIM	–	4	–	–	–
TRAN	Trancas	Claudia A. Romo de Vivar Alvarez	Lab de Ornitología del CIB-UAEM	Pasture/grassland with fir-pine forest	2700	19.0286/-99.2783	HIM	–	4	–	–	–
SAC1	San Andres de la Cal Uno	Claudia A. Romo de Vivar Alvarez	Lab de Ornitología del CIB-UAEM	Disturbed tropical dry forest	1470	18.9600/-99.1028	HIM	2	5	5	3	2
SAC2	San Andres de la Cal Dos	Claudia A. Romo de Vivar Alvarez	Lab de Ornitología del CIB-UAEM	Disturbed tropical dry forest	1470	18.9600/-99.1028	HIM	2	5	–	4	2
YAVE	Yavesia Shora	Ramiro Aragon	Independent biologist	Riparian woodland, scrub	2050	17.2431/-96.4311	HIM	–	4	–	–	–
CAMP	El Capamento	Ramiro Aragon	Independent biologist	Pine-oak forest	2950	17.2206/-96.6561	HIM	2	5	–	–	–
TERR	El Terrero	Ramiro Aragon	Independent biologist	Pine-oak forest	2950	17.1744/-96.6842	HIM	–	4	–	–	–
LLGR	Llano Grande	Ramiro Aragon	Independent biologist	Pine-oak forest	3000	17.1431/-96.4089	HIM	2	3	–	–	–
CARR	Carricitos	Patricia Escalante Pliego	Instituto de Biología, UNAM, Ciudad		.		HIM	1	–	–	–	–
ETLA	Etla Viguera	Manuel Grosselet	CONANP	Woodland/edge	1691	17.1439/-96.7439	HIM	3	–	–	–	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
GFPF	Gomez Farias Primary Forest	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Mature (old second growth) forest	250	23.0853/-99.1639	ALM	–	–	–	3	3
ACSG	Alta Cima Secondary Growth	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Old-field, shrubland, pasture	940	23.0639/-99.1969	ALM	–	–	–	3	3
ACPF	Alta Cima Primary Forest	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Mixed hardwood woodland/forest	960	23.0553/-99.1853	ALM	–	–	–	3	3
GFSG	Gomez Farias Secondary Growth	Hector Arturo Garza Torres	Instituto de Ecología y Alimentos	Second-growth woodland, shrubland, & edge with small agricultural plots	310	23.0494/-99.1519	ALM	–	–	–	3	3
SUI1	Suiza 1	Hiram Gayosso Faisal	Independent biologist	Dry forest between ranch & farmland	4	21.2572/-89.0628	ALM	–	–	–	4	–
SUI2	Suiza 2	Hiram Gayosso Faisal	Independent biologist	Mangrove forest	4	21.3667/-88.9833	ALM	–	–	–	4	–
PASO	Paso Salinas	Jesus Eduardo Martinez Leyva	Pronatura A.C. Veracruz	Secondary and low forest, dominated by fruit and palm trees	6	18.9156/-95.9531	PLM	–	–	3	–	3
CABU	Cansaburro	Angelina Ruiz Sanchez	Pronatura Veracruz	Secondary forest & areas with native vegetation	20	19.5667/-96.3833	ALM	–	–	3	3	3
ECOL	Parque Ecología Clarvijero	Jesus Eduardo Martinez Leyva	Pronatura A.C. Veracruz	Cloud forest, second. forest, abandoned rustic coffee plant.	1280	19.5181/-96.9342	ALM	–	–	–	–	2
TUX3	Est. de Biología Tropical	David Curiel Cante	Instituto de Biología, UNAM	Mature & secondary rain forests	30	18.6422/-95.0911	ALM	–	3	–	3	1

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Mexico (continued)												
TUX4	Est. de Biología Tropical	David Curiel Cante	Instituto de Biología, UNAM	Mature & secondary rain forests	30	18.6361/-95.0903	ALM	–	3	–	3	–
TUX1	Est. de Biología Tropical	David Curiel Cante	Instituto de Biología, UNAM	Mature & secondary rain forests	300	18.5869/-95.0772	ALM	–	3	–	3	1
TUX2	Est. de Biología Tropical	David Curiel Cante	Instituto de Biología, UNAM	Mature & secondary rain forests	300	18.5811/-95.0722	ALM	–	3	–	3	1
TUX5	Los Tuxtlas 5	David Curiel Cante	Instituto de Biología, UNAM	Mature & secondary rain forests	83	18.6156/ -95.0935	ALM	–	–	–	1	–
CATA	Laguna de Catazaja	Esteban Pineda Diez de Bonilla	Inst. de Hist. Nat. y Ecol. (IHNE)	Lowland wet forest, secondary vegetation	20	17.7253/-92.0111	ALM	–	2	–	–	–
IRLA	Finca Irlanda	Manuel Grosselet	CONANP	Shade coffee plantation	940		LCA	1	–	–	–	–
PSJB	Centro Educativo San José Boco	Esteban Pineda Diez de Bonilla	Inst. de Hist. Nat. y Ecol. (IHNE)	Secondary cloud forest, secondary oak forest	2240	16.7225/-92.7119	HCA	–	–	3	3	3
Belize												
RCPC	Runaway Creek Nature Preserve	Victoria Piaskowski	Birds without Borders - Aves Sin Fronteras, Found. for Wildlife	Riverine Forest on the Sibun River	38	17.3578/-88.4781	ALM	4	4	–	1	–
RCPB	Runaway Creek Nature Preserve	Victoria Piaskowski	Birds without Borders - Aves Sin Fronteras, Found. for Wildlife	Transition zone from karst hill forest to seasonal wetland	15	17.3136/-88.4606	ALM	4	3	–	1	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Belize (continued)												
CHAA	Chaa Creek	Victoria Piaskowski	Birds without Borders - Aves Sin Fronteras, Found. for Wildlife	Secondary Broadleaf Forest	80	17.1133/-89.0761	ALM	3	4	–	–	–
Guatemala												
ARAN	Carboneras 2	Alexis Cerezo	FUNDAECO	Primary tropical forest	450	15.6389/-88.8694	LCA	–	5	4	5	2
CARB	Carboneras 3	Alexis Cerezo	FUNDAECO	Primary tropical forest	400	15.6389/-88.8694	LCA	–	4	4	5	2
RANC	Carboneras 1	Alexis Cerezo	FUNDAECO	Primary tropical forest	450	15.6389/-88.8694	LCA	–	5	4	5	2
RMMO	Reserva Municipal Morales	Alexis Cerezo	FUNDAECO	Primary tropical forest	400	15.6389/-88.8167	LCA	–	4	–	–	–
MCHI	Montana Chiclera	Alexis Cerezo	FUNDAECO	Primary tropical forest	200	15.5219/-88.8619	LCA	–	–	4	5	2
BTCM	Navajoa	Alexis Cerezo	FUNDAECO	Primary tropical forest	37	15.4833/-88.8167	LCA	3	–	–	–	–
LATO	Las Torres	Alexis Cerezo	FUNDAECO	Primary tropical forest	37	15.4833/-88.8167	LCA	2	–	–	–	–
PUMA	Punta de Manabique	Alexis Cerezo	FUNDAECO	Primary tropical forest	37	15.4833/-88.8167	LCA	3	–	–	–	–
El Salvador												
SVIM	Parque Nacional El Imposible	Leticia Andino	SalvaNatura	Secondary forest	700	13.8231/-89.9433	LCA	–	5	4	5	5
SVMC	Parque Nacional Montecristo	Leticia Andino	SalvaNatura	Pine-oak forest	1950	14.4025/-89.3603	HCA	–	5	–	–	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
El Salvador (continued)												
SVMO	Parque Nacional Montecristo II	Leticia Andino	SalvaNatura	Pine-oak forest	1800	14.3919/-89.3771	HCA	–	–	5	5	5
SVLV	Los Volcanes	Leticia Andino	SalvaNatura	Secondary forest bordering cypress plantation	1800	13.9433/-89.6167	HCA	–	5	5	2	4
SVNH	Finca Nuevas Horizontes	Leticia Andino	SalvaNatura	Shade coffee plantation	1250	13.8211/-89.6531	HCA	–	5	5	5	5
SVMN		Leticia Andino	SalvaNatura	Pine-oak forest	2186	14.4109/-89.3682	HCA	–	–	–	5	5
Honduras												
PIBO	Pico Bonito	David Anderson	Museum of Natural Science, Louisiana State University	Primary rain forest	323	15.7206/-86.7389	LCA	–	–	–	3	–
LPCV	Estación de Monitoreo P. N. Cerro Azul Meambar	Johana Mejia	Universidad Nacional Autónoma de Honduras	Secondary forest	720	14.7933/-87.9522	LCA	1	3	–	–	–
Nicaragua												
MSB1	Mayanga Sauni Bu Bosque	Carlos Gonzales	BOSAWAS Biosphere Reserve	Mature primary forest	236	14.1325/-85.0708	LCA	–	–	–	3	5
CHOC	Chocoyero - El Brujo	Edgar Castañeda Mendoza	Fauna & Flora International	Riparian premontane forest	350	11.9789/-86.2628	LCA	2	5	4	4	4

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Nicaragua (continued)												
QUEL	Quelantero	Freddy Ramírez Muñoz	Amigos de la Tierra	Secondary forest	125	11.9269/-86.4939	LCA	–	–	–	–	4
CA01	Cafetal de Sombra	José Manuel Zolotoff-Pallais	Fundación Cocibolca	Shade coffee plantation	350	11.8336/-85.9792	LCA	2	4	4	4	4
BN01	Bosque Nuboso	José Manuel Zolotoff-Pallais	Fundación Cocibolca	Tropical cloud forest	350	11.8322/-86.0083	LCA	2	4	4	4	4
CHAC	Chacocente	Salvadora Morales Velásquez	Fauna y Flora International	Mature riparian forest surrounded by dry forest	100	11.5269/-86.1681	LCA	–	–	–	3	–
ESVE	Esperanza Verde	Osmar Arróliga	Fund. Amigos del Río San Juan		0	11.0864/-84.7361	LCA	–	2	2	–	4
PUNU	Pueblo Nuevo	Osmar Arróliga	Fund. Amigos del Río San Juan	Agricultural system	350	11.0633/-85.0908	LCA	–	2	–	–	–
PAPA	Papaturro	Osmar Arróliga	Fund. Amigos del Río San Juan	Abandoned cacao plantation	350	11.0264/-85.0592	LCA	1	5	3	–	–
BOSQ	Bosque Jaguar	Marvin Torres	Alianza para las Areas Silvestres	Tropical cloud forest	1300	13.2408/-86.0564	HCA	2	3	5	5	4
CAFE	Cafetál con Bordes de Bosque	Marvin Torres	Alianza para las Areas Silvestres	Coffee plantation with some shade	1300	13.2325/-86.0526	HCA	2	3	5	5	4
Costa Rica												
ESNA	Estero Naranjo	John M. Woodcock	Independent biologist	Early successional dry Southern Pacific mangroves	1	10.7833/-85.6667	LCA	–	4	5	4	4

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Costa Rica (continued)												
ESIG	Estero Iguanita	John M. Woodcock	Independent biologist	Southern dry Pacific coast mangroves	2	10.6167/-85.6167	LCA	–	–	4	5	5
PV01	Palo Verde	María Alejandra Maglianesi	Instituto Internacional en Conservación y Manejo de Vida Silvestre	Tropical dry forest	500	10.3527/-85.3592	LCA	–	–	–	–	3
REFR	Refugio Ecológico Finca Rodriguez	Debra Hamilton	Fundación Conservación Costaricense	Mixed: Primary & secondary forest & coffee plantation	1275	10.3203/-84.8364	LCA	–	3	–	4	2
ESTA	Estero Tamarindo	John M. Woodcock	Independent biologist	Southern dry Pacific mangroves	2	10.3167/-85.8333	LCA	–	4	5	5	5
PLGR	Playa Grande	John M. Woodcock	Independent biologist	Central American dry forest	5	10.3167/-85.8333	LCA	–	4	5	5	4
CURU	Refugio Nacional de Vida Silvestre	Alejandro Solano Ugalde	Independent biologist	Southern dry Pacific coast mangroves	50	9.7833/-84.9167	LCA	–	4	3	–	–
CUII		Jennifer McNicoll	York University	Mature and second-growth forest	0	9.4167/-83.5833	LCA	–	–	–	1	–
TAHO	Sendero Tajo	Jennifer McNicoll	York University	Mid- to upper-elevation rainforest, pasture	1276	9.3917/-83.5994	LCA	–	–	–	3	–
COOP	Finca Granotico de Coopeagri	Jennifer McNicoll	York University	Mixed agricultural	1019	9.3694/-83.6153	LCA	–	–	–	2	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Costa Rica (continued)												
MARV	Finca Cafetal de sombra de Mar	Jennifer McNicoll	York University	Mixed agricultural	700	9.3519/-83.6325	LCA	–	–	–	3	–
MONT	Finca en Monte Carlo	Jennifer McNicoll	York University	Coffee, sugar, forest	900	9.3431/-83.6094	LCA	–	–	–	3	–
CUSI	Los Cusingos I	Jennifer McNicoll	York University	Mature forest	788	9.3361/-83.6247	LCA	–	–	–	5	–
HERN	La finca de Hernan Solano	Jennifer McNicoll	York University	Abandoned coffee, monoculture canopy	947	9.3356/-83.5900	LCA	–	–	–	2	–
LAES	La Escondida	Jennifer McNicoll	York University	Shade coffee	748	9.3269/-83.6247	LCA	–	–	–	3	–
SAMA	Cafetal de menos sombra en San	Jennifer McNicoll	York University	Low-shade coffee, forest edge, pasture	900	9.3208/-83.5903	LCA	–	–	–	3	–
LASC	Las Caletas	Doug Collister	Calgary Bird Banding Society	Second growth adjacent to primary forest	50	8.6833/-83.6333	LCA	–	–	–	3	–
VIOL	Violin	Doug Collister	Calgary BBS	Mangroves			LCA	–	–	–	2	–
Panama												
PNCH	Campo Chagres, Parque Nacional	Belkys Jimenez	Independent biologist	Primary & secondary forests	150	9.3500/-79.4667	LCA	–	3	3	4	4
ESDV	Finca El Suspiro del Valle	Chelina Batista	ACHIOTE	Shade coffee plantation	20	9.2314/-80.0283	LCA	–	2	5	3	3
PNSA	P.N. Soberiana - Av	Chelina Batista	ACHIOTE	Mature & secondary tropical rain forest	90	9.1303/-79.7200	LCA	–	–	–	3	3

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
Jamaica												
WRC1	Windsor Res. Centre 1	Susan Koenig	Windsor Research Centre	Organic coffee/citrus farm, regenerating wet limestone forest	100	18.3564/-77.6469	CAR	–	4	5	5	–
WRC2	Windsor Res. Centre 2	Susan Koenig	Windsor Research Centre	Regenerating pasture adjacent to coffee & regenerating edge	100	18.3564/-77.6469	CAR	–	3	5	5	–
WRC3	Windsor Research Centre 3	Dr. SusanKoenig	Windsor Research Centre		0		CAR	–	–	5	–	–
Dominican Republic												
GUAR	Guaraguao	Jorge Luis Brocca	Sociedad Ornitología de la Hispaniola	Coastal forest on karst soil	5	18.3278/-68.8028	CAR	–	–	–	2	–
LAOV	Laguna de Oviedo	Jorge Luis Brocca	Sociedad Ornitología de la Hispaniola	Edge between mangrove & dry forest	5	17.8100/-71.3364	CAR	–	–	–	2	–
FOPA	Fondo Paradi	Jorge Luis Brocca	Sociedad Ornitología de la Hispaniola	Primary karst dry forest	175	17.7956/-71.4681	CAR	–	–	–	2	–
French Antilles												
SCRU	St. Martin Th. Scrub Forest	Adam Brown	Envr Protect in the Caribbean -EPIC	Thorn scrub forest			CAR	3	–	–	–	–
FORE	St. Martin 2° Dry Forest	Adam Brown	Envr Protect in the Caribbean -EPIC	Secondary dry forest	205	18.0772/-63.0572	CAR	3	3	–	–	–

Appendix 1 (continued).

Station code	Station name	Station manager	Organization	Habitat	Elev (m)	Lat./Long. (°)	Reg[1]	Season[2] 03	04	05	06	07
French Antilles (continued)												
MANG	St. Martin Mangrove Site	Adam Brown	Envr Protect in the Caribbean -EPIC	Mangrove/scrub	0	18.0383/-63.1200	CAR	3	2	–	–	–
Anguilla (UK)												
ANGU	Anguilla Pilot Station	Adam Brown	Envr Protect in the Caribbean -EPIC				CAR	–	1	–	–	–
Trinidad												
ARSA	Aripa Savannah	Daveka Boodram	Klamath Bird Observatory				CAR	–	1	–	–	–
SIML	Simla Research Station	Daveka Boodram	Klamath Bird Observatory				CAR	–	1	–	–	–
VMR1	Victoria Mayaro Reserve 1	Daveka Boodram	Klamath Bird Observatory	Mature primary & secondary forest (some logged areas)			CAR	–	2	–	–	–
Colombia												
GAIA	Estacion de Monitoreo Gaia	Carlos José Ruiz	Asociación Calidris		1400	4.4642/-75.2200	NSA	–	–	–	–	5

[1] PLM = Pacific Lowland Mexico, HIM = Highland and Interior Mexico, ALM = Atlantic Lowland Mexico (including the Atlantic lowlands of northern Central American), LCA = Lowland Central America (including the Pacific slope of Chiapas), HCA = Highland Central America (including the highlands of Chiapas), CAR = Caribbean, NSA = Northern South America

[2] For each season, number of pulses of operation is indicated.

Appendix 2. Banding summary for migratory bird species captured as part if the Monitoreo de Sobrevivencia Invernal (MoSI) program during the winters of 2002-03 through 2006-07. We grouped Willow Flycatcher (*Empidonax traillii*) and Alder Flycatcher (*E. alnorum*) under the super-species "Traill's Flycatcher", as these species are not reliably distinguished in the hand (although some were identified based on timing/range). Similarly, we grouped Pacific-slope Flycatcher (*E. difficillis*) and Cordilleran Flycatcher (*E. occidentalis*) as "Western Flycatcher". We excluded shorebirds and hummingbirds, which are not banded at most MoSI stations. 'Station-pulses' refers to the summed number of pulses of operation for stations where the species was banded. Birds $\times$ pulse^{-1} refers to the mean number of individuals captured per pulse (i.e., number of pulse-unique captures).

Common name	Scientific name	Stations	Station -pulses	Banded	Between-pulse recaps	Birds $\times$ pulse^{-1}
Sharp-shinned Hawk	*Accipiter striatus*	4	57	10	0	0.070
Cooper's Hawk	*Accipiter cooperii*	2	28	2	0	0.071
White-winged Dove	*Zenaida asiatica*	4	70	8	0	0.057
Mourning Dove	*Zenaida macroura*	1	6	1	0	0.167
Groove-billed Ani	*Crotophaga sulcirostris*	2	37	2	0	0.054
Lesser Nighthawk	*Chordeiles acutipennis*	4	46	5	0	0.087
Whip-poor-will	*Caprimulgus vociferus*	2	35	2	0	0.057
Yellow-bellied Sapsucker	*Sphyrapicus varius*	11	96	17	2	0.115
Red-naped Sapsucker	*Sphyrapicus nuchalis*	2	13	2	0	0.154
Red-breasted Sapsucker	*Sphyrapicus ruber*	1	4	1	0	0.250
Northern Flicker	*Colaptes auratus*	1	1	1	0	1.000
Greater Pewee	*Contopus pertinax*	8	71	13	1	0.113
Eastern Wood-Pewee	*Contopus virens*	2	11	4	0	0.182
Yellow-bellied Flycatcher	*Empidonax flaviventris*	36	298	144	33	0.121
Acadian Flycatcher	*Empidonax virescens*	10	101	47	2	0.099
Traill's Flycatcher	*Empidonax alnorum/traillii*	9	113	14	0	0.080
Least Flycatcher	*Empidonax minimus*	34	314	146	26	0.108
Hammond's Flycatcher	*Empidonax hammondii*	20	168	94	18	0.119
Gray Flycatcher	*Empidonax wrightii*	7	71	10	0	0.099
Dusky Flycatcher	*Empidonax oberholseri*	22	157	107	35	0.140
Western Flycatcher	*Empidonax difficilis/occidentalis*	35	264	355	62	0.133
Eastern Phoebe	*Sayornis phoebe*	1	6	3	0	0.167
Vermilion Flycatcher	*Pyrocephalus rubinus*	7	67	15	0	0.104
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	39	371	149	16	0.105
Ash-throated Flycatcher	*Myiarchus cinerascens*	13	111	65	12	0.117
Great Crested Flycatcher	*Myiarchus crinitus*	8	64	28	3	0.125
Brown-crested Flycatcher	*Myiarchus tyrannulus*	17	208	174	57	0.082
Cassin's Kingbird	*Tyrannus vociferans*	2	32	8	0	0.063
Western Kingbird	*Tyrannus verticalis*	2	41	13	0	0.049
Loggerhead Shrike	*Lanius ludovicianus*	7	60	22	3	0.117
White-eyed Vireo	*Vireo griseus*	17	119	157	43	0.143
Bell's Vireo	*Vireo bellii*	15	98	170	47	0.153
Black-capped Vireo	*Vireo atricapilla*	3	35	5	1	0.086
Gray Vireo	*Vireo vicinior*	1	5	1	1	0.200
Yellow-throated Vireo	*Vireo flavifrons*	8	105	27	5	0.076
Plumbeous Vireo	*Vireo plumbeus*	7	87	10	2	0.080
Solitary Vireo	*Vireo (sp)*	2	15	3	0	0.133
Cassin's Vireo	*Vireo cassinii*	9	71	18	7	0.127
Blue-headed Vireo	*Vireo solitarius*	22	253	117	16	0.087

Appendix 2 continued.

Common name	Scientific name	Stations	Station -pulses	Banded	Between-pulse recaps	Birds × pulse^{-1}
Warbling Vireo	*Vireo gilvus*	20	224	223	35	0.089
Philadelphia Vireo	*Vireo philadelphicus*	12	107	25	1	0.112
Red-eyed Vireo	*Vireo olivaceus*	4	46	9	0	0.087
Tree Swallow	*Tachycineta bicolor*	1	4	1	0	0.250
Violet-green Swallow	*Tachycineta thalassina*	1	9	4	0	0.111
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	4	22	12	0	0.182
Brown Creeper	*Certhia americana*	9	53	37	11	0.170
House Wren	*Troglodytes aedon*	27	238	128	28	0.113
Winter Wren	*Troglodytes troglodytes*	1	5	1	0	0.200
Marsh Wren	*Cistothorus palustris*	1	4	1	0	0.250
Golden-crowned Kinglet	*Regulus satrapa*	2	14	2	0	0.143
Ruby-crowned Kinglet	*Regulus calendula*	31	241	589	86	0.129
Blue-gray Gnatcatcher	*Polioptila caerulea*	32	236	388	60	0.136
Eastern Bluebird	*Sialia sialis*	2	17	7	0	0.118
Western Bluebird	*Sialia mexicana*	2	13	18	8	0.154
Veery	*Catharus fuscescens*	1	19	1	0	0.053
Swainson's Thrush	*Catharus ustulatus*	55	498	715	97	0.110
Hermit Thrush	*Catharus guttatus*	30	200	156	47	0.150
Wood Thrush	*Hylocichla mustelina*	47	418	950	152	0.112
American Robin	*Turdus migratorius*	18	140	176	7	0.129
Gray Catbird	*Dumetella carolinensis*	29	236	460	32	0.123
Bendire's Thrasher	*Toxostoma bendirei*	1	9	1	0	0.111
Cedar Waxwing	*Bombycilla cedrorum*	8	117	280	0	0.068
Blue-winged Warbler	*Vermivora pinus*	9	82	18	4	0.110
Golden-winged Warbler	*Vermivora chrysoptera*	8	112	16	2	0.071
Tennessee Warbler	*Vermivora peregrina*	30	326	1252	93	0.092
Orange-crowned Warbler	*Vermivora celata*	39	285	1610	165	0.137
Nashville Warbler	*Vermivora ruficapilla*	30	248	903	86	0.121
Virginia's Warbler	*Vermivora virginiae*	5	62	62	18	0.081
Lucy's Warbler	*Vermivora luciae*	3	22	3	0	0.136
Northern Parula	*Parula americana*	10	78	39	2	0.128
Yellow Warbler	*Dendroica petechia*	32	275	621	263	0.116
Chestnut-sided Warbler	*Dendroica pensylvanica*	22	168	91	11	0.131
Magnolia Warbler	*Dendroica magnolia*	21	160	151	31	0.131
Cape May Warbler	*Dendroica tigrina*	1	2	4	0	0.500
Black-throated Blue Warbler	*Dendroica caerulescens*	8	92	102	52	0.087
Yellow-rumped Warbler	*Dendroica coronata*	31	232	742	39	0.134
Black-throated Gray Warbler	*Dendroica nigrescens*	21	200	84	4	0.105
Black-throated Green Warbler	*Dendroica virens*	20	200	76	14	0.100
Townsend's Warbler	*Dendroica townsendi*	28	266	216	17	0.105
Hermit Warbler	*Dendroica occidentalis*	10	87	39	4	0.115
Blackburnian Warbler	*Dendroica fusca*	1	5	2	0	0.200
Grace's Warbler	*Dendroica graciae*	1	6	1	0	0.167
Prairie Warbler	*Dendroica discolor*	6	32	24	2	0.188
Palm Warbler	*Dendroica palmarum*	1	4	5	0	0.250
Bay-breasted Warbler	*Dendroica castanea*	2	27	11	1	0.074
Cerulean Warbler	*Dendroica cerulea*	1	5	1	0	0.200

Appendix 2 continued.

Common name	Scientific name	Stations	Station -pulses	Banded	Between-pulse recaps	Birds × pulse^{-1}
Black-and-white Warbler	*Mniotilta varia*	74	637	377	78	0.116
American Redstart	*Setophaga ruticilla*	29	208	132	22	0.139
Prothonotary Warbler	*Protonotaria citrea*	9	116	986	414	0.078
Worm-eating Warbler	*Helmitheros vermivorum*	40	366	263	73	0.109
Swainson's Warbler	*Limnothlypis swainsonii*	5	30	14	1	0.167
Ovenbird	*Seiurus aurocapilla*	73	598	718	222	0.122
Northern Waterthrush	*Seiurus noveboracensis*	40	302	808	357	0.132
Louisiana Waterthrush	*Seiurus motacilla*	11	100	26	11	0.110
Kentucky Warbler	*Oporornis formosus*	36	300	260	100	0.120
Mourning Warbler	*Oporornis philadelphia*	11	66	47	12	0.167
MacGillivray's Warbler	*Oporornis tolmiei*	34	308	291	93	0.110
Common Yellowthroat	*Geothlypis trichas*	26	199	297	44	0.131
Hooded Warbler	*Wilsonia citrina*	34	301	274	57	0.113
Wilson's Warbler	*Wilsonia pusilla*	67	554	1155	199	0.121
Canada Warbler	*Wilsonia canadensis*	2	18	8	3	0.111
Red-faced Warbler	*Cardellina rubrifrons*	3	27	4	2	0.111
Yellow-breasted Chat	*Icteria virens*	29	205	231	50	0.141
Hepatic Tanager	*Piranga flava*	9	90	21	0	0.100
Summer Tanager	*Piranga rubra*	35	411	103	8	0.085
Scarlet Tanager	*Piranga olivacea*	6	66	6	0	0.091
Western Tanager	*Piranga ludoviciana*	15	212	258	15	0.071
Green-tailed Towhee	*Pipilo chlorurus*	9	40	95	10	0.225
Spotted Towhee	*Pipilo maculatus*	3	18	20	5	0.167
Eastern Towhee	*Pipilo erythrophthalmus*	2	23	5	2	0.087
Cassin's Sparrow	*Aimophila cassinii*	4	27	52	1	0.148
Chipping Sparrow	*Spizella passerina*	15	133	210	6	0.113
Clay-colored Sparrow	*Spizella pallida*	4	35	19	0	0.114
Brewer's Sparrow	*Spizella breweri*	5	32	181	9	0.156
Field Sparrow	*Spizella pusilla*	1	18	1	0	0.056
Black-chinned Sparrow	*Spizella atrogularis*	3	36	24	2	0.083
Vesper Sparrow	*Pooecetes gramineus*	2	14	7	0	0.143
Lark Sparrow	*Chondestes grammacus*	7	36	32	2	0.194
Savannah Sparrow	*Passerculus sandwichensis*	2	10	26	0	0.200
Grasshopper Sparrow	*Ammodramus savannarum*	1	4	5	0	0.250
Song Sparrow	*Melospiza melodia*	7	59	44	3	0.119
Lincoln's Sparrow	*Melospiza lincolnii*	27	183	317	22	0.148
Swamp Sparrow	*Melospiza georgiana*	1	9	1	0	0.111
White-crowned Sparrow	*Zonotrichia leucophrys*	5	28	202	13	0.179
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	18	211	48	1	0.085
Black-headed Grosbeak	*P. melanocephalus*	21	177	189	14	0.119
Blue Grosbeak	*Passerina caerulea*	10	98	122	2	0.102
Lazuli Bunting	*Passerina amoena*	7	54	17	0	0.130
Indigo Bunting	*Passerina cyanea*	33	372	206	6	0.089
Varied Bunting	*Passerina versicolor*	16	132	85	6	0.121
Painted Bunting	*Passerina ciris*	41	392	734	60	0.105
Dickcissel	*Spiza americana*	1	19	1	0	0.053
Red-winged Blackbird	*Agelaius phoeniceus*	2	13	27	0	0.154

Appendix 2 continued.

Common name	**Scientific name**	**Stations**	**Station -pulses**	**Banded**	**Between-pulse recaps**	**Birds × pulse^{-1}**
Western Meadowlark	*Sturnella neglecta*	1	4	2	0	0.250
Bronzed Cowbird	*Molothrus aeneus*	4	65	12	0	0.062
Brown-headed Cowbird	*Molothrus ater*	1	9	1	0	0.111
Orchard Oriole	*Icterus spurius*	7	77	75	24	0.091
Hooded Oriole	*Icterus cucullatus*	14	118	42	2	0.119
Bullock's Oriole	*Icterus bullockii*	11	112	67	3	0.098
Baltimore Oriole	*Icterus galbula*	13	200	99	18	0.065
Scott's Oriole	*Icterus parisorum*	9	102	30	0	0.088
Purple Finch	*Carpodacus purpureus*	3	19	21	0	0.158
Pine Siskin	*Carduelis pinus*	4	26	34	0	0.154
Lesser Goldfinch	*Carduelis psaltria*	16	163	114	0	0.098
Evening Grosbeak	*Coccothraustes vespertinus*	1	4	1	0	0.250

Appendix 3. Estimates of percent cover and height in four vegetation layers and indices of snag abundance in the canopy and subcanopy layers (see Methods for detail) at 40 MoSI stations.

Station code	Canopy cover (%)	Canopy height (m)	Canopy snag index	Subcanopy cover (%)	Subcanopy height (m)	Subcanopy snag index	Shrub cover (%)	Shrub height (m)	Ground cover (%)	Ground cover height (m)
NAVO	1.90	3.80	0.00	0.00	0.22	0.00	50.70	2.40	21.48	0.63
MOJO	45.00	18.50	0.50	50.00	7.50	1.00	7.50	2.00	5.00	0.25
BCLN	20.00	20.00	0.00	35.00	9.00	0.00	35.00	2.00	15.00	0.30
CETA	52.50	6.00	1.35	37.00	1.30	0.65	27.00	0.77	1.75	0.17
SEME	52.70	17.01	1.00	19.25	6.16	0.77	65.00	4.00	87.30	0.00
RIPA	37.80	10.68	0.88	54.60	5.88	0.84	45.60	2.36	44.60	0.00
SJPF	30.00	30.00	1.00	50.00	15.00	2.00	60.00	4.00	10.00	0.30
SJSG	35.50	30.00	1.00	50.00	14.45	1.00	50.00	3.50	15.50	0.25
NEVA	10.00	—	0.40	0.00	0.00	0.00	16.00	1.70	4.00	0.08
ROCA	53.50	13.60	0.75	15.50	9.15	0.80	39.00	1.58	6.38	0.32
COCO	22.00	12.80	0.20	12.00	4.80	1.00	38.00	1.60	40.50	0.32
ARCO	90.00	20.00	1.00	25.00	10.00	1.00	75.00	3.00	35.00	0.50
GFPF	20.00	25.00	1.00	70.00	12.00	2.00	40.00	3.00	20.00	0.30
ACSG	2.50	18.88	0.00	17.20	7.44	0.72	61.60	3.72	44.00	0.39
ACPF	30.00	30.00	2.00	30.00	10.00	1.00	60.00	4.00	30.00	0.40
GFSG	8.03	11.40	0.00	31.42	7.82	0.45	36.30	2.36	34.15	0.23
PASO	30.00	3.00	2.00	30.00	2.00	3.00	20.00	1.00	10.00	0.25
CABU	6.00	4.50	0.00	0.00	0.00	0.00	77.00	0.90	17.00	0.15
ECOL	35.00	30.00	2.00	20.00	10.00	2.00	20.00	4.00	20.00	0.25
ARAN	25.00	50.00	0.00	35.00	25.00	1.00	20.00	5.00	20.00	0.50
CARB	25.00	40.00	1.00	35.00	25.00	1.00	20.00	5.00	20.00	0.25
RANC	35.00	40.00	1.00	25.00	25.00	1.00	20.00	5.00	20.00	0.25
MCHI	45.00	36.00	0.00	25.00	16.00	0.00	15.00	3.00	15.00	0.10
PIBO	38.00	22.00	1.00	58.00	10.80	1.00	52.00	5.00	64.00	0.50
SVIM	60.00	25.00	1.00	50.00	10.00	2.00	40.00	2.00	80.00	0.20
SVMO	70.00	30.00	1.00	70.00	20.00	3.00	30.00	5.00	20.00	0.20
SVLV	60.00	35.00	2.00	30.00	10.00	1.00	70.00	3.00	80.00	0.00
SVNH	10.00	25.00	1.00	50.00	9.00	2.00	60.00	3.00	30.00	0.10
SVMN	80.00	40.00	2.00	50.00	20.00	3.00	40.00	5.00	20.00	0.20
QUEL	30.00	10.00	2.00	20.00	6.00	1.00	40.00	1.50	7.00	0.30
CA01	80.00	—	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN01	20.00	—	0.00	0.00	0.00	0.00	80.00	0.00	0.00	0.00
ESVE	80.00	—	0.00	0.00	0.00	0.00	80.00	0.00	0.00	0.00
PAPA	97.50	—	0.00	0.00	0.00	0.00	80.00	0.00	0.00	0.00
ESNA	80.00	10.20	2.00	27.00	6.85	2.00	26.00	2.90	12.50	0.25
ESIG	76.30	16.85	2.00	30.00	5.55	2.00	20.00	1.48	17.95	0.09
ESTA	44.70	9.90	2.00	25.50	1.53	1.02	29.80	2.45	17.25	0.12
PLGR	80.00	20.00	2.00	30.00	10.00	2.00	15.00	5.00	20.00	0.25
PNCH	2.50	37.00	0.00	15.00	20.00	0.40	93.00	4.00	10.00	0.25
GAIA	4.53	5.88	1.00	10.80	1.89	0.54	67.30	2.00	30.00	0.42