MAPS (Monitoring Avian Productivity and Survivorship) Data Provide Inferences on Demographic Drivers of Population Trends for 158 Species of North American Landbirds

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ABSTRACT

The Monitoring Avian Productivity and Survivorship (MAPS) Program is a continent-wide bird banding and data collection effort among public agencies, non-governmental organizations, and individuals to assist the conservation of birds and their habitats through demographic monitoring. We analyzed MAPS data from 1992 through 2006 to provide temporal (annual) and spatial (at the scale of Bird Conservation Regions [BCRs]) estimates or indices for key vital rates, including population change, population density, adult apparent survival, recruitment, productivity, and other demographic parameters for 158 species of landbirds. We presented results, along with pair-wise correlations among vital rates, for all 158 species and provided detailed discussions of results and research and management suggestions for 60 of the species (discussions for the remaining 98 species are currently being drafted) on a newly released website, Vital Rates of North American Landbirds (www.vitalratesofnorthamericanlandbirds.org). The results and accompanying discussions provide inferences about which vital rate(s) appear to be driving population change and could significantly improve strategies for reversing population declines that are occurring in many of these species. Here we provide a summary of the information provided on the website and illustrate how the information is presented and interpreted through one example species, Wood Thrush (Hylocichla mustelina).

INTRODUCTION

Demographic monitoring, whereby important demographic parameters (vital rates) are estimated across space and time, provides fundamental information to enhance our basic understanding of avian population ecology and can provide important clues to the factors that drive population changes (Sillett et al. 2000, Sillett and Holmes 2002, Julliard 2004). Assessing and monitoring vital rates, especially survival, productivity, and recruitment, in addition to abundance and population trend, can enhance the effectiveness of landbird conservation by enabling management to be directed at the stage in the annual-cycle that limits populations (Saracco et al. 2008).

The Monitoring Avian Productivity and Survivorship (MAPS) program is North America's most comprehensive avian demographic monitoring program. It was initiated by The Institute for Bird Populations (IBP) in 1989 and has amassed more than two million bird capture records from more than 1,200 mist-netting stations spread across 48 states and ten Canadian provinces. About 400 stations, on average, have been operated in any given year. Data collection from about a quarter of the station-years has been conducted by IBP biologists and interns through funding primarily from federal agencies, while data from the remainder of the station-years has been conducted by "independent" organizations and individuals, often with some government support.

In June 2015, IBP launched a website, Vital Rates of North American Landbirds (www.vitalratesofnorthamericanlandbirds.org; DeSante, Kaschube, and Saracco 2015), that presents temporal and spatial estimates of the vital rates of 158 species of landbirds, examines pair-wise correlations among the vital rates of all of these species, and provides detailed discussions, including inferences about which vital rates appear to be most important in regulating populations, for 60 of the species (discussions will be completed for the remaining 98 species during the next 6-8 months). Though IBP and our collaborators have published more than 40 peer-reviewed papers and more than 100 technical and agency reports related to the MAPS program, this is the first large-scale effort to estimate and examine the vital rates and relationships among them for such a large number of species over so long a period. Here, we summarize information provided on the vital rates of north american landbirds website and illustrate how the information is presented and interpreted through one example species, Wood Thrush (*Hylocichla mustelina*).

METHODS

Following is a brief summary of the methodology used in the collection, vetting, and analysis of the data and the interpretation of results. A much more detailed description, along with the assumptions and constraints inherent in these methods, can be found in the Methods section of www.vitalratesofnorthamericanlandbirds.org.

MAPS Stations and MAPS Data

MAPS utilizes a constant-effort mist-netting field protocol. The design of the program and field methods were standardized in 1992 and are described in DeSante (1992) and DeSante, Burton, Saracco, and Walker 1995; DeSante, Burton, and O'Grady 1996; DeSante, Saracco, O'Grady, Burton and Walker 2004; DeSante, Burton, Velez, Froehlich and Kaschube 2015). The number, location, and operation of mist nets at each station were kept consistent over all days and years that the station was operated. Data recorded for all birds captured, including species, age, sex, ageing and sexing criteria (skull pneumatization, breeding condition, molt limits, and plumage characteristics), physical condition and other capture details. Ageing and sexing followed guidelines developed by Pyle (1997).

Following computer entry, data were extensively vetted to verify coding and internal consistency of each banding record and consistency in species, age, and sex determinations for all records of each band number. We only included data from stations that were operated with sufficient effort for at least four years. Other restrictions on the quality of data brought the total number for which data were include in these analyses to 628 stations, 231 (37%) of which were operated for ten or more years. In total, data used in the analyses included 403,711 adult birds captured and banded; 212,237 young (hatch year) birds captured and banded; and 66,171 between-year recaptures of adults during the 15 years 1992-2006, the limit for which we had fully verified data. We limited analyses to species with 75 adult individuals banded and released during those 15 years, as we found that at least 75 captures was the lower limit for achieving statistical rigor in the analysis. In addition, we used only data for which at least 14 between-year recaptures were recorded, as recapture data is essential in analyzing adult apparent survival. Because of the difficulty of distinguishing Alder (*Empidonax alnorum*) from Willow (*E. traillii*) flycatchers, and Pacific-slope (*E. difficilis*) from Cordilleran (*E. occidentalis*) flycatchers, we combined data for these species pairs and analyzed them as two super-species, "Traill's" Flycatcher and "Western" Flycatcher, respectively. This brought the total number of "species" treated to 158 including 15 flycatchers (*Tyrannidae*), 33 wood warblers (*Parulidae*), 23 sparrows and towhees (*Emberizidae*), and 12 cardinals, grosbeaks, and tanagers (*Cardinalidae*).

Analytical Methods

We conducted temporal (by year) and spatial (at the scale of North America Bird Conservation Initiative [NABCI] Bird Conservation Regions [BCRs]; U.S. Fish and Wildlife Service 2000) analyses to provide estimates or indices for eight demographic parameters (Table 1). We used Pradel capture-mark-recapture (CMR) models (Pradel 1996) to estimate year-specific population change (lambda), and used transient Cormack-Jolly-Seber CMR models (Pradel et al. 1997) to estimate adult apparent survival rates (phi) and residency (tau). Recruitment (f) is an estimate of the annual number of new individuals in year t+1 relative to the total number of individuals in year t; thus, we calculated recruitment as the difference between lambda and adult apparent survival. We ran all CMR models with Program MARK (White and Burnham 1999) using the RMark package (Laake and Rexstad 2008). We modeled indices of adults (Ad) and young (Yg) birds per station at the station-scale as Poisson random variables with mean (and variance) parameters and we used a binomial model whereby productivity (RI) represented the probability of a captured bird being a young bird. We used generalized linear mixed models (GLMMs) to assess temporal (by year) and spatial variation in adult and young capture indices and modeled productivity using a logistic model. We used regional spatial replication of sites to calculate correction offsets for missed or excess effort and incorporated the offsets into the linear models. We used generalized linear mixed models to assess temporal and spatial variation in adult and young capture indices and productivity. We obtained temporal estimates from year-specific, linear function of year, and year-constant models and, for CMR models only, calculated model-averaged estimates using AIC_C weights (Burnham and Anderson 1992, 1998). We obtained spatial estimates from BCR-specific and BCR-constant models and, for CMR models only, calculated model-averaged estimates using AIC_C weights. Post-breeding effects (PBE) is an index calculated as f/RI. Because recruitment (f) includes two age-class components, SY birds hatched the preceding year and ASY immigrant birds, post-breeding effects (PBE) reflects both first-year survival of young birds and immigration of adults.

Table 1. Demographic parameters (vital rates) estimated.

Parameter	Abbreviation(s)	Description
Parameter	λ; lambda	An estimate of the net change in adult population size, typically measured between years.
Adult apparent survival probability	Φ; phi	An estimate of the probability that a resident bird that was alive and present at the station in a given year (t) will also be alive and present in the following year (t+1).
Residency	ι; tau	An estimate of the proportion of newly camptured adults of unknown residence that are actually residents at the station.
Recruitment	f	An estimate of the number of new individuals in year t+1 relative to the total number of individuals in year t.
Index of adults per station	Ad	An index of the number of adult birds captured per year. Because MAPS stations are established to be approximately the same size (20 ha), this index can be considered an index of population density (adults per 20 ha).
Index of young birds per station.	Yg	An index of the number of captures of young (hatching-year [HY]) birds that reach independence from their parents per year.
Productivity (reproductive index)	RI	An index of the number of young (hatching-year [HY]) birds that reach independence from their parents produced per adult.
Post-breeding effects	PBE	An index calculated as *f*/RI. Includes first-year survival of young birds (likely the major contributor) as well as immigration of adults.

RESULTS

The Vital Rates of North American Landbirds website presents the results of temporal and spatial analyses of vital rates for 158 species. Results of temporal analyses for each of the 158 species are presented by:

(1) Graphs showing annual numbers of adults captured and the number of MAPS stations capturing adult birds; and annual estimates of population change (lambda, λ); adult apparent survival (Φ); residency (proportion of newly captured birds that are resident, 1); recruitment (f); indices of numbers of adult (Ad) and young (Yg) birds per station; productivity (reproductive index, RI); and index of post-breeding effects (PBE).

(2) Tabular information on the mean estimates, standard deviations, and coefficients of variation from each of the temporal models for each of the eight demographic parameters, along with information on the overall sample sizes.

(3) Scatterplots and correlation matrices for the 15 pair-wise temporal correlations among adult population size, population change, adult apparent survival, productivity, recruitment, and post-breeding effects, along with numerical and visual representations of the strength of each correlation. The correlations provide inferences for how the various vital rates interact with each other, and which vital rate(s) might be most influencing population change.

Results of spatial analyses for each species are presented in an analogous manner, except that the BCR-specific estimates for each parameter are presented on color-coded maps showing the BCRs within which the species was captured, rather than in graphs showing annual estimates.

The website also presents species account narratives that summarize important results and conclusions for each of 60 (9 thrushes, 5 mimids, 1 waxwing, 33 wood warblers, and 12 cardinalids) of the 158 species included on the website (species account narratives for the remaining 98 species will be added during the latter part of 2015 and first part of 2016). In these narratives, we first provide information on how well the species was represented in the 1992-2006 MAPS database, along with any notable temporal or spatial heterogeneity in the data. Next, for four important vital rates: adult population density, population change (lambda), adult apparent survival, and productivity, we present and discuss parameter estimates and their variabilities (coefficients of variation) obtained from both the temporal and spatial models. We then discuss the results of the temporal and spatial correlations among the vital rates and make inferences about the vital rate(s) that appear to drive temporal and spatial variation in the population dynamics of the species. Finally, we close each species account narrative with a brief "summary of research and management hypotheses" section in which we provide hypotheses as to when and where in the annual cycle we believe these drivers are exerting their effects and suggest research and management strategies or actions that should be undertaken in order to reverse declining populations and maintain stable or increasing populations.

Summary of Wood Thrush Analysis

Figure 1 provides temporal results for three important vital rates taken from the website for a declining species of wide conservation concern, Wood Thrush (*Hylocichla mustelina*). During 1992-2006, 7,383 adult Wood Thrushes were banded and 1,212 between-year captures were recorded at 166 MAPS stations spread over 11 BCRs. As shown in Fig. 1, the time-constant annual population change (lambda) estimate (0.967[0.011 SE]) indicated a significantly declining population. The time-constant annual adult apparent survival rate (0.447 [0.012 SE]) was very low for a roughly 50g landbird, much lower than those for other smaller (roughly 30g) related thrushes. For example, the annual adult apparent survival rate was 0.602 [0.005 SE] for Swainson's Thrush (*Catharus ustulatus*) and 0.609 [0.012 SE] for Veery (*C. fuscescens*).

Temporal analyses of Wood Thrush vital rates showed that lambda was very strongly and highly positively significantly correlated with post-breeding effects (r=0.906; p=0.000), highly significantly positively correlated with adult apparent survival (r=0.741; p=0.002), and only weakly and non-significantly positively correlated with productivity (r=0.206; p=0.481). These results are presented graphically in Fig. 2, which shows the relative strength of each pairwise correlation, and the corresponding r and p-values. These results indicate that annual variation in lambda was driven primarily by annual variation in both post-breeding effects (likely primarily first-year survival of young) and adult apparent survival, and to a much smaller degree by annual variation in productivity. This suggests that low survival of both young and adult birds, rather than low productivity, was the primary demographic driver of the Wood Thrush population decline.

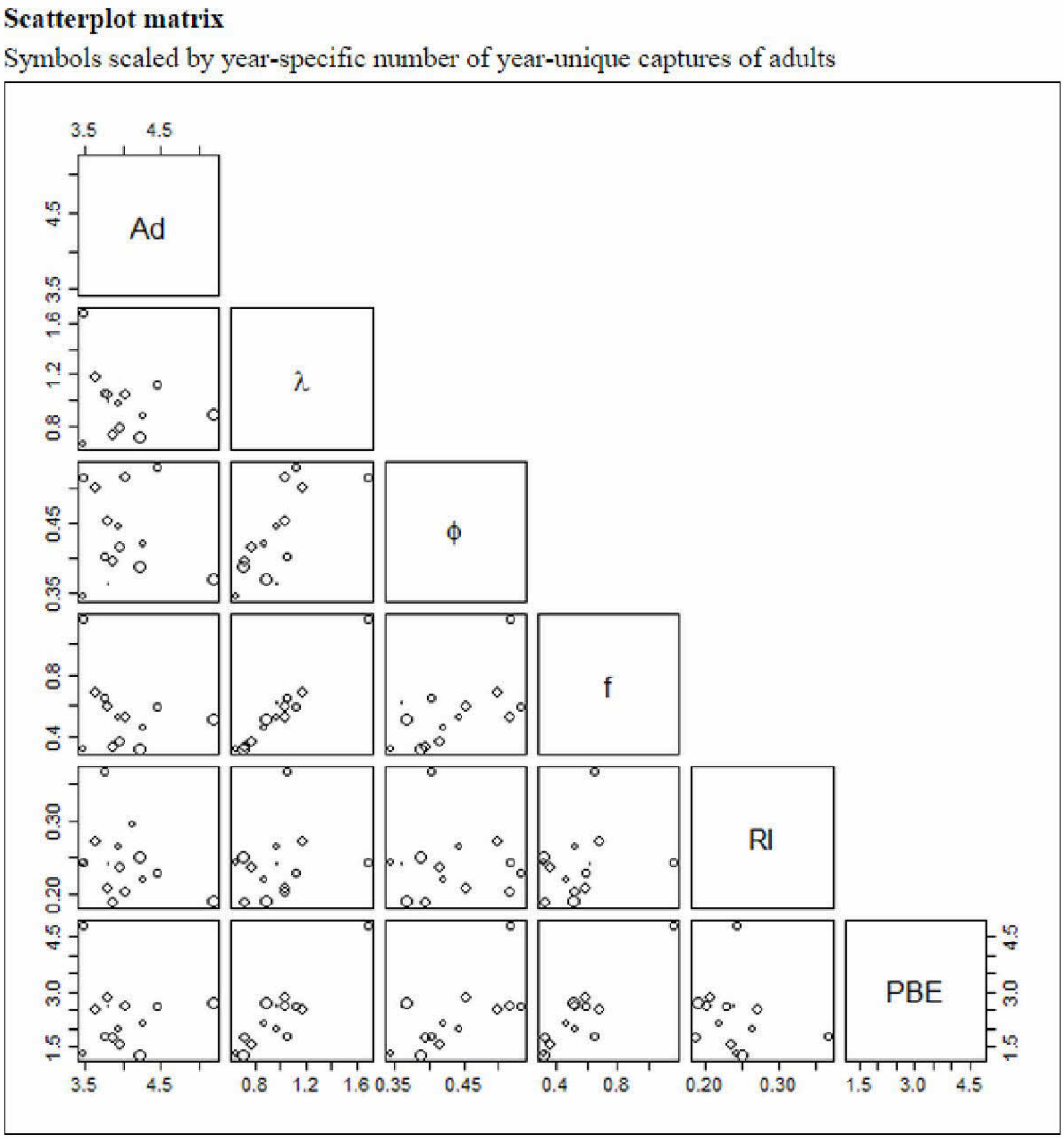

Fig. 1. Annual estimates (and 95% confidence intervals) for population change (lambda), adult apparent survival and reproductive index (yg/adult) for Wood Thrush from temporal modeling of 15 years (1992-2006) of Monitoring Avian Productivity and Survivorship (MAPS) data.

Weighted pair-wise correlations

Weight: year-specific number of year-unique captures of adults

Variable	By Var.	N	r	P
Ad	λ	14	-0.2995	0.2982
Ad	ϕ	14	-0.2669	0.3562
Ad	f	14	-0.2813	0.3299
Ad	RI	15	-0.3903	0.1504
Ad	PBE	14	-0.0702	0.8115
λ	ϕ	14	0.7411	0.0024
λ	f	14	0.9818	0.0000
λ	RI	14	0.2057	0.4806
λ	PBE	14	0.9063	0.0000
ϕ	f	14	0.6001	0.0233
ϕ	RI	14	0.0267	0.9279
ϕ	PBE	14	0.5839	0.0284
f	RI	14	0.2375	0.4137
f	PBE	14	0.9147	0.0000
RI	PBE	14	-0.1680	0.5659

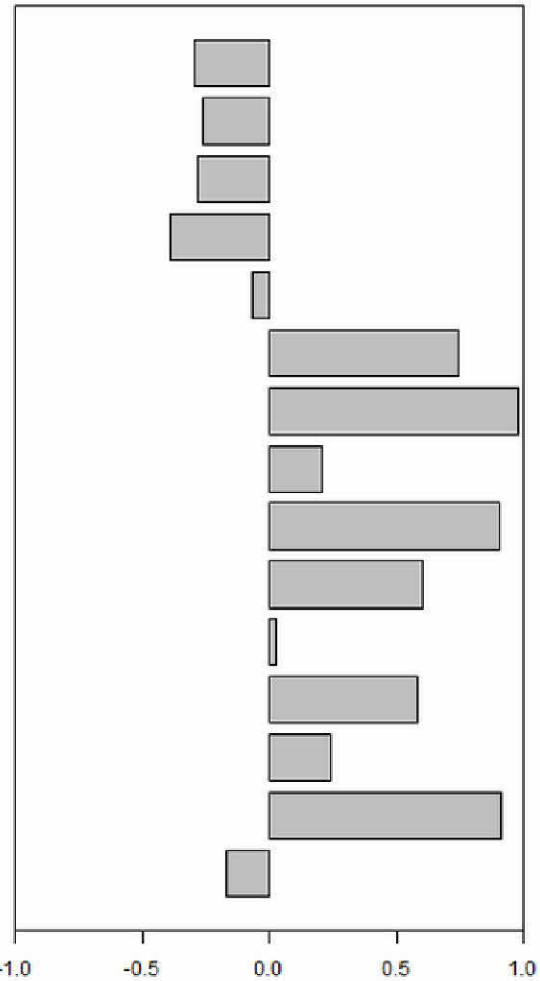

Fig. 2. Scatterplot matrix and weighted pair-wise temporal (by year) correlations among demographic parameters (vital rates) for Wood Thrush. Symbols are scaled and correlations are weighted by year-specific number of year-unique captures of adults.

DISCUSSION

Determining which vital rates are the likely drivers of population change is critical for informing effective conservation because management can be directed at the stage of the annual cycle that most strongly limits a population. The information on the Vital Rates of North American Landbirds website presents hypotheses that suggest where and when in the annual life cycle the vital rates are exerting their effects. For Wood Thrush, results suggested that management and conservation efforts are most likely to be effective at reversing population declines if they are directed toward enhancing survival rates on the non-breeding grounds, particularly the species' migratory stop-over and wintering grounds in eastern Mexico and Central America where forest loss has been severe in recent decades (Aide et al. 2013). Conservation efforts aimed at enhancing productivity on the species' breeding grounds in the eastern United States may be helpful, but by themselves will be incapable of reversing the species' population decline because survival, the likely limiting factor, must be addressed during the non-breeding season and on the non-breeding grounds. We hope scientists, planners, and managers will find the website useful for setting avian conservation goals and priorities. We also hope to keep the website updated as more analysis are completed and new information becomes available.

ACKNOWLEDGMENTS

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News, Notes, Comments

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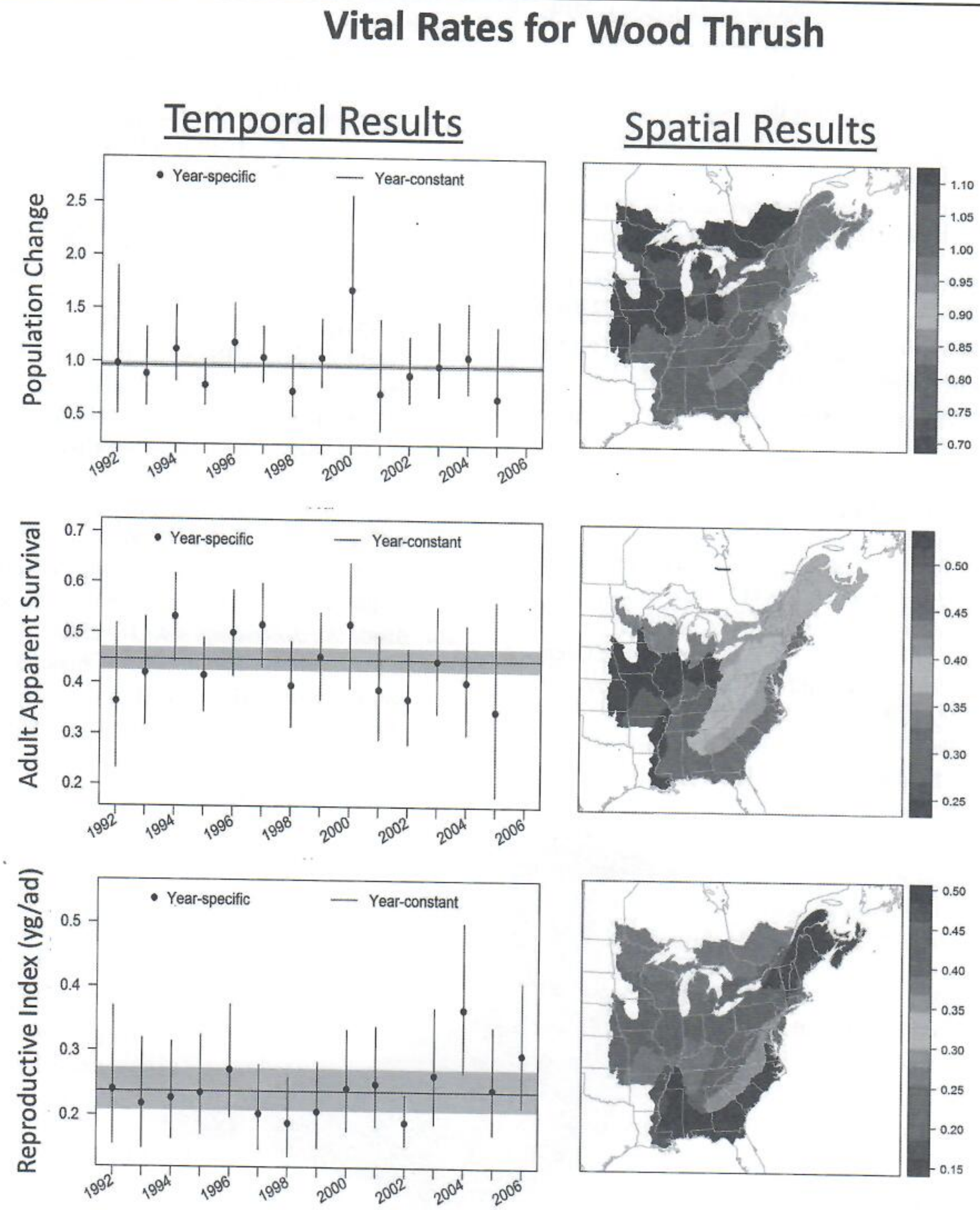

Fig. 1. Temporial (left column) and spatial (right column) results of vital rates analysis for Wood Thrush. Among the findings are that population change (top row) was below 1.0 over the time period analyzed, indicating a decreasing population; adult apparent survival (middle row) of 0.44 was much lower than similar-sized thrushes; and reproductive index of 2.4 (bottom row) was intermediate for the thrush species studied.