IDENTIFYING PROXIMATE CAUSES OF POPULATION TRENDS IN MIGRATORY BIRDS

An analysis of spatial variation at the scale of Bird Conservation Regions in vital rates and population trends from the Monitoring Avian Productivity and Survivorship (MAPS) program

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EXECUTIVE SUMMARY

The Institute for Bird Populations (IBP) established the Monitoring Avian Productivity and Survivorship (MAPS) program in 1989 to provide data on vital rates and identify causes of population declines in North American landbirds. The MAPS program consists of a network of nearly 500 constant-effort mist-netting and bird-banding stations that operate each year using standardized field protocols. Here we report results of analyses of 12 years (1992-2003) of MAPS data conducted at the scale of North American Bird Conservation Initiative Bird Conservation Regions (BCRs). We focus on 39 target migratory bird species, 10 of which are primarily distributed in western North America, 21 that are primarily distributed in eastern North America, and 8 that are broadly distributed. Our goals were to: (1) highlight species and BCRs in particular need of conservation or management action based on MAPS 12-yr population trends and long-term (1966-2007) trends from the North American Breeding Bird Survey (BBS), (2) compare the relative importance of adult apparent survival rate and recruitment rate in driving population trend at the scale of BCRs, and (3) identify proximate causes of spatial variation in population trend among BCRs. We use results to suggest whether management and conservation aimed at reversing population declines should focus on increasing productivity (which might be best achieved on breeding grounds), increasing adult apparent survival (which might be best addressed on wintering grounds or migration routes), or increasing recruitment (which might be addressed throughout the life cycle).

We assessed 12-yr MAPS trends and demographic contributions of adult apparent survival and recruitment rates using reverse-time and 'transient' Cormack-Jolly-Seber (CJS) capture-recapture models. We indexed productivity using the ratio of young to adult birds in the MAPS constant-effort data base. We used 'estimating equations' trend estimates from the 42-yr BBS data set.

Trend estimates for the 39 target species suggest that particular conservation attention should be focused on six species that significantly declined in both data sets/time periods at the program-wide scale: Bell's Vireo, Veery, Blue-winged Warbler, Chestnut-sided Warbler, Common Yellowthroat, and Baltimore Oriole. Three of these species (Blue-winged and Chestnut-sided warblers, and Common Yellowthroat), as well as an additional six, Orange-crowned Warbler, Black-and-white Warbler, Wilson's Warbler, Yellow-breasted Chat, Chipping Sparrow, and Bullock's Oriole, also warrant special conservation consideration based on significant population declines in both data sets/time periods in at least one-third of the BCRs included in analyses. Our results suggested that regional conservation priority should be focused on the Northern Pacific Rainforest (BCR 5), Atlantic Northern Forest (BCR 14), and New England/Mid-Atlantic Coast (BCR 30) regions, which had large numbers of significantly declining target

species (5-9 in both programs), few significantly increasing target species (1 in each region/program), and many species that showed significant negative trends in both data sets/time periods (4 in each region).

We found strong evidence of BCR-scale spatial variation in 1992-2003 MAPS population trends for 32 of 38 target species (84%) that occurred in multiple BCRs in sufficient numbers for analysis. Relatively few species (nine) showed evidence of adult apparent survival-rate estimates driving spatial variation in regional trends. The most striking case of adult apparent survival rates driving spatial variation in trend was for Gray Catbird. Recruitment of new individuals – both immigrating adults and local and immigrating young from the previous year – was more important for driving spatial variation in population trends than was adult apparent survival for most (25) target species. Recruitment-rate and trend estimates were not strongly related to productivity in most cases, suggesting that first-year survival of young was, overall, the most important factor driving spatial variation in population trends. The strongest positive relationships between productivity and recruitment and trend were for Black-and-white Warbler; eight additional species showed at least some evidence of productivity influencing recruitment and trend. Negative relationships between productivity and trend and declines in survival rate estimates for increasing populations suggested that density-dependent effects on vital rates may occur in some instances where populations have exceeded carrying capacity.

Emergent patterns from our results suggest that adult survival of local residents (adult apparent survival rate) and, especially, survival components of recruitment (first-year survival and survival of immigrants) were more important drivers of spatial variation in 1992-2003 population trends for our 39 target species than was productivity. Nevertheless, productivity was clearly important in some cases, and efforts to enhance productivity may be especially important in order to increase populations, once their declines have been arrested. Strong positive relationships between adult apparent survival and population trend, on the other hand, at least within the range of declining populations, suggest that efforts to enhance survival will be especially important for slowing declines and maintaining stable populations. Because survival of migratory landbirds may be largely driven by processes that act on their wintering grounds, we suggests that reversing population declines in these migratory species will hinge on the identification, improvement, and conservation of important overwintering habitats, as well as a basic understanding of the ways in which habitats and bird populations are impacted by weather and climate. This challenge to understand ultimate (environmental) drivers of landbird population changes is pressing, given that most natural over-wintering habitats in the northern Neotropics are considered "vulnerable, threatened, or endangered" and that climate change (particularly reduction in precipitation) over much of this region during this century is predicted to be dramatic.

Introduction

Broad-scale landbird monitoring in North America is largely count-based (e.g., the North American Breeding Bird Survey – BBS) and directed at monitoring relative abundance and trends (Bart 2005, Sauer et al. 2008). Such data are invaluable for identifying conservation targets and priorities (Rich et al. 2004); they are less useful for directing research, management, and conservation actions because they cannot provide direct information on causes of trends (DeSante et al. 2005*a*). Standardized mist-netting and bird-banding can complement count-based monitoring and provide focus for conservation (Saracco et al. 2008). Constant-effort capture data and capture-recapture data from networks of bird-banding stations can provide indices or estimates of vital rates (survival, productivity, recruitment). Such data are critical for identifying proximate (demographic) and ultimate (environmental) causes of population change (DeSante et al. 2001, Nott et al. 2002, Robinson et al. 2007, Saracco et al. 2008).

The Institute for Bird Populations (IBP) established the Monitoring Avian Productivity and Survivorship (MAPS) program in 1989 to provide data on vital rates and identify causes of population declines in North American landbirds. The MAPS program consists of a network of constant-effort mist-netting and bird-banding stations operated using standardized field protocols (DeSante et al. 2008). More than 1,000 stations have been established as part of the MAPS program, and nearly 500 stations are operated each breeding season. Approximately 80% of MAPS stations are operated by independent bird banders (i.e., trained citizen scientists), governmental agencies, or non-governmental organizations. Remaining stations are operated by biologists and interns recruited and trained by IBP (Burton and DeSante 1999).

Here we report results of analyses of 12 years (1992-2003) of MAPS data conducted at the scale of North American Bird Conservation Initiative Bird Conservation Regions (BCRs) as part of our 2005-funded NFWF project, *Identifying Causes of Population Change in Migratory Birds*. We focus on 39 target species, 10 that are primarily distributed in western North America, 21 that are primarily distributed in eastern North America, and 8 that are broadly distributed (Table 1). Our goals were to: (1) highlight species and BCRs in particular need of conservation or management action based on MAPS 12-year population trends and long-term (1966-2007) trends from the BBS (Sauer et al. 2008), (2) compare the relative importance of adult apparent survival rate and recruitment rate in driving population trend at the scale of BCRs, and (3) identify proximate causes of spatial variation in population trend among BCRs. We use results to suggest research, management, and conservation needs. Specifically, we suggest whether management or conservation action aimed at reversing population declines should focus on increasing productivity (which might be best achieved on breeding grounds) increasing adult apparent survival (which might be best addressed on wintering grounds or migration routes), or increasing recruitment (which might be addressed throughout the life cycle).

Table 1. Nearctic-Neotropical migratory landbird species targeted by the project *Identifying Causes of Population Declines in Migratory Birds*.

Species name	Species code	Distrib. [1]
Western Wood-Pewee (*Contopus sordidulus*)	WEWP	W
Eastern Wood-Pewee (*C. virens*)	EAWP	E
Acadian Flycatcher (*Empidonax virescens*)	ACFL	E
"Traill's" (Alder/Willow) Flycatcher (*E. alnorum/trailii*)	TRFL	C
Hammond's Flycatcher (*E. hammondii*)	HAFL	W
Dusky Flycatcher (*E. oberholseri*)	DUFL	W
"Western" (Pacific-slope/Cordilleran) Flycatcher (*E. difficilis/occidentalis*)	WEFL	W
White-eyed Vireo (*Vireo griseus*)	WEVI	E
Bell's Vireo (*V. bellii*)	BEVI	W
Warbling Vireo (*V. gilvus*)	WAVI	C
Red-eyed Vireo (*V. olivaceus*)	REVI	E
Veery (*Catharus fuscescens*)	VEER	E
Swainson's Thrush (*C. ustulatus*)	SWTH	C
Wood Thrush (*Hylocichla mustelina*)	WOTH	E
Gray Catbird (*Dumetella carolinensis*)	GRCA	E
Blue-winged Warbler (*Vermivora pinus*)	BWWA	E
Orange-crowned Warbler (*V. celata*)	OCWA	W
Yellow Warbler (*Dendroica petechia*)	YWAR	C
Chestnut-sided Warbler (*D. pensylvanica*)	CSWA	E
Prairie Warbler (*D. discolor*)	PRAW	E
Black-and-white Warbler (*Mniotilta varia*)	BAWW	E
American Redstart (*Setophaga ruticilla*)	AMRE	E
Prothonotary Warbler (*Protonotaria citrea*)	PROW	E
Worm-eating Warbler (*Helmitheros vermivora*)	WEWA	E
Ovenbird (*Seiurus aurocapilla*)	OVEN	E
Louisiana Waterthrush (*S. motacilla*)	LOWA	E
Kentucky Warbler (*Oporornis formosus*)	KEWA	E
MacGillivray's Warbler (*O. tolmiei*)	MGWA	W
Common Yellowthroat (*Geothlypis trichas*)	COYE	C
Hooded Warbler (*Wilsonia citrina*)	HOWA	E
Wilson's Warbler (*W. pusilla*)	WIWA	C
Yellow-breasted Chat (*Icteria virens*)	YBCH	C
Chipping Sparrow (*Spizella passerina*)	CHSP	C
Black-headed Grosbeak (*Pheucticus melanocephalus*)	BHGR	W
Lazuli Bunting (*Passerina amoena*)	LAZB	W
Indigo Bunting (*P. cyanea*)	INBU	E
Painted Bunting (*P. ciris*)	PABU	E
Bullock's Oriole (*Icterus bullockii*)	BUOR	W
Baltimore Oriole (*I. galbula*)	BAOR	E

[1] W = primarily western North America; E = primarily eastern North America; C = continent-wide.

Methods

The Data

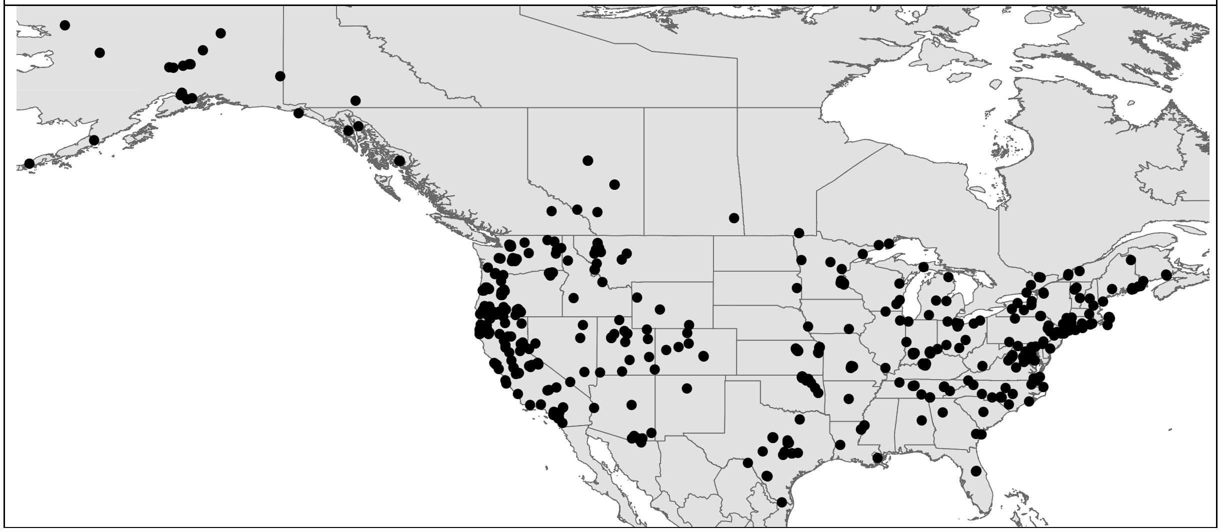
We analyzed 12 years (1992-2003) of data from the Monitoring Avian Productivity and Survivorship (MAPS) program. The MAPS program is a cooperative network of nearly 500 constant-effort mist-netting stations operated across North America each summer; it provides demographic data for > 180 landbird species (DeSante and Kaschube 2007). Details of MAPS data collection are described in DeSante et al. (2008). Briefly, a mist net array (typically 10 12m × 2.5m nets) is operated at each station (approx. 20-ha) on 6-9 d per year. Although some stations drop out and new stations enter the program each year, many are operated for long time spans (e.g., 227 stations [nearly 25% of registered MAPS stations] have operated ≥ 10 yrs). With few exceptions, unbanded birds captured during mist-netting operations are identified to species, age, and (if possible) sex (Pyle 1997); and are banded with uniquely numbered metal bands issued by the USGS Bird Banding Laboratory. Band numbers of recaptures are recorded.

Table 2. Number of years of operation for 492 Monitoring Avian Productivity and Survivorship (MAPS) stations in the 1992-2003 data base with data usable for both productivity and survival analyses (see text for detail). We counted multiple stations with centroids < 1.35 km apart as single ‘super-stations’.

No. years of operation	No. stations
4	52
5	96
6	35
7	55
8	41
9	52
10	48
11	46
12	67

The complete verified 12-yr data MAPS data set included data usable for survival and productivity analyses from 492 MAPS stations (or ‘super-stations’ for multiple stations with centroids < 1.35 km apart) operated for 3,869 station-years (Table 2). The distribution of these stations is presented in Figure 1. For analyses reported here, we only used data collected during the 10 standardized 10-d MAPS periods, which normally extend from May 1 to August 8 each year. We included all individuals of a species at a station if the species was found to be a usual breeder at that station (i.e., if the species bred within station boundaries on > 1/2 of the years that the station was operated). We do not include, in any analyses, data for a species at a station that was outside of the species’ breeding range or at an altitude at which the species does not breed. We further limited the data set to stations with > 4 years of data (minimum usable for survival analyses from ‘transient’ models; see below), and for which data were usable for both productivity (sufficient data through the MAPS season) and survivorship analyses. Finally, for BCR-scale analyses, we eliminated data for BCRs with < 3 stations and < 120 banded adult individuals (i.e., a mean of 10 individuals / yr).

Figure 1. Distribution of 492 Monitoring Avian Productivity and Survivorship (MAPS) stations operated between 1992 and 2003 with sufficient effort for analyses of productivity and survival (see text for detail).



Analyses

We estimated 'time-constant' population growth-rates, λ (i.e., population trends) at the program-wide scale by applying reverse-time capture-recapture models to MAPS data (Pradel 1996). We also estimated adult apparent survival rate, ϕ, and the 'nuisance parameter', capture probability, p, from these models. We considered two models for each species. For one model, we assumed all parameters (λ, ϕ, and p) to be constant across stations; for the second, we allowed p to vary as a linear function of the mean number of within-season captures of individual birds (p_{cap}) at the scale of stations (Julliard 2004, Saracco et al. 2008).

We also used reverse-time Pradel (1996) models to assess MAPS population trends at the BCR-scale. We conducted two sets of BCR-scale analyses. In the first set, we considered 12 model parameterizations (2 parameterizations of ϕ × 2 parameterizations of λ × 3 parameterization of p). We modeled ϕ and λ as either constant across BCRs ($\phi_{\cdot}$) or BCR-specific (ϕ_{BCR}) and p as constant across BCRs ($p_{\cdot}$), BCR-specific (p_{BCR}), or as a linear function of station-specific capture rates (p_{cap}; Julliard 2004, Saracco et al. 2008). In the second set of analyses, we considered the same set of models as in the first set, plus six additional models that allowed λ to vary as a linear function of the BCR-specific MAPS reproductive index, RI$_{BCR}$ (λ_{RI}), where RI$_{BCR}$ is defined as the ratio of young summed across years to year-unique adult birds summed across years in the constant-effort catch. We restricted this second set of analyses to species captured in $\geq$ 10 BCRs. For one species, Bell's Vireo, we did not consider BCR effects on ϕ, λ, or p (or RI$_{BCR}$ effects on λ) because minimum sample size was only met for one BCR (BCR 22 – Eastern Tallgrass Prairie).

We report model-averaged time-constant estimates of λ (i.e., program-wide trend), ϕ_{BCR}, and λ_{BCR} (and standard errors) based on AIC$_c$ model weights, w_i, calculated from the full set of i = 2-18 models (Burnham and Anderson 2003). We considered MAPS population trend estimates, $\hat{\lambda}$ and $\hat{\lambda}_{BCR}$, to be statistically significant if 95% confidence intervals did not include 1.00 ($\lambda < 1$ indicates a declining population; $\lambda > 1$ indicates an increasing population). BCR-specific BBS trends are only available for three time periods, 1966-2007, 1966-1980, and 1980-2007 (Sauer et al. 2008). Because 12-yr (1992-2003) BCR-specific BBS trends were not available to compare directly to 12-yr MAPS trends, we present 42-yr (1966-2007) program-wide and BCR-specific BBS trends to highlight areas in particular conservation need.

Estimates of adult apparent survival from reverse-time capture-recapture models will be biased if transient individuals (e.g., passage migrants, dispersing birds, 'floaters' [sensu Brown 1969]) are present in populations. Because of this potential bias, we also estimated BCR-scale adult apparent survival rates (ϕ^{tr}_{BCR}) from modified Cormack-Jolly-Seber (CJS) models that account for transients (Pradel et al. 1997, Nott and DeSante 2002, Hines et al. 2003). We considered two (Bell's Vireo only) to six models with ϕ as constant ($\phi^{tr}_{\square}$) or varying by BCR (ϕ^{tr}_{BCR}); and p as constant ($p_{\square}$), varying by BCR (p^{tr}_{BCR}), or varying as a linear function of the mean number of within-season captures of individual birds (p^{tr}_{cap}) at the scale of stations. We report model-averaged estimates for each species based on AIC$_c$ weights, w_i, from the full set of i = 2-6 models.

Despite (negative) bias in survival-rate estimates from Pradel reverse-time models, estimates of population trend from these models will be unbiased if we assume that under-estimation of survival rates is balanced by over-estimation of recruitment rates (i.e., transience in survival and recruitment are of equal magnitude). Based on this assumption, we calculated estimates of BCR-specific recruitment rate as:

$$\hat{f}^{tr}_{BCR} = \hat{\lambda}_{BCR} - \hat{\phi}^{tr}_{BCR},$$

where $\hat{f}^{tr}_{BCR}$ represents the estimated (average, or time-constant) number of new individuals in the population in year *t* per individual in year *t* – 1 based on $\hat{\lambda}_{BCR}$ from Pradel reverse-time models and $\hat{\phi}^{tr}_{BCR}$ from the transient CJS models. We estimated the relative contribution of survival rates to BCR-specific time-constant population growth, "seniority", as:

$$\hat{\gamma}^{tr}_{BCR} = \hat{\phi}^{tr}_{BCR} / \hat{\lambda}_{BCR} .$$

Although inference regarding demographic contributions to trend can be based on survival, recruitment, and seniority estimates derived solely from Pradel reverse-time models (e.g., Saracco et al. 2008), we feel that combining information from Pradel and transient CJS models, as we have done here, provides a more appropriate basis for assessing demographic components of trends.

We inferred the relative contributions of adult apparent survival and recruitment to BCR-scale population trends based on the magnitude of seniority parameter estimates (Nichols et al. 2000, Nichols and Hines 2002). We assessed the relative importance of adult apparent survival and recruitment to explaining spatial variation in population trend based on levels of statistical support for models for which BCR effects were included for λ and ϕ^{tr} (i.e., summed AIC$_c$ weights across all models with BCR effects included for these parameters). We represent the nature of relationships between MAPS population trend estimates $\hat{\lambda}_{BCR}$ and the demographic parameter estimates, $\hat{\phi}^{tr}_{BCR}$ and $\hat{f}^{tr}_{BCR}$, with scatterplots. To assess the role of productivity in affecting trends we show scatterplots of RI$_{BCR}$ against $\hat{f}^{tr}_{BCR}$ and $\hat{\lambda}_{BCR}$. Additionally, for those species for which we had adequate data in ≥ 10 BCRs (i.e., those for which we conducted the second set of Pradel reverse-time models), we assessed the importance of RI$_{BCR}$ in affecting trend using the summed AICc weights for models including RI$_{BCR}$ effects on λ_{BCR} and from the direction and significance of linear relationship between RI$_{BCR}$ and λ_{BCR} (Nichols et al. 2005, Saracco et al. 2008).

We ran all capture-recapture models and produced model-averaged parameter estimates with program MARK (White and Burnham 1999) using the RMark package (Laake and Rexstad 2008) in R ver. 2.7.0 (R Development Core Team 2008).

Results

Population Trends

Program-wide scale. — We found significant ($P < 0.05$) declines for 14 bird species based on 1992-2003 MAPS data and for 20 species based on the 1966-2007 BBS data set (Table 3). Seven species significantly declined in both data sets: Bell's Vireo, Veery, Blue-winged Warbler, Chestnut-sided

Table 3. Population trends derived from the 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) program and the 1966-2007 North American Breeding Bird Survey (BBS) for 39 target species (see Table 1). MAPS trends are expressed as time-constant population growth rate estimates ($\hat{\lambda}$). BBS trends are expressed as % change per year (Sauer et al. 2008). Significant trends ($P < 0.05$) are indicated with an asterisk. Species with significant MAPS and BBS declines are bolded.

	1992-2003 MAPS			1966-2007 BBS	
Species	No. stations	No. individuals	$\hat{\lambda}$	No. routes	Trend
Western Wood-Pewee	84	1928	1.010	913	-0.86*
Eastern Wood-Pewee	114	815	1.005	2147	-1.67*
Acadian Flycatcher	81	3174	0.998	973	-0.10
Traill's Flycatcher	87	3861	1.009	1271	-0.93
Hammond's Flycatcher	56	1369	1.003	355	+1.02
Dusky Flycatcher	52	2751	0.971*	434	-0.79
Western Flycatcher	73	3081	0.972*	469	-0.98
White-eyed Vireo	88	3527	1.022*	1163	+0.41*
Bell's Vireo	**18**	**650**	**0.952***	**322**	**-2.64***
Warbling Vireo	132	6226	0.987*	2190	+0.92*
Red-eyed Vireo	181	5816	0.999	2584	+1.19*
Veery	**61**	**2700**	**0.964***	**1114**	**-1.46***
Swainson's Thrush	118	12335	1.002	855	-0.63*
Wood Thrush	138	6098	0.991	1836	-1.74*
Gray Catbird	137	12241	1.006*	2349	+0.06
Blue-winged Warbler	**36**	**1120**	**0.937***	**494**	**-1.14***
Orange-crowned Warbler	72	4458	0.993	504	-1.06*
Yellow Warbler	150	12200	1.011*	2682	+0.05
Chestnut-sided Warbler	**22**	**926**	**0.952***	**922**	**-0.68***
Prairie Warbler	27	668	0.992	862	-2.02*
Black-and-white Warbler	83	1367	0.994	1253	-0.78*
American Redstart	71	3951	0.990	1430	-0.77*
Prothonotary Warbler	22	745	1.021	489	-1.08
Worm-eating Warbler	31	920	1.022	407	+0.70
Ovenbird	126	4691	1.000	1529	+0.28*
Louisiana Waterthrush	37	684	1.020	599	+0.74
Kentucky Warbler	62	2179	0.991	773	-0.91*
MacGillivray's Warbler	101	7454	1.002	486	-0.79*
Common Yellowthroat	**213**	**11357**	**0.979***	**3084**	**-0.49***
Hooded Warbler	50	1509	0.964*	702	+0.85
Wilson's Warbler	86	11269	0.999	584	-2.30*
Yellow-breasted Chat	77	3945	0.972*	1475	+0.14
Chipping Sparrow	93	1797	0.961*	3073	-0.13
Black-headed Grosbeak	117	4927	0.952*	718	+0.83
Lazuli Bunting	52	2153	0.944*	523	+0.63
Indigo Bunting	131	4963	0.990	2134	-0.54*
Painted Bunting	32	1978	1.023*	376	-1.30*
Bullock's Oriole	51	1580	1.004	784	-0.81*
Baltimore Oriole	**55**	**901**	**0.948***	**1862**	**-0.64***

Warbler, Common Yellowthroat, and Baltimore Oriole. Three species in the MAPS data set (White-eyed Vireo, Gray Catbird, and Painted Bunting) and four in the BBS data set (White-eyed Vireo, Warbling Vireo, Red-eyed Vireo, and Ovenbird) significantly increased.

BCR-scale.— Trend estimates for individual species-BCR combinations are presented in the Appendix. Below we summarize patterns across species and regions and highlight regions and species of particular interest or concern.

Based on our first set of BCR-scale reverse-time capture-recapture models, we found 71 (31%) significant ($P < 0.05$) negative 1992-2003 MAPS population trends and 34 (15%) significant positive trends in 230 species-BCR combinations considered. Of the 25 BCRs for which we were able to estimate trend for at least one of the target species, 19 had at least one target species with a significant negative MAPS population trend (Fig. 2). The Northern Pacific Rainforest region (BCR 5) and New England/Mid-Atlantic Coast (BCR 30) regions had the largest number of significantly declining species, with nine each (Table 3). The largest number of significantly increasing target species, seven, was found in the Eastern Tallgrass Prairie region (BCR 22), followed by Coastal California (BCR 32) with five.

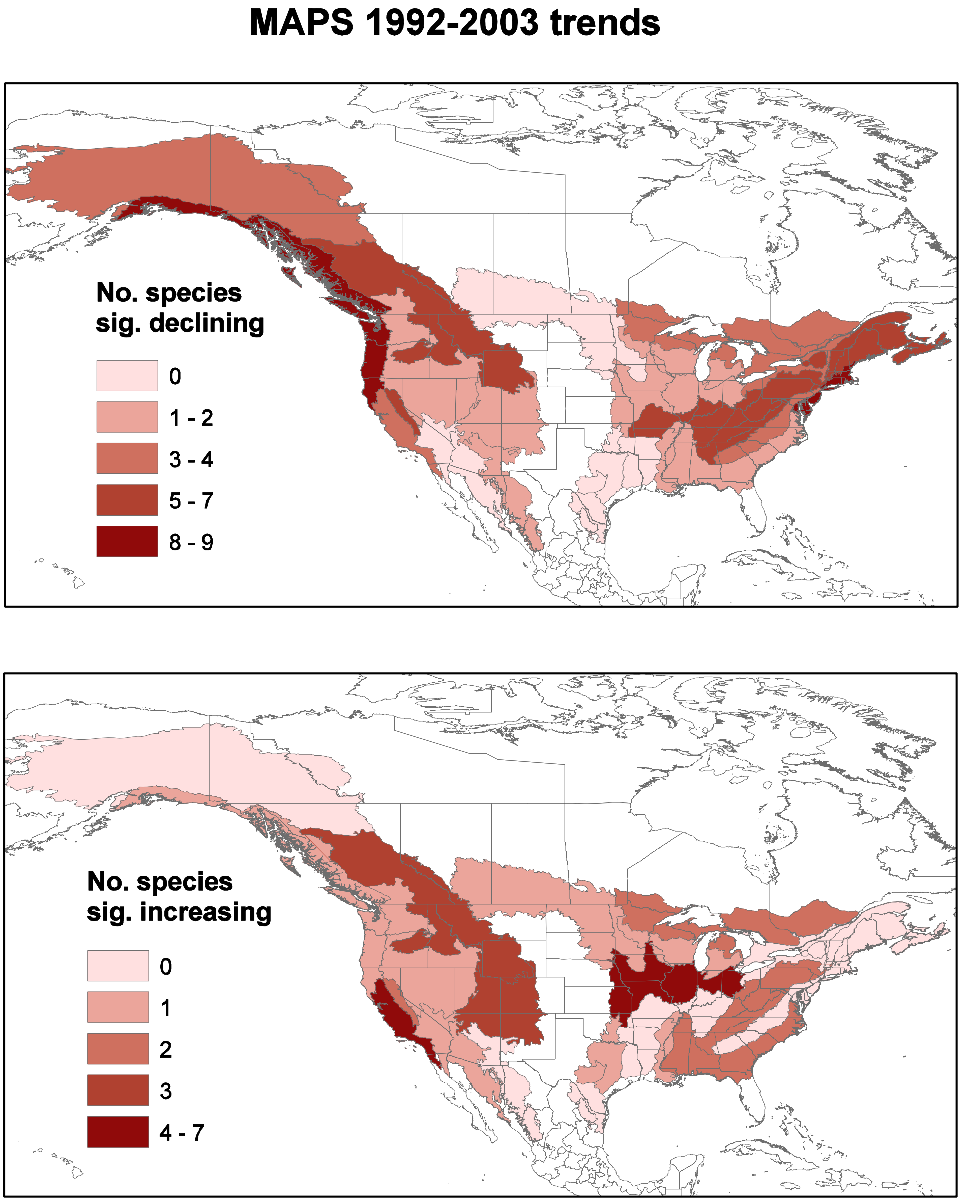
Long-term (1966-2007) data from the North American Breeding Bird Survey (BBS) showed 63 (27%) significant negative trends and 28 (12%) positive trends. The spatial pattern of significant long-term BBS trends was similar to the spatial pattern for the 1992-2003 MAPS trends, although the specific BCRs with the largest numbers of declining and increasing species differed between the two data sets (Table 4; Fig. 3). BCRs with the largest numbers of significantly declining species according to the 1966-2007 BBS data were the Atlantic Northern Forest (BCR 14) and Central Hardwoods (BCR 24) regions (each with eight species) and the Appalachian Mountain (BCR 28) and New England/Mid-Atlantic Coast regions (each with seven species; Table 4). The largest number of increasing species was found in the Northern Rockies (BCR 10) with five, followed by the Appalachian Mountains with four.

MAPS data provided strong evidence of BCR-scale spatial variation in population trends for 32 of the 38 target species (84%) that occurred in multiple BCRs in sufficient numbers for analysis (summed AIC$_c$ weights, $\sum_i w_i$, > 0.50 for the six models allowing BCR effects on λ; Table 5). Each of the six species not showing strong spatial effects (i.e., $\sum_i w_i < 0.5$) was a predominantly Eastern species. Species showing the largest number of significant 1992-2003 MAPS declines were Veery and Common Yellowthroat, each with significant declines in seven regions (Table 4). Species showing the highest proportion of BCRs with significant declines were Veery (7 of 7), Dusky Flycatcher (4 of 5), Black-and-white Warbler (3 of 4), Black-headed Grosbeak (5 of 7), and Wilson's Warbler (4 of 6; Table 4). Species with significant 1992-2003 MAPS increases in the largest number of BCRs were Gray Catbird (in 5 BCRs), followed by Yellow Warbler (in 4 BCRs). Western Wood-Pewee was the only species that had at least 50% of BCRs with significant increases (3 of 6; Table 5).

Common Yellowthroat also showed the largest number of significant 1966-2007 BBS declines (6 BCRs, 3 of which were shared with the MAPS trends; Table 5), followed by Wood Thrush (5 BCRs). Species showing the highest proportion of BCRs with significant BBS declines were Black-and-white Warbler (3 of 4), Eastern Wood-Pewee, Baltimore Oriole, and Bullock's Oriole (2 of 3 each), Wood Thrush (5 of 8), and Chipping Sparrow (3 of 5; Table 5). The species with the largest number of BCRs with significant BBS increases was Red-eyed Vireo (6 BCRs); no other species had significant increases in more than three BCRs. Only two species had at least 50% of the BCRs with significant BBS increases, Red-eyed Vireo (6 of 10) and Louisiana Waterthrush (1 of 2).

A total of 41 species-BCR combinations had both significant 12-yr MAPS trends and 42-yr BBS trends. Concordance between these significant trends occurred for 33 (80%) of the 41 species-BCR combinations; 27 of these 33 concordant Species-BCR significant trends were declines (Table 6), while only 6 were increases (White-eyed Vireo in BCRs 20 and 21, Red-eyed Vireo in BCRs 12 and 28, and Gray Catbird in BCRs 16 and 23). Species with the largest numbers of significant declining trends in both programs/time periods were Gray Catbird, Common Yellowthroat, and Wilson's Warbler, each with significant negative trends from both programs in 3 BCRs. BCRs with the most shared species with declining trends between the two programs/time periods were BCRs 5, 14, 24, and 30, each of which had 4 shared species. Of the 8 Species-BCR combinations with discordant significant trends between the 12-yr (1992-2003) MAPS and 42-yr (1966-2007) BBS programs, 7 had significant positive MAPS trends and significant negative BBS trends, while only one had a significant negative MAPS and significant positive BBS trend.

Figure 2. Number of target species (see Table 1) showing significant trends ($P < 0.05$) in 25 Bird Conservation Regions (BCRs) based on reverse-time capture-recapture models (Pradel 1996) applied to 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data.



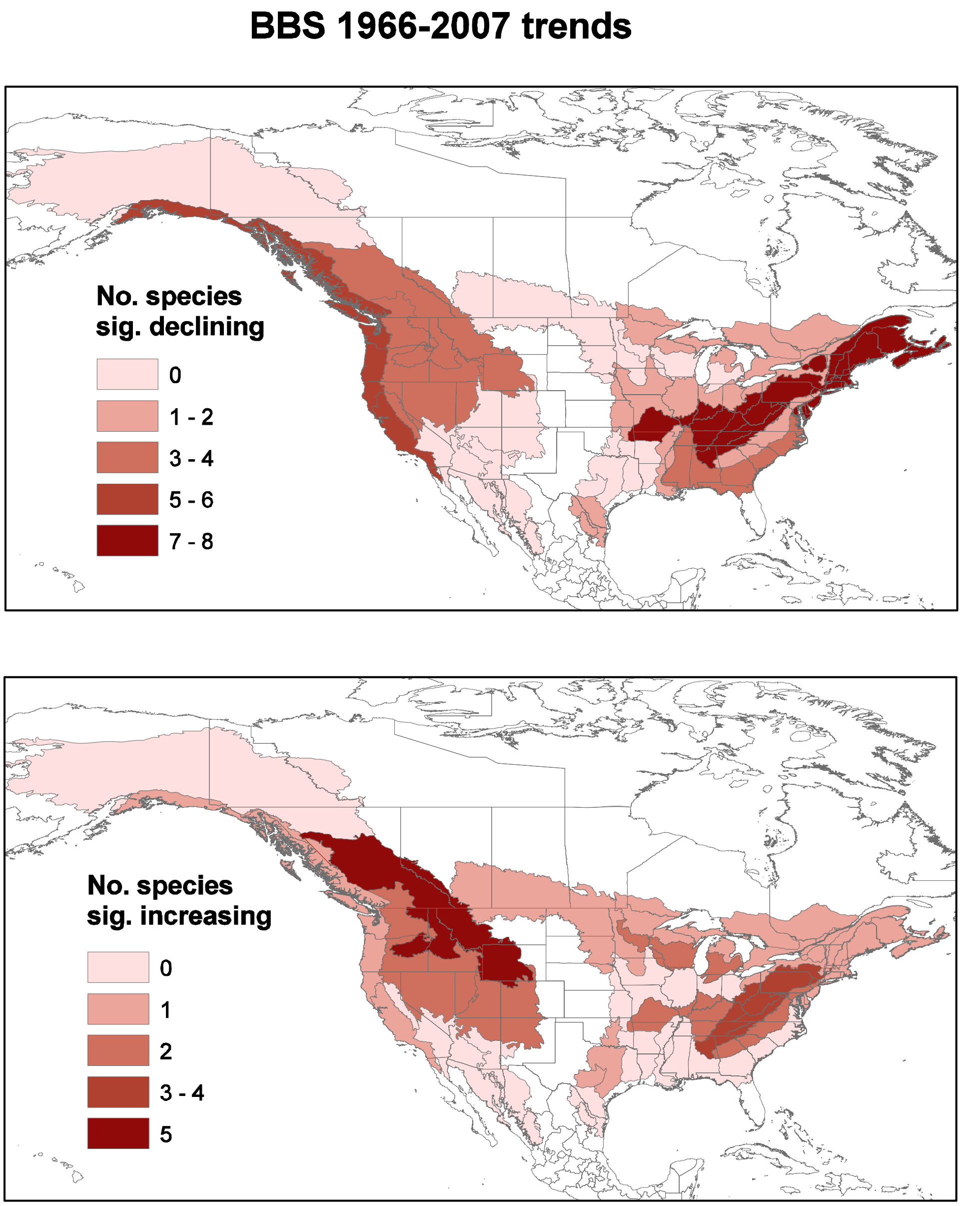


Figure 3. Number of significant trends ($P < 0.05$) by Bird Conservation Region (BCR) based on North American Breeding Bird Survey (BBS) 1966-2007 trend estimates (Sauer et al. 2008). Thirty-nine target species (see Table 1) and 25 BCRs were considered for a total of 230 species-BCR combinations.

Table 4. Numbers of target species with significant ($P < 0.05$) population trends in 25 Bird Conservation Regions (BCRs) based on 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data and 1966-2007 North American Breeding Bird Survey (BBS) data.

			MAPS 1992-2003		BBS 1966-2007	
BCR No.	BCR name	No. target species	No. signif. decl.	No. signif. incr.	No. signif. decl.	No. signif. incr.
4	Northwestern Interior Forest	5	3	0	0	0
5	Northern Pacific Rainforest	16	9	1	6	1
9	Great Basin	16	1	1	3	2
10	Northern Rockies	18	6	3	4	5
11	Prairie Potholes	3	0	1	0	1
12	Boreal Hardwood Transition	10	3	2	2	1
13	Lower Great Lakes/St. Lawrence Plain	10	3	0	1	1
14	Atlantic Northern Forest	11	5	0	8	1
15	Sierra Nevada	9	5	2	3	0
16	Southern Rockies/Colorado Plateau	13	2	3	0	2
20	Edwards Plateau	2	0	1	0	1
21	Oaks and Prairies	2	0	1	0	1
22	Eastern Tallgrass Prairie	14	1	7	2	0
23	Prairie Hardwood Transition	8	1	1	0	2
24	Central Hardwoods	15	5	0	8	2
25	West Gulf Coastal Plain/Ouachitas	1	0	0	0	0
26	Mississippi Alluvial Valley	7	1	1	1	0
27	Southeastern Coastal Plain	11	2	2	3	0
28	Appalachian Mountains	17	7	2	7	4
29	Piedmont	9	3	0	2	2
30	New England/Mid-Atlantic Coast	17	9	0	7	1
32	Coastal California	12	4	5	5	1
33	Sonoran and Mojave Deserts	1	0	1	0	0
34	Sierra Madre Occidental	2	1	0	0	0
36	Tamaulipan Brushlands	1	0	0	1	0

Table 5. Numbers (percentage) of Bird Conservation Regions (BCRs) for which population trend estimates for the 39 target species were significant ($P < 0.05$) based on 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data and 1966-2007 North American Breeding Bird Survey (BBS) data (scientific names in Table 1). Level of support for spatial variation in trend in MAPS data is expressed as summed AIC$_c$ weights ($\sum_i w_i$) over all i = 6 models that included BCR effects.

		MAPS 1992-2003			BBS 1966-2007	
Species	No. BCRs	$\sum_i w_i$ for models with BCR effects on λ	No. (%) BCRs signif. decl.	No. (%) BCRs signif. incr.	No. (%) BCRs signif. decl.	No. (%) BCRs signif. incr.
Western Wood-Pewee	6	0.992	0	3 (50)	2 (33)	0
Eastern Wood-Pewee	3	0.122	0	0	2 (67)	0
Acadian Flycatcher	6	0.854	0	0	1 (17)	0
Traill's Flycatcher	10	0.849	0	2 (20)	2 (20)	1 (10)
Hammond's Flycatcher	4	0.582	0	0	0	1 (25)
Dusky Flycatcher	5	0.692	4 (80)	0	1 (20)	0
Western Flycatcher	3	1.000	1 (33)	0	0	0
White-eyed Vireo	9	1.000	2 (22)	3 (33)	1 (11)	2 (22)
Bell's Vireo	1	—	1	0	0	0
Warbling Vireo	6	0.918	2 (33)	0	1 (17)	2 (33)
Red-eyed Vireo	10	1.000	2 (20)	3 (30)	2 (20)	6 (60)
Veery	7	0.029	7 (100)	0	2 (29)	0
Swainson's Thrush	7	1.000	2 (29)	1 (14)	1 (14)	0
Wood Thrush	8	1.000	1 (13)	2 (25)	5 (63)	0
Gray Catbird	13	1.000	5 (38)	5 (38)	4 (31)	2 (15)
Blue-winged Warbler	3	0.903	1 (33)	0	1 (33)	0
Orange-crowned Warbler	5	1.000	2 (40)	1 (20)	2 (40)	1 (20)
Yellow Warbler	15	1.000	3 (20)	4 (27)	3 (20)	3 (20)
Chestnut-sided Warbler	3	0.345	1 (33)	0	1 (33)	1 (33)
Prairie Warbler	2	0.271	0	0	1 (50)	0
Black-and-white Warbler	4	1.000	3 (75)	1 (25)	3 (75)	0
American Redstart	7	0.886	1 (14)	0	1 (14)	0
Prothonotary Warbler	2	0.674	0	0	0	0
Worm-eating Warbler	3	0.572	0	0	1 (33)	0
Ovenbird	8	0.994	2 (25)	1 (13)	0	2 (25)
Louisiana Waterthrush	2	0.291	0	0	0	1 (50)
Kentucky Warbler	4	1.000	2 (50)	1 (25)	1 (25)	0
MacGillivray's Warbler	5	0.973	1 (20)	1 (20)	2 (40)	0
Common Yellowthroat	17	1.000	7 (41)	2 (12)	7 (41)	2 (12)
Hooded Warbler	4	0.967	2 (50)	0	0	1 (25)
Wilson's Warbler	6	1.000	4 (67)	1 (17)	3 (50)	0
Yellow-breasted Chat	8	1.000	4 (50)	1 (13)	4 (50)	0
Chipping Sparrow	5	1.000	2 (40)	1 (20)	3 (60)	0
Black-headed Grosbeak	7	1.000	5 (71)	0	1 (14)	2 (29)
Lazuli Bunting	5	0.929	2 (40)	0	0	1 (20)
Indigo Bunting	8	1.000	1 (13)	1 (13)	4 (50)	0
Painted Bunting	3	0.408	0	0	1 (33)	0
Bullock's Oriole	3	0.992	1 (33)	0	2 (67)	0
Baltimore Oriole	3	0.850	0	0	2 (67)	0

Table 6. Species-BCR combinations showing significant ($P < 0.05$) declining trends in both the 12-yr (1992-2003) Monitoring Avian Productivity and Survivorship (MAPS) data set and the 42-yr (1966-2007) North American Breeding Bird Survey (BBS) data set.

Species	BCR number	BCR name
Dusky Flycatcher	5	Northern Pacific Rainforest
Red-eyed Vireo	30	New England/Mid-Atlantic Coast
Veery	12	Boreal Hardwood Transition
	14	Atlantic Northern Forest
Wood Thrush	30	New England/Mid-Atlantic Coast
Gray Catbird	12	Boreal Hardwood Transition
	14	Atlantic Northern Forest
	24	Central Hardwoods
Blue-winged Warbler	24	Central Hardwoods
Orange-crowned Warbler	5	Northern Pacific Rainforest
Black-and-white Warbler	14	Atlantic Northern Forest
	30	New England/Mid-Atlantic Coast
Kentucky Warbler	30	New England/Mid-Atlantic Coast
MacGillivray's Warbler	5	Northern Pacific Rainforest
Common Yellowthroat	14	Atlantic Northern Forest
	24	Central Hardwoods
	28	Appalachian Mountains
Wilson's Warbler	10	Northern Rockies
	15	Sierra Nevada
	5	Northern Pacific Rainforest
Yellow-breasted Chat	24	Central Hardwoods
	28	Appalachian Mountains
Chipping Sparrow	10	Northern Rockies
	15	Sierra Nevada
Black-headed Grosbeak	32	Coastal California
Indigo Bunting	28	Appalachian Mountains
Bullock’s Oriole	32	Coastal California

Demographic drivers of trends

Adult apparent survival rate, $\hat{\phi}^{tr}_{BCR}$, contributed more to 1992-2003 MAPS population trend than recruitment rate (i.e., $\hat{\gamma}^{tr}_{BCR} > 0.5$) for 60% (138 of 230) of the species-BCR combinations considered (Table 7; see Appendix for parameter estimates for individual species). Adult apparent survival was more important than recruitment in at least one BCR for all species except Hammond's Flycatcher, Orange-crowned Warbler, Prothonotary Warbler, and Wilson's Warbler, and the average value of $\hat{\gamma}^{tr}_{BCR}$ across BCRs exceeded 0.5 for 24 of the 39 target species (Table 7).

We found strong support for spatial variation in both population trend (summed AIC$_c$ weights, $\sum_i w_i$ for the six Pradel models with BCR effects on λ > 0.50) and adult apparent survival rate (summed AIC$_c$ weights, $\sum_i w_i$ for the 3 transient survival models with BCR effects on ϕ^{tr} > 0.50) for 17 of the 38 target species that were found in > 1 BCR in sufficient numbers for analysis (Table 7). Strong correspondence between adult apparent survival rate and population trend, however, was evident for only a few of these 17 species (Figure 4). Species for which adult apparent survival appeared to be important in driving spatial variation in trends included (although some outliers were evident): Gray Catbird, Indigo Bunting, MacGillivray's Warbler, Traill's Flycatcher, Warbling Vireo, Western Wood Pewee, Yellow-breasted Chat, and Yellow Warbler. Adult apparent survival seemed to be related to population trend primarily whenever $\hat{\lambda}_{BCR}$ < 1 (i.e., for declining populations). In some cases (e.g., Gray Catbird and Yellow-breasted Chat), declines in survival-rate estimates for increasing populations suggested density-dependent survival in populations presumably approaching or exceeding carrying capacity.

We found stronger evidence for recruitment-driven spatial variation in trend than for adult apparent survival-driven spatial variation in trend. Fifteen target species showed strong statistical support for spatial variation in trend, but little or no support for spatial variation in adult apparent survival (implying recruitment-driven trends; Table 7). In addition, positive relationships between recruitment and trend were evident for most species (Fig. 5). The relative importance of recruitment is further demonstrated by scatterplots of $\hat{\gamma}^{tr}_{BCR}$ vs. $\hat{\lambda}_{BCR}$, for which positive relationships indicate adult-apparent survival driven spatial variation in trends and negative relationships indicate recruitment-driven spatial variation in trends (Fig. 6).

Table 7. Importance of adult apparent survival rate in determining 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) population trend for 230 species-BCR combinations. Values of $\hat{\gamma}^{tr}_{BCR} > 0.5$ indicate that adult apparent survival is of greater importance than recruitment in determining trend.

Species	No. BCRs	No. BCRs with $\hat{\gamma}^{tr}_{BCR} > 0.5$	Mean ($\hat{\gamma}^{tr}_{BCR}$)	$\sum_i w_i$ for models with BCR effects on λ	$\sum_i w_i$ for models with BCR effects on ϕ^{tr}
Western Wood-Pewee	6	4	0.518	0.992	0.682
Eastern Wood-Pewee	3	1	0.522	0.122	0.930
Acadian Flycatcher	6	5	0.511	0.854	0.013
Traill's Flycatcher	10	4	0.479	0.849	0.726
Hammond's Flycatcher	4	0	0.447	0.582	0.281
Dusky Flycatcher	5	4	0.508	0.692	0.214
Western Flycatcher	3	1	0.469	1.000	1.000
White-eyed Vireo	9	7	0.518	1.000	0.473
Bell's Vireo	1	1	0.644	—	—
Warbling Vireo	6	5	0.526	0.918	1.000
Red-eyed Vireo	10	10	0.601	1.000	0.001
Veery	7	7	0.622	0.029	0.006
Swainson's Thrush	7	7	0.596	1.000	1.000
Wood Thrush	8	1	0.442	1.000	0.917
Gray Catbird	13	6	0.480	1.000	1.000
Blue-winged Warbler	3	3	0.574	0.903	0.150
Orange-crowned Warbler	5	0	0.441	1.000	0.030
Yellow Warbler	15	8	0.504	1.000	1.000
Chestnut-sided Warbler	3	1	0.444	0.345	0.956
Prairie Warbler	2	1	0.500	0.271	0.292
Black-and-white Warbler	4	3	0.571	1.000	0.249
American Redstart	7	5	0.508	0.886	0.135
Prothonotary Warbler	2	0	0.489	0.674	0.162
Worm-eating Warbler	3	3	0.563	0.572	0.335
Ovenbird	8	8	0.578	0.994	0.001
Louisiana Waterthrush	2	2	0.526	0.291	0.171
Kentucky Warbler	4	4	0.573	1.000	0.656
MacGillivray's Warbler	5	2	0.490	0.973	0.800
Common Yellowthroat	17	6	0.479	1.000	1.000
Hooded Warbler	4	2	0.507	0.967	0.098
Wilson's Warbler	6	0	0.406	1.000	1.000
Yellow-breasted Chat	8	6	0.520	1.000	0.642
Chipping Sparrow	5	1	0.445	1.000	0.005
Black-headed Grosbeak	7	7	0.586	1.000	0.438
Lazuli Bunting	5	1	0.496	0.929	0.998
Indigo Bunting	8	6	0.528	1.000	0.903
Painted Bunting	3	3	0.554	0.408	0.228
Bullock's Oriole	3	2	0.542	0.992	0.532
Baltimore Oriole	3	1	0.428	0.850	0.996

Figure 4. Scatterplots showing relationship between adult apparent survival-rate estimates from transient CJS models ($\hat{\phi}^{tr}_{BCR}$) and estimates of time-constant population growth rate (i.e., trend, $\hat{\lambda}_{BCR}$) from reverse-time Pradel models (see Methods for detail) based on 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data for 17 target species that showed strong evidence of spatial variation in both population trend and survival (see Table 6).

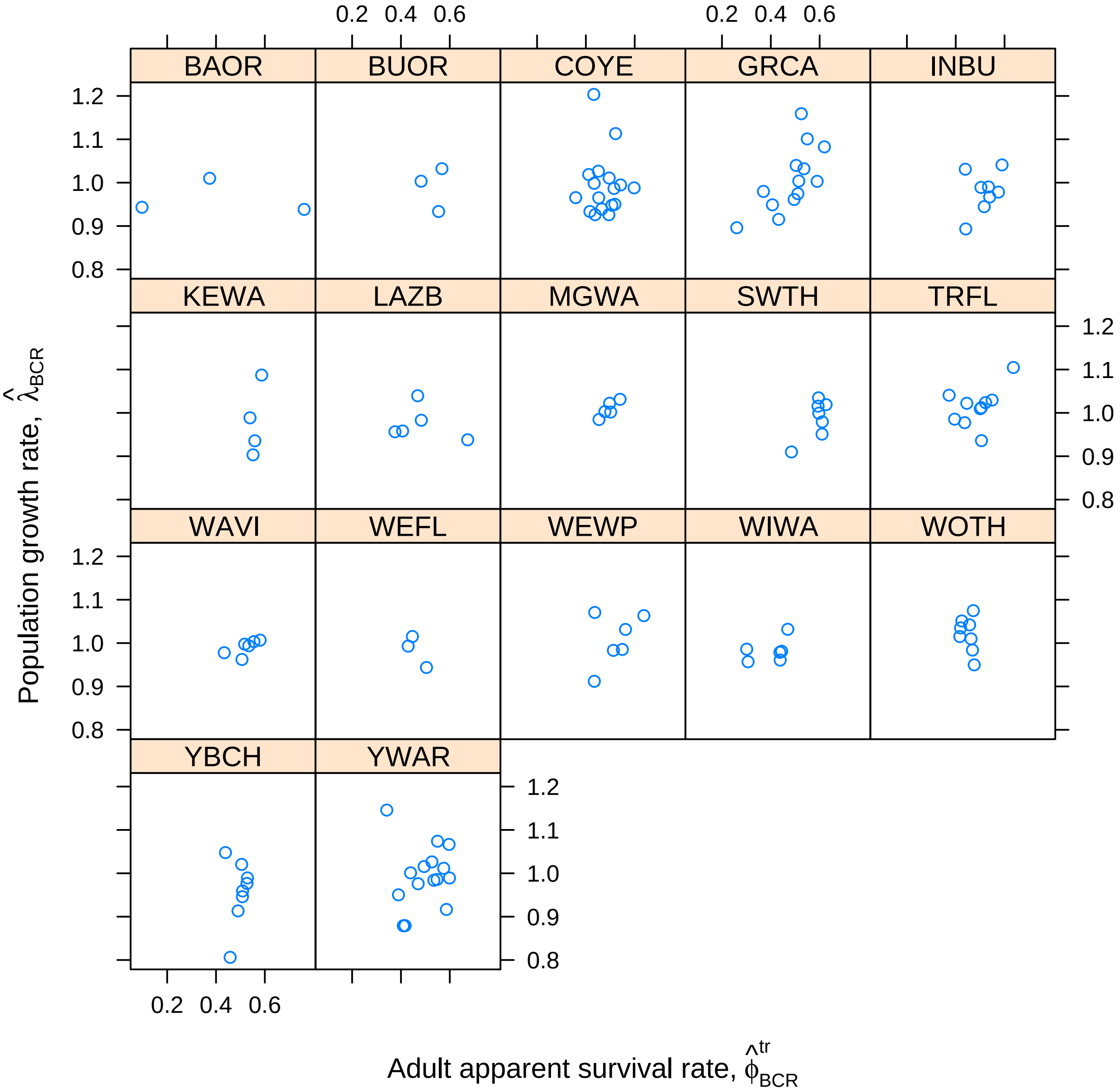


Figure 5. Scatterplots showing relationship between recruitment-rate estimates ($\hat{f}^{tr}_{BCR}$) and estimates of time-constant population growth rate (i.e., trend, $\hat{\lambda}_{BCR}$) from reverse-time Pradel models (see Methods for detail) based on 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data for 32 target species that showed strong evidence of spatial variation in population trend (Table 7).

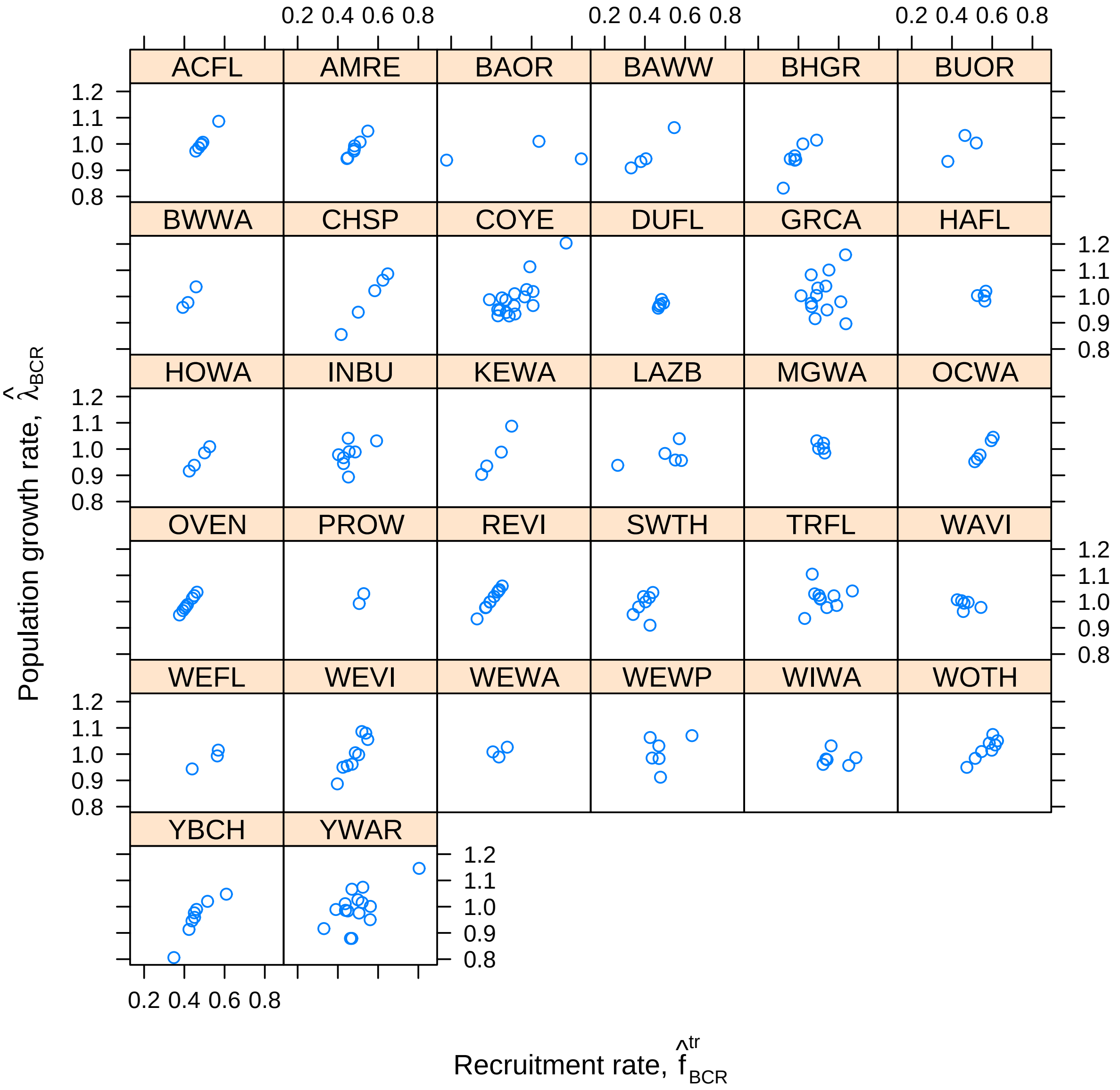


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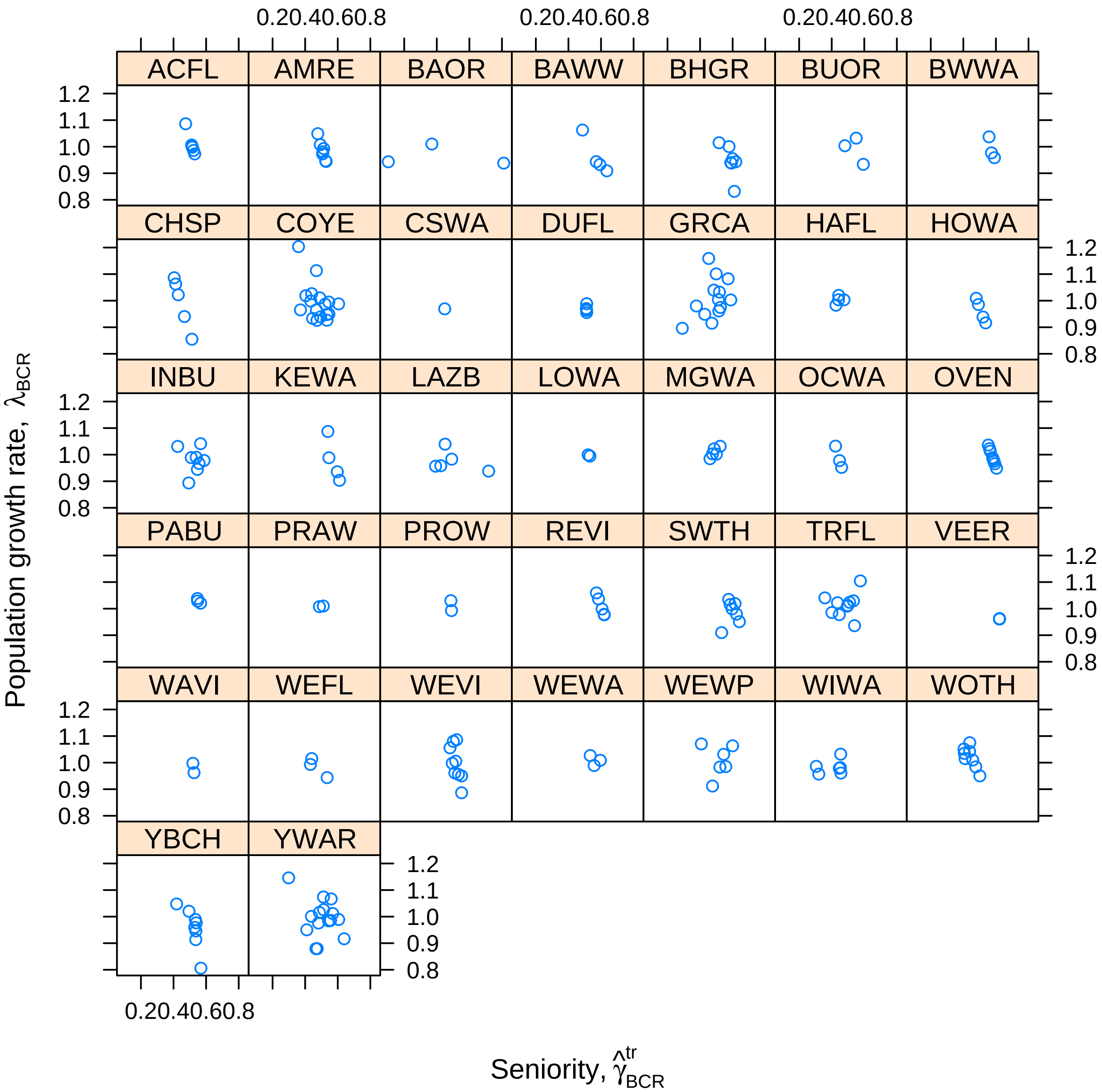
Figure 6. Scatterplots showing relationship between seniority estimates ($\hat{\gamma}^{tr}_{BCR}$) and estimates of time-constant population growth rate (i.e., trend, $\hat{\lambda}_{BCR}$) from reverse-time Pradel models (see Methods for detail) for 32 target species that showed strong evidence of spatial variation in population trend (Table 7).



Productivity, as measured by the MAPS reproductive index (RI_{BCR}) appeared to have little effect on recruitment and population growth rates for most species. Correlation between RI_{BCR} and recruitment-rate estimates ($\hat{f}^{tr}_{BCR}$) and population trend estimates ($\hat{\lambda}_{BCR}$) from the first set of Pradel reverse-time models (i.e., for models not including RI_{BCR} as a covariate of λ) was generally weak and not always positive (Figs.7 and 8). The strongest relationships between RI_{BCR} and $\hat{f}^{tr}_{BCR}$ and $\hat{\lambda}_{BCR}$ were for Black-and white Warbler. Additional species for which scatterplots suggested that RI_{BCR} was important to some degree in driving spatial variation in $\hat{f}^{tr}_{BCR}$ and $\hat{\lambda}_{BCR}$ included Bullock's Oriole, Blue-winged Warbler, Ovenbird, Prothonotary Warbler, Red-eyed Vireo, Swainson's Thrush, Worm-eating Warbler, and Western Wood-Pewee. We also found little statistical support for RI effects on population trend from our second set of Pradel models, which were conducted for a subset of five target species that were captured in sample sizes large enough for analysis in ≥ 10 BCRs (Table 8). Only one of the five species, Traill's Flycatcher (which is actually comprised of the two related species Willow and Alder Flycatcher) showed statistical support for RI_{BCR} effects on trend, and RI_{BCR} was negatively related to trend for that species. Two additional species, although showing little statistical support for models with RI as a covariate of trend, had significant regression coefficients from the 'best' model that included RI effects on λ (i.e., the one with the lowest AIC_c); one of these had a positive relationship between RI and trend (Red-eyed Vireo), while the other had a negative relationship with trend (Yellow Warbler).

We summarize the 39 target species with respect to the importance of productivity, recruitment rate, and adult apparent survival rate in driving variation in population trends among BCRs in Table 9. Overall, adult apparent survival and/or recruitment, but not productivity, appeared to be the principal drivers of spatial variation in trend for 19 of the 32 target species showing strong special variation in trend. Of these 19 species, recruitment alone appeared to be of primary importance for 12, recruitment and adult apparent survival together for four, and adult apparent survival alone for three. Productivity and recruitment together appeared to be an important driver of spatial variation in trends for nine species; two of these species also showed evidence of the importance of adult apparent survival in explaining trends. Demographic causes of trend were not clear for four species that showed at least some evidence of spatial variation in trend. Program-wide trend estimates from MAPS tended to be more positive for species for which we determined adult apparent survival or productivity to be important causes of variation in trend among BCRs than for those species for which these parameters did not appear to be important causes of variation in trend (Fig. 9). Of these two parameters, productivity appeared to be more important for increasing species (most species with productivity important had $\hat{\lambda} > 1$) while adult apparent survival seemed to be most important for species with relatively small declines (most species with adult apparent survival important had $\hat{\lambda} > 1$). In contrast, program-wide trends tended to substantially negative for species for which recruitment was important in driving spatial variation in trends, and were more negative than for species for which recruitment was not important in driving such spatial variation (Fig.9).

Figure 7. Scatterplots showing relationships between the 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) constant-effort productivity index (RI_{BCR} = young/adult summed across years) and time-constant recruitment-rate estimates ($\hat{f}^{tr}_{BCR}$) from capture-recapture models at the scale of BCRs.

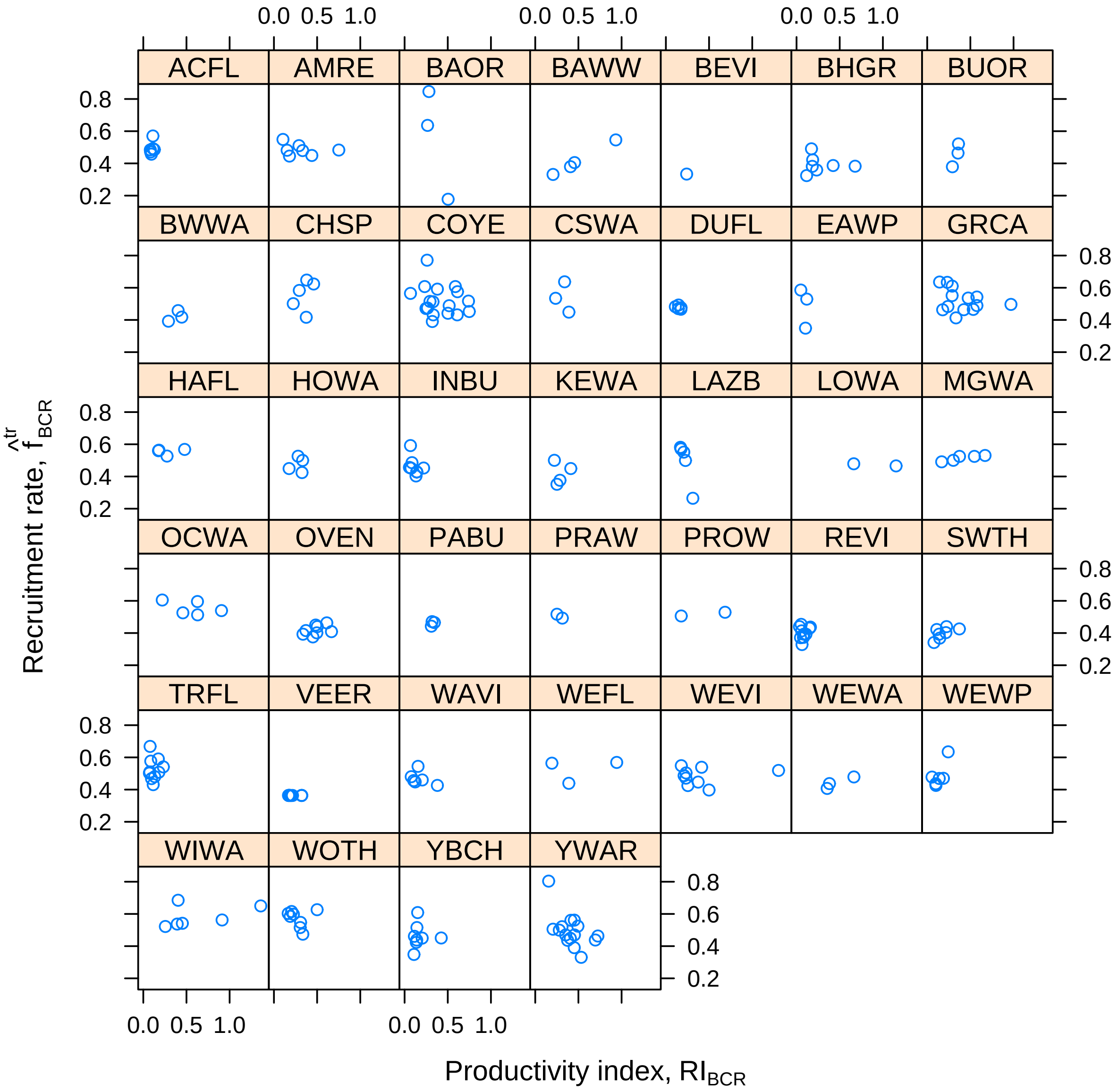


Figure 8. Scatterplots showing relationships between the 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) constant-effort productivity index (RI_{BCR} = young/adult summed across years) and time-constant population growth rate estimates (i.e., trend, $\hat{\lambda}_{BCR}$) from capture-recapture models at the scale of BCRs.

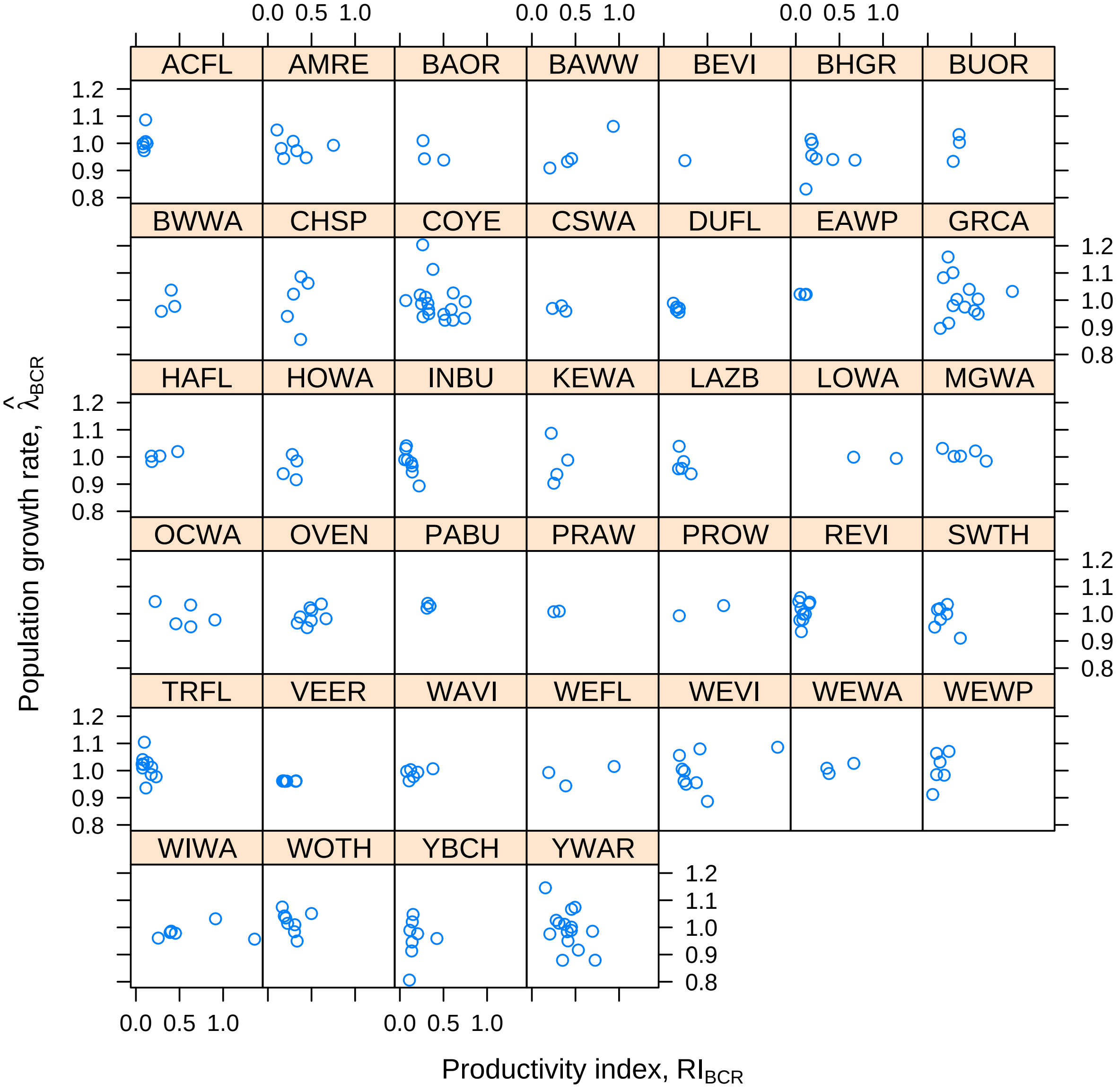


Table 8. Statistical support for models with RIBCR included as a covariate of population trend (λ_{BCR}) for five species captured in sample sizes large enough for analysis in ≥ 10 BCRs, and coefficient estimates, standard errors (SE), and confidence limits that describe the direction and significance of the relationship between RI_{BCR} and λ_{BCR}.

Species	$\sum_i w_i$ for models with RI_{BCR} effects on λ	Slope estimate	SE	95% lower limit	95% upper limit
Traill's Flycatcher	0.754	-1.156	0.202	-1.550	-0.760
Red-eyed Vireo	0.000	0.348	0.119	0.115	0.581
Gray Catbird	0.000	0.107	0.016	-0.021	0.042
Yellow Warbler	0.000	-0.122	0.028	-0.178	-0.066
Common Yellowthroat	0.000	-0.030	0.019	-0.068	0.008

Discussion

Based on trend estimates for the 39 target species from the MAPS 12-yr and BBS 42-yr data sets, particular conservation attention should be focused on six species that significantly declined in both data sets at the program-wide scale: Bell's Vireo, Veery, Blue-winged Warbler, Chestnut-sided Warbler, Common Yellowthroat, and Baltimore Oriole. Although overall correspondence between MAPS 12-yr and BBS 42-yr trend estimates was not great, program-wide estimates based on data from the same 12-yr time period (1992-2003) from the two programs were positively correlated for these 39 species ($r = 0.32$, $P < 0.05$; Saracco unpublished data; also see Saracco et al. 2008). Three of the species that declined at the program-wide scale in both data sets (Blue-winged Warbler, Chestnut-sided Warbler, and Common Yellowthroat), as well as an additional six species, Orange-crowned Warbler, Black-and-white Warbler, Wilson's Warbler, Yellow-breasted Chat, Chipping Sparrow, and Bullock's Oriole, also warrant special conservation consideration based on significant population declines in both programs/time periods in at least 1/3 of the BCRs included in analyses. Regional conservation priority based on these 39 target species should be focused on the Northern Pacific Rainforest (BCR 5), Atlantic Northern Forest (BCR 14), and New England/Mid-Atlantic Coast (BCR 30) regions. These regions had large numbers of significantly declining target species (5-9 in both programs), few significantly increasing target species (1 in each region/program), and many species that showed significant negative trends in both data sets (4 in each region).

Table 9. Trend direction, support for BCR-scale spatial variation, and demographic causes of trend for 39 target species based on 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data.

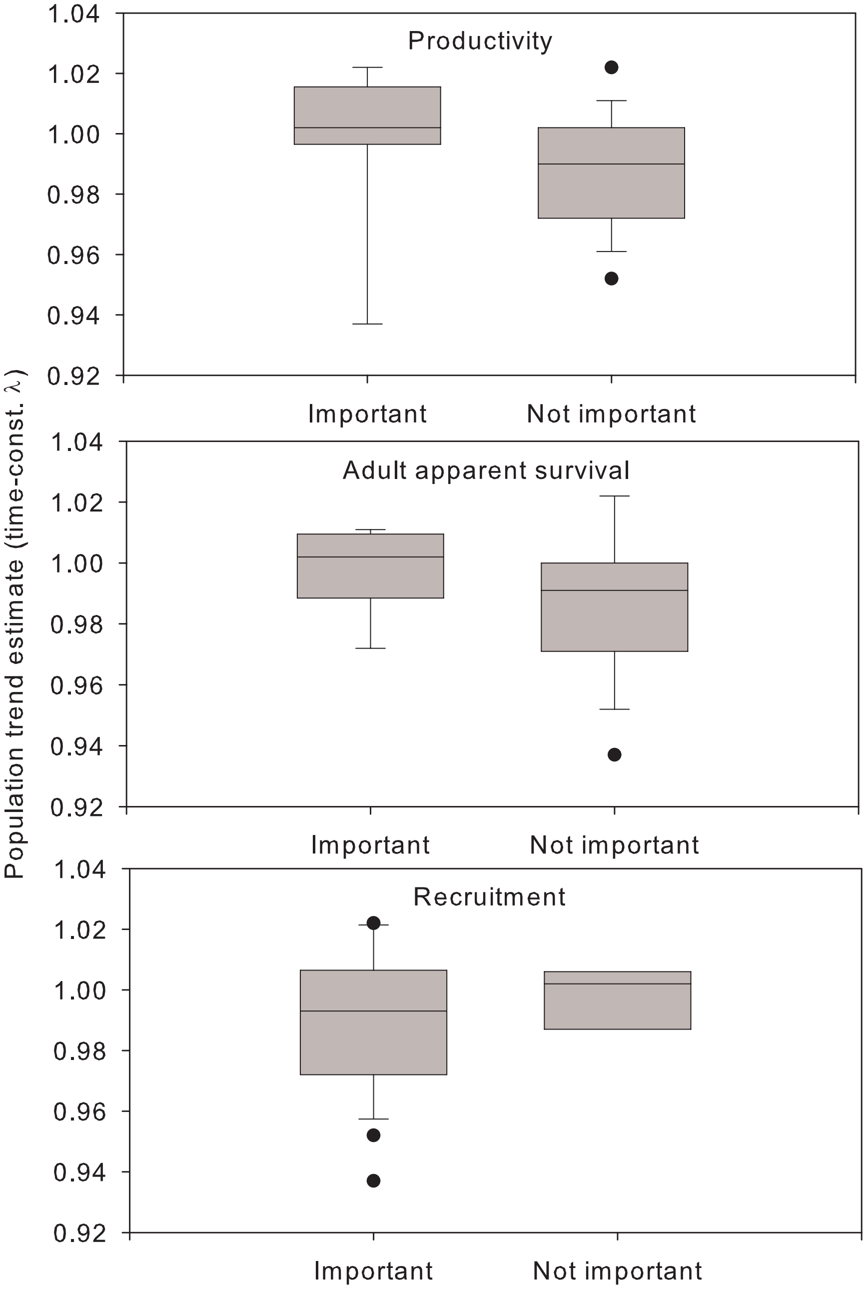
Species	1992-2003 MAPS trend [1]	Trend spatial variation? [2]	Demographic cause(s) of trend [3]
Western Wood-Pewee	+	X	SRP
Eastern Wood-Pewee	+	—	—
Acadian Flycatcher	-	X	R
Traill's Flycatcher	+	X	SR
Hammond's Flycatcher	+	X	?
Dusky Flycatcher	-*	X	R
Western Flycatcher	-*	X	R
White-eyed Vireo	+*	X	R
Bell's Vireo	-*	—	—
Warbling Vireo	-*	X	S
Red-eyed Vireo	-	X	RP
Veery	-*	—	—
Swainson's Thrush	+	X	SRP
Wood Thrush	-	X	R
Gray Catbird	+*	X	S
Blue-winged Warbler	-*	X	RP
Orange-crowned Warbler	-	X	R
Yellow Warbler	+*	X	SR
Chestnut-sided Warbler	-*	—	—
Prairie Warbler	-	—	—
Black-and-white Warbler	-	X	RP
American Redstart	-	X	R
Prothonotary Warbler	+	X	RP
Worm-eating Warbler	+	X	RP
Ovenbird	-	X	RP
Louisiana Waterthrush	+	—	—
Kentucky Warbler	-	X	R
MacGillivray's Warbler	+	X	S
Common Yellowthroat	-*	X	R
Hooded Warbler	-*	X	R
Wilson's Warbler	-	X	?
Yellow-breasted Chat	-*	X	SR
Chipping Sparrow	-*	X	R
Black-headed Grosbeak	-*	X	R
Lazuli Bunting	-*	X	?
Indigo Bunting	-	X	SR
Painted Bunting	+*	—	—
Bullock's Oriole	+	X	RP
Baltimore Oriole	-*	X	?

[1] Direction of trend estimates indicated by + (positive) or - (negative). Significance of trend estimate ($P < 0.05$) denoted with asterisk (see Table 3).

[2] X = Strong statistical support for BCR variation in trend (Table 6). — = Little support for BCR variation in trend.

[3] **S = Trends driven by adult apparent survival**. This designation is based on strong statistical support for spatial variation in trends *and* adult apparent survival (Table 6) and a positive relationship between trend and adult apparent survival rate estimates (Fig. 4). **R = Trends driven by recruitment**. This designation is based on strong statistical support for spatial variation in trends (see [2]) and a positive relationship between trend and recruitment-rate estimates (Fig. 5). **P = Trends driven by productivity**. This designation is based on positive relationships between productivity and recruitment rate estimates (Fig. 7) and between productivity and trend (Fig. 8). — = Demographic causes unclear because little evidence of spatial variation in trend. ? = Some indication of variation in trend among BCRs, but demographic causes unclear.

Figure 9. Box plots showing population trend estimates for groups of species determined based on whether or not ('important' v. 'not important') we determined productivity (RI_{BCR}), adult apparent survival rate (ϕ^{tr}_{BCR}) or recruitment rate (f^{tr}_{BCR}) to be important drivers of spatial variation in population trend (see Table 9). Boxes represent upper and lower quartiles (separated by median); whiskers represent 95 percentiles; dots represent outliers.



Although knowledge of trends can be useful for identifying species or species groups in need of management or conservation action, they may not provide the most useful information for directing such efforts. Demographic monitoring can provide greater focus for directing research into where and what types of management are most likely to yield the greatest conservation benefit (DeSante and Rosenberg 1998, DeSante et al. 2005*a*). Demographic monitoring can provide land managers with information as to whether management should be directed at increasing survival rates, increasing recruitment rates, or increasing productivity – distinguishing between these options is critical for migratory species because factors affecting these processes may largely act at different times of the year and in distinct geographic areas.

Although adult apparent survival rate contributed more to population trend than did recruitment rate for most (60%) the 230 species-BCR combinations considered, only a few species showed strong evidence of adult apparent survival-rate estimates driving spatial variation in regional trends. The most striking case of spatial variation in trend being driven largely by adult apparent survival was for Gray Catbird, a finding that supports previous published data for this species (DeSante et al. 2001). It is interesting to note, however, that positive relationships between adult apparent survival rate and population trend tended to be strongest for declining and stable populations; in some cases, apparent survival-rate estimates were relatively low in increasing populations ($\hat{\lambda}_{BCR} > 1$), suggesting density-dependent mortality as those populations approach or exceed carrying capacity.

Recruitment of new individuals – both immigrating adults and local and immigrating young from the previous year – was more important for driving spatial variation in population trends than was adult apparent survival for most target species. Recruitment-rate and trend estimates, however, were not strongly related to productivity in most cases (only nine species appeared to have trend positively related to productivity), indicating that the survival, rather than productivity, component of recruitment (especially first-year survival) was the primary driver of spatial variation in population trends for most species of migratory birds considered here. A notable exception was Black-and-white Warbler, a species that was significantly declining at MAPS stations in three of the four strata included in the analysis, and for which both recruitment and population trend appeared to increase linearly as a function of productivity. In addition to the general lack of correlation between productivity and recruitment or trend, we found significant negative relationships between productivity and population trend for two of five target species for which we included productivity effects (RI_{BCR}) in capture-recapture models (Traill's Flycatcher and Yellow Warbler). Negative relationships between productivity and trend could be another indicator of density dependence in some increasing populations. Only one of the five species included in models that allowed trend to vary as a function of productivity showed a significant positive relationship between productivity and trend, Red-eyed Vireo. Interestingly, this species had the most positive and highly significant increasing 42-yr program-wide BBS trend of all of the 39 species we considered.

It could be argued that our productivity index based on constant-effort capture data (*RI*) might not accurately reflect productivity (Sauer and Link 2004). Available evidence suggests otherwise. For example, capture rates often compare favorably with count data and indices of productivity are often positively correlated with local or regional nest success (Bart et al. 1999, Dunn and Ralph 2004). Differences in *RI* among nesting migratory guilds are often consistent with differences expected from theory and nest monitoring data (DeSante 1999), and *RI* often correlates with weather and habitat variables in expected ways (Nott et al. 2002; Nott et al. 2003). Although further investigation into the relationship between reproductive indices from mist-netting data and other productivity measures (e.g., estimates of nest success) is warranted, we suggest that sufficient evidence exists to be reasonably confident in the ecological significance of *RI*.

Emergent patterns from the above set of analyses suggest that adult survival of local residents (adult apparent survival rate) and, especially, survival components of recruitment (first-year survival and, perhaps, survival of potential immigrants) were more important drivers of spatial variation in 1992-2003 population trends for our 39 target species than was productivity. It should be noted, however, that productivity was important for some species (e.g., Black-and-white Warbler), and may have been especially important for species for which program-wide populations increased over the 12-year period (see Fig. 9). Adult apparent survival rate also appeared to be of slightly greater importance for species that had more positive program-wide trends; however, BCR-scale relationships between adult apparent survival rate and trend were typically strongest within the range of declining populations. Moreover, species for which recruitment, acting primarily through first-year survival of young, was an important driver of spatial variation in population trends tended to have the strongest declining populations. This suggests that increasing the first-year survival of young birds may be the most important conservation strategy for slowing population declines and achieving stable populations of migratory birds, followed by increasing adult survival. Our results also indicate, however, that although enhancing survival may be especially important for halting population declines and achieving stable populations, improvements in productivity may often be needed to further increase and, thus, to recover populations whose declines have been arrested.

Clearly, we are only beginning to tap the richness of the MAPS data set for increasing our understanding of the causes of spatial variation in landbird population trends and for informing their management and conservation. Based on data reported here, we cannot speak directly to the relative importance of immigration/emigration processes in driving patterns of recruitment and population trends. Nevertheless, dispersal of first-year birds between populations and source-sink dynamics (sensu Pulliam

1988) could be responsible for at least some of the apparent decoupling of productivity, recruitment, and population trend that we observed here. For example, we found adult apparent survival of Wood Thrushes to be inordinately low given their body mass (see Appendix), suggesting that emigration of second-year birds, as well as high adult mortality rates, may be contributing to the low apparent survival. Further, we found that productivity of Wood Thrushes was very low for MAPS stations in the Eastern Tallgrass Prairie region (BCR 22), yet the Wood Thrush population at these sites significantly increased at over the 12 years for which we had MAPS data (see Appendix). Our finding of low productivity is consistent with earlier studies that have shown elevated levels of nest predation and parasitism (Robinson et al. 1995) in this region where forests are highly fragmented (Ritters et al.2002), and suggests that these populations may be maintained by immigration from a larger region (Schlaepfer et al. 2002). In future analyses, we hope to include age-effects in our adult survival and recruitment models and examine age-effects in estimates of numbers of transients; these analytical improvements will allow us to investigate both emigration/immigration and source/sink phenomena, and provide insights into differences in demographic responses that might result from habitat destruction as opposed to habitat degradation.

Management Recommendations

Our findings of the general importance of survival, and particularly first-year survival, in driving trends suggests that managing to reverse population declines in migratory birds will largely hinge on the identification of habitat characteristics that promote high survival rates and the creation and conservation of habitats that contain these characteristics. Indeed, for many species it appears that increasing productivity of strongly declining populations without first (or at least simultaneously) managing to increase survival rates will be ineffective for recovering declining populations. Although mortality in many long-distant migrants may largely occur during migration (Sillett and Holmes 2002), habitat conditions during pre-migratory periods, particularly late winter, may be critical determinants of survival (Sillett et al. 2000). Thus efforts to reverse declines should probably be focused on identifying, improving, and conserving important over-wintering habitats for these species. Managers interested in identifying deficient demographic parameters for particular species or species-BCR combinations should refer to Table 9 and the Appendix.

Based on our growing awareness of the importance of processes acting during the non-breeding season in affecting the population dynamics of migratory birds, we have begun investigating spatial variation in, and habitat correlates of, apparent overwintering survival rates of migratory landbirds in the northern Neotropics (DeSante et al. 2005*b*). Preliminary results from this work suggests that structural habitat features (forest cover and complexity) and changes in habitat characteristics over the winter season due to seasonal drought are important factors influencing overwintering site persistence and survival rates of at least some migratory bird species (Saracco et al. 2008). These results suggest that we not only need to identify important over-wintering habitats and habitat features, but that we also need to understand habitat quality within the context of interactions between weather, climate, habitat, and landbird population parameters. The challenge to understand these ultimate (environmental) drivers of landbird population changes is pressing given that most natural over-wintering habitats in the northern Neotropics are considered “vulnerable, threatened, or endangered” due to direct human impacts (Olson and Dinerstein 1998), and that climate change (particularly reduction in precipitation) over much of this region during this century is predicted to be dramatic (IPCC 2007).

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Appendix. Model-averaged parameter estimates from capture-recapture models applied to 1992-2003 Monitoring Avian Productivity and Survivorship (MAPS) data and 1966-2007 population trend estimtates from the North American Breeding Bird Survey (BBS) for 39 target species in 25 Bird Conservation Regions (BCRs).

Species		MAPS 1992-2003									BBS 1966-2007		
				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations ^{a}	No. individ. ^{b}	$\hat{\phi}_{BCR}$ (SE) ^{c}	$\hat{\lambda}_{BCR}$ (SE) ^{d}	$\hat{\lambda}_{BCR}$ 95% CI ^{e}	$\hat{\phi}^{tr}_{BCR}$(SE) ^{f}	$\hat{f}^{tr}_{BCR}$ ^{g}	$\hat{\gamma}^{tr}_{BCR}$ ^{h}	RI_{BCR} ^{i}	No. routes ^{j}	Trend est. ^{k}	Trend 95% CI ^{l}
Western Wood-Pewee													
5	Northern Pacific Rainforest	18	207	0.505 (0.060)	0.983 (0.025)	(0.936, 1.033)	0.513 (0.078)	0.470	0.521	0.188	112	-1.6	(-3.9, 0.6)
9	Great Basin	21	570	0.468 (0.035)	0.985 (0.015)	(0.956, 1.015)	0.549 (0.039)	0.436	0.557	0.100	149	0.2	(-1.2, 1.5)
10	Northern Rockies	6	189	0.436 (0.055)	1.071 (0.027)	(1.019, 1.125)	0.437 (0.097)	0.634	0.408	0.243	173	-1.0	(-2.3, 0.2)
15	Sierra Nevada	15	393	0.505 (0.038)	1.031 (0.016)	(1.000, 1.064)	0.562 (0.045)	0.469	0.545	0.140	35	-1.8	(-3.2, -0.4)
16	Southern Rockies/Colorado Plateau	8	132	0.313 (0.078)	0.912 (0.045)	(0.829, 1.004)	0.434 (0.122)	0.477	0.476	0.056	142	-0.3	(-1.4, 0.9)
32	Coastal California	8	210	0.617 (0.054)	1.063 (0.028)	(1.010, 1.119)	0.637 (0.085)	0.426	0.599	0.101	78	-1.9	(-3.5, -0.3)
Eastern Wood-Pewee													
22	Eastern Tallgrass Prairie	17	205	0.433 (0.076)	1.020 (0.018)	(0.986, 1.055)	0.671 (0.101)	0.349	0.658	0.104	250	-0.5	(-1.3, 0.2)
24	Central Hardwoods	25	163	0.398 (0.079)	1.021 (0.018)	(0.987, 1.057)	0.492 (0.122)	0.529	0.482	0.119	131	-1.4	(-1.9, -0.9)
30	New England/Mid-Atlantic Coast	21	139	0.415 (0.069)	1.022 (0.018)	(0.987, 1.058)	0.436 (0.097)	0.586	0.427	0.049	125	-1.4	(-2.2, -0.5)
Acadian Flycatcher													
24	Central Hardwoods	27	1065	0.402 (0.017)	0.986 (0.011)	(0.964, 1.008)	0.515 (0.018)	0.471	0.522	0.085	112	-0.2	(-1.2, 0.8)
26	Mississippi Alluvial Valley	7	675	0.404 (0.018)	1.000 (0.013)	(0.975, 1.025)	0.514 (0.018)	0.485	0.514	0.128	25	2.7	(-4.2, 9.6)
27	Southeastern Coastal Plain	11	394	0.416 (0.028)	0.973 (0.020)	(0.934, 1.013)	0.516 (0.019)	0.457	0.530	0.094	221	0.3	(-0.5, 1.2)
28	Appalachian Mountains	10	122	0.379 (0.046)	1.006 (0.034)	(0.942, 1.076)	0.514 (0.019)	0.492	0.511	0.111	252	-1.2	(-1.6, -0.8)
29	Piedmont	9	191	0.420 (0.036)	1.086 (0.046)	(0.999, 1.181)	0.515 (0.019)	0.571	0.475	0.112	106	0.7	(-1.0, 2.4)
30	New England/Mid-Atlantic Coast	12	657	0.400 (0.019)	0.998 (0.011)	(0.976, 1.020)	0.514 (0.018)	0.484	0.515	0.082	60	0.5	(-0.3, 1.3)
Traill's Flycatcher													
4	Northwestern Interior Forest	9	390	0.239 (0.037)	0.985 (0.028)	(0.933, 1.041)	0.395 (0.082)	0.590	0.401	0.175	76	-0.6	(-1.9, 0.7)
5	Northern Pacific Rainforest	14	455	0.385 (0.033)	1.012 (0.016)	(0.981, 1.044)	0.505 (0.040)	0.508	0.499	0.180	102	-3.0	(-4.5, -1.4)
9	Great Basin	7	175	0.368 (0.058)	1.022 (0.026)	(0.973, 1.074)	0.445 (0.079)	0.577	0.436	0.087	85	-2.0	(-3.0, -0.9)
10	Northern Rockies	12	821	0.421 (0.028)	1.024 (0.012)	(1.000, 1.048)	0.522 (0.036)	0.502	0.510	0.071	154	0.8	(0.2, 1.4)
12	Boreal Hardwood Transition	4	352	0.441 (0.040)	1.029 (0.027)	(0.978, 1.084)	0.549 (0.056)	0.480	0.533	0.132	218	0.5	(-0.1, 1.0)
13	Lower Great Lakes/St. Lawrence Plain	8	279	0.319 (0.041)	0.977 (0.027)	(0.925, 1.032)	0.436 (0.068)	0.541	0.446	0.232	158	0.5	(-0.4, 1.4)
14	Atlantic Northern Forest	4	390	0.296 (0.042)	1.010 (0.016)	(0.979, 1.042)	0.500 (0.058)	0.509	0.496	0.076	235	0.2	(-0.4, 0.8)
16	Southern Rockies/Colorado Plateau	4	148	0.308 (0.075)	1.105 (0.048)	(1.014, 1.203)	0.636 (0.158)	0.468	0.576	0.096	35	-0.6	(-5.7, 4.4)
22	Eastern Tallgrass Prairie	4	381	0.263 (0.045)	1.041 (0.019)	(1.003, 1.079)	0.373 (0.102)	0.668	0.358	0.079	164	-0.5	(-1.9, 0.8)
23	Prairie Hardwood Transition	3	127	0.402 (0.072)	0.936 (0.051)	(0.840, 1.042)	0.505 (0.088)	0.431	0.540	0.114	122	0.8	(-0.3, 1.9)

		MAPS 1992-2003											
Species					Pradel model		Transient CJS model				BBS 1966-2007		
BCR no.	BCR name	No. stations [a]	No. individ.[b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est.[k]	Trend 95% CI [l]
Hammond's Flycatcher													
5	Northern Pacific Rainforest	16	324	0.395 (0.028)	1.020 (0.020)	(0.981, 1.060)	0.452 (0.037)	0.568	0.443	0.479	79	1.8	(0.3, 3.3)
9	Great Basin	17	441	0.387 (0.028)	1.003 (0.012)	(0.980, 1.026)	0.443 (0.033)	0.560	0.442	0.176	68	1.5	(-1.3, 4.3)
10	Northern Rockies	13	314	0.388 (0.028)	0.983 (0.022)	(0.940, 1.027)	0.419 (0.050)	0.564	0.427	0.182	131	1.2	(-0.5, 2.9)
15	Sierra Nevada	9	282	0.399 (0.031)	1.004 (0.014)	(0.977, 1.031)	0.477 (0.059)	0.527	0.475	0.275	24	0.0	(-2.4, 2.3)
Dusky Flycatcher													
5	Northern Pacific Rainforest	6	277	0.406 (0.037)	0.970 (0.015)	(0.942, 0.999)	0.494 (0.027)	0.476	0.509	0.176	38	-4.7	(-6.5, -2.9)
9	Great Basin	10	683	0.436 (0.029)	0.989 (0.016)	(0.958, 1.020)	0.506 (0.031)	0.483	0.512	0.109	96	-0.9	(-2.9, 1.1)
10	Northern Rockies	14	635	0.341 (0.030)	0.975 (0.011)	(0.953, 0.996)	0.482 (0.030)	0.492	0.495	0.146	149	0.1	(-3.5, 3.8)
15	Sierra Nevada	12	755	0.412 (0.030)	0.955 (0.014)	(0.929, 0.983)	0.489 (0.025)	0.466	0.512	0.174	29	1.7	(-2.9, 6.3)
16	Southern Rockies/Colorado Plateau	8	391	0.310 (0.051)	0.964 (0.017)	(0.930, 0.999)	0.493 (0.033)	0.471	0.512	0.144	93	1.4	(-0.8, 3.6)
Western Flycatcher													
5	Northern Pacific Rainforest	36	1527	0.444 (0.025)	0.944 (0.008)	(0.929, 0.959)	0.505 (0.028)	0.439	0.535	0.389	124	-0.7	(-1.9, 0.5)
9	Great Basin	13	339	0.399 (0.047)	0.993 (0.016)	(0.963, 1.024)	0.429 (0.069)	0.564	0.432	0.193	65	-1.3	(-2.8, 0.2)
32	Coastal California	17	1036	0.267 (0.035)	1.015 (0.011)	(0.993, 1.038)	0.447 (0.063)	0.568	0.440	0.943	58	-0.2	(-1.9, 1.4)
White-eyed Vireo													
20	Edwards Plateau	7	641	0.463 (0.026)	1.086 (0.016)	(1.055, 1.118)	0.567 (0.047)	0.519	0.522	1.305	16	9.6	(5.0, 14.2)
21	Oaks and Prairies	6	550	0.485 (0.032)	1.080 (0.016)	(1.048, 1.113)	0.541 (0.029)	0.539	0.501	0.414	51	5.6	(4.0, 7.2)
22	Eastern Tallgrass Prairie	5	186	0.426 (0.038)	1.005 (0.023)	(0.961, 1.052)	0.519 (0.035)	0.486	0.516	0.210	69	1.9	(-1.4, 5.2)
24	Central Hardwoods	23	652	0.426 (0.023)	0.950 (0.014)	(0.924, 0.977)	0.525 (0.023)	0.425	0.553	0.255	128	0.2	(-0.4, 0.9)
26	Mississippi Alluvial Valley	6	491	0.399 (0.031)	1.056 (0.017)	(1.023, 1.089)	0.508 (0.036)	0.548	0.481	0.178	40	-1.6	(-3.4, 0.2)
27	Southeastern Coastal Plain	10	211	0.362 (0.048)	0.956 (0.026)	(0.905, 1.009)	0.509 (0.045)	0.446	0.533	0.373	263	0.4	(-0.1, 0.9)
28	Appalachian Mountains	7	244	0.438 (0.038)	0.962 (0.031)	(0.902, 1.025)	0.491 (0.054)	0.471	0.511	0.232	209	-0.5	(-1.6, 0.7)
29	Piedmont	7	120	0.459 (0.048)	0.887 (0.035)	(0.821, 0.957)	0.489 (0.059)	0.397	0.552	0.500	116	1.4	(-0.1, 2.9)
30	New England/Mid-Atlantic Coast	9	232	0.346 (0.048)	0.998 (0.023)	(0.953, 1.044)	0.494 (0.055)	0.504	0.495	0.234	86	-1.4	(-2.1, -0.7)
Bell's Vireo													
22	Eastern Tallgrass Prairie	6	353	0.536 (0.045)	0.936 (0.017)	(0.904, 0.970)	0.603 (0.046)	0.334	0.644	0.241	92	-2.0	(-6.3, 2.4)

		MAPS 1992-2003									BBS 1966-2007		
Species				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations [a]	No. individ. [b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est. [k]	Trend 95% CI [l]
Warbling Vireo													
5	Northern Pacific Rainforest	24	662	0.418 (0.026)	0.962 (0.014)	(0.936, 0.990)	0.506 (0.038)	0.456	0.526	0.106	129	0.5	(-0.7, 1.7)
9	Great Basin	24	1189	0.448 (0.021)	0.997 (0.009)	(0.979, 1.016)	0.517 (0.028)	0.480	0.519	0.077	112	2.3	(1.5, 3.2)
10	Northern Rockies	23	862	0.451 (0.023)	0.994 (0.011)	(0.973, 1.015)	0.534 (0.029)	0.460	0.537	0.205	184	1.9	(0.9, 2.9)
15	Sierra Nevada	17	1462	0.344 (0.019)	0.978 (0.008)	(0.962, 0.994)	0.434 (0.027)	0.544	0.443	0.156	33	-0.2	(-2.3, 1.9)
16	Southern Rockies/Colorado Plateau	13	672	0.522 (0.029)	1.003 (0.015)	(0.974, 1.034)	0.555 (0.039)	0.448	0.554	0.123	114	0.0	(-0.8, 0.8)
32	Coastal California	7	1093	0.184 (0.021)	1.007 (0.010)	(0.988, 1.026)	0.581 (0.055)	0.426	0.577	0.379	52	-2.2	(-3.6, -0.8)
Red-eyed Vireo													
10	Northern Rockies	5	128	0.508 (0.054)	0.999 (0.026)	(0.948, 1.052)	0.606 (0.015)	0.393	0.607	0.109	75	-2.5	(-3.9, -1.2)
12	Boreal Hardwood Transition	8	378	0.541 (0.028)	1.059 (0.023)	(1.016, 1.105)	0.606 (0.015)	0.454	0.572	0.053	228	1.1	(0.7, 1.6)
13	Lower Great Lakes/St. Lawrence Plain	13	287	0.587 (0.054)	1.043 (0.028)	(0.988, 1.100)	0.606 (0.015)	0.437	0.581	0.160	164	3.3	(2.0, 4.5)
14	Atlantic Northern Forest	7	221	0.544 (0.032)	1.019 (0.025)	(0.971, 1.070)	0.606 (0.015)	0.413	0.594	0.060	243	1.8	(1.1, 2.5)
22	Eastern Tallgrass Prairie	15	409	0.526 (0.036)	1.045 (0.018)	(1.011, 1.080)	0.606 (0.015)	0.440	0.580	0.034	209	0.4	(-1.1, 1.9)
24	Central Hardwoods	28	1065	0.538 (0.021)	0.999 (0.011)	(0.977, 1.020)	0.606 (0.015)	0.393	0.607	0.085	128	1.5	(0.5, 2.6)
27	Southeastern Coastal Plain	18	353	0.536 (0.029)	0.934 (0.019)	(0.898, 0.972)	0.606 (0.015)	0.328	0.648	0.063	255	0.0	(-1.0, 1.0)
28	Appalachian Mountains	28	875	0.512 (0.042)	1.036 (0.013)	(1.011, 1.062)	0.606 (0.015)	0.431	0.584	0.151	335	0.9	(0.5, 1.2)
29	Piedmont	13	302	0.551 (0.031)	0.979 (0.023)	(0.935, 1.024)	0.606 (0.015)	0.373	0.619	0.080	132	1.7	(1.2, 2.2)
30	New England/Mid-Atlantic Coast	23	1483	0.560 (0.022)	0.977 (0.008)	(0.962, 0.992)	0.606 (0.015)	0.371	0.620	0.046	128	-1.3	(-1.7, -0.9)
Veery													
10	Northern Rockies	5	160	0.500 (0.020)	0.962 (0.008)	(0.947, 0.977)	0.598 (0.014)	0.364	0.622	0.168	71	-1.1	(-3.1, 0.9)
12	Boreal Hardwood Transition	7	370	0.500 (0.017)	0.962 (0.007)	(0.948, 0.976)	0.598 (0.014)	0.364	0.622	0.183	223	-2.0	(-2.5, -1.4)
13	Lower Great Lakes/St. Lawrence Plain	9	217	0.479 (0.034)	0.962 (0.008)	(0.947, 0.977)	0.598 (0.014)	0.364	0.621	0.322	143	-0.8	(-1.9, 0.4)
14	Atlantic Northern Forest	7	264	0.491 (0.021)	0.961 (0.007)	(0.947, 0.975)	0.597 (0.014)	0.363	0.622	0.196	233	-2.0	(-2.6, -1.4)
28	Appalachian Mountains	13	918	0.504 (0.015)	0.961 (0.007)	(0.948, 0.974)	0.598 (0.014)	0.363	0.622	0.173	133	-0.3	(-1.1, 0.6)
29	Piedmont	4	288	0.505 (0.018)	0.961 (0.007)	(0.948, 0.975)	0.598 (0.014)	0.364	0.622	0.215	25	2.0	(-0.6, 4.6)
30	New England/Mid-Atlantic Coast	9	324	0.483 (0.028)	0.961 (0.007)	(0.947, 0.975)	0.598 (0.014)	0.363	0.622	0.320	49	-0.7	(-1.5, 0.2)

		MAPS 1992-2003									BBS 1966-2007		
Species				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations [a]	No. individ.[b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est.[k]	Trend 95% CI [l]
Swainson's Thrush													
4	Northwestern Interior Forest	12	632	0.446 (0.024)	0.910 (0.016)	(0.880, 0.941)	0.485 (0.034)	0.425	0.533	0.372	82	0.6	(-0.4, 1.5)
5	Northern Pacific Rainforest	44	5645	0.482 (0.007)	0.999 (0.004)	(0.991, 1.007)	0.597 (0.008)	0.403	0.597	0.216	122	-0.6	(-1.4, 0.2)
9	Great Basin	12	1083	0.521 (0.014)	1.016 (0.009)	(0.999, 1.033)	0.594 (0.017)	0.422	0.585	0.111	62	0.6	(-0.3, 1.6)
10	Northern Rockies	25	2039	0.525 (0.012)	0.979 (0.006)	(0.967, 0.992)	0.611 (0.015)	0.369	0.624	0.145	151	-0.4	(-1.3, 0.6)
14	Atlantic Northern Forest	6	123	0.646 (0.048)	1.019 (0.042)	(0.941, 1.104)	0.626 (0.066)	0.393	0.615	0.138	180	-1.6	(-2.7, -0.6)
16	Southern Rockies/Colorado Plateau	5	227	0.654 (0.040)	0.951 (0.029)	(0.896, 1.009)	0.610 (0.056)	0.341	0.641	0.079	39	0.5	(-4.3, 5.2)
32	Coastal California	9	2311	0.332 (0.012)	1.035 (0.007)	(1.022, 1.048)	0.595 (0.019)	0.440	0.575	0.224	23	-1.0	(-4.1, 2.1)
Wood Thrush													
13	Lower Great Lakes/St. Lawrence Plain	10	219	0.362 (0.048)	1.035 (0.030)	(0.979, 1.094)	0.420 (0.069)	0.615	0.406	0.204	158	-1.1	(-2.4, 0.1)
22	Eastern Tallgrass Prairie	9	261	0.516 (0.042)	1.075 (0.024)	(1.029, 1.123)	0.472 (0.052)	0.603	0.439	0.165	168	0.3	(-1.7, 2.4)
23	Prairie Hardwood Transition	5	141	0.407 (0.062)	1.051 (0.037)	(0.982, 1.125)	0.425 (0.087)	0.626	0.404	0.500	117	0.4	(-0.7, 1.5)
24	Central Hardwoods	27	1291	0.432 (0.020)	1.010 (0.011)	(0.989, 1.031)	0.463 (0.025)	0.547	0.458	0.308	125	-0.7	(-1.3, -0.1)
27	Southeastern Coastal Plain	12	688	0.394 (0.028)	1.042 (0.017)	(1.010, 1.075)	0.457 (0.038)	0.585	0.438	0.188	249	-1.8	(-2.8, -0.9)
28	Appalachian Mountains	28	869	0.327 (0.027)	1.015 (0.013)	(0.990, 1.041)	0.417 (0.041)	0.598	0.411	0.225	337	-1.8	(-2.2, -1.3)
29	Piedmont	14	885	0.361 (0.024)	0.984 (0.012)	(0.961, 1.007)	0.468 (0.032)	0.516	0.476	0.305	133	-1.7	(-2.5, -1.0)
30	New England/Mid-Atlantic Coast	24	1589	0.389 (0.016)	0.950 (0.008)	(0.934, 0.966)	0.476 (0.020)	0.474	0.501	0.335	127	-2.3	(-2.9, -1.7)
Gray Catbird													
10	Northern Rockies	8	692	0.439 (0.025)	1.101 (0.015)	(1.073, 1.130)	0.549 (0.036)	0.551	0.499	0.288	77	4.9	(-0.4, 10.2)
11	Prairie Potholes	5	436	0.528 (0.027)	1.083 (0.017)	(1.051, 1.115)	0.619 (0.035)	0.463	0.572	0.179	171	0.4	(-1.0, 1.8)
12	Boreal Hardwood Transition	4	141	0.235 (0.049)	0.896 (0.026)	(0.847, 0.948)	0.261 (0.077)	0.636	0.291	0.143	175	-1.7	(-2.4, -1.1)
13	Lower Great Lakes/St. Lawrence Plain	11	829	0.433 (0.024)	1.004 (0.017)	(0.971, 1.038)	0.515 (0.035)	0.489	0.513	0.576	162	0.0	(-0.8, 0.7)
14	Atlantic Northern Forest	5	305	0.275 (0.035)	0.949 (0.023)	(0.905, 0.995)	0.407 (0.059)	0.542	0.429	0.576	217	-2.0	(-2.6, -1.5)
16	Southern Rockies/Colorado Plateau	6	202	0.549 (0.047)	1.159 (0.036)	(1.091, 1.231)	0.525 (0.075)	0.634	0.453	0.233	26	5.5	(0.1, 10.9)
22	Eastern Tallgrass Prairie	18	2290	0.418 (0.015)	1.040 (0.008)	(1.025, 1.055)	0.504 (0.021)	0.536	0.485	0.475	252	0.8	(-0.1, 1.6)
23	Prairie Hardwood Transition	9	1083	0.440 (0.019)	1.032 (0.010)	(1.012, 1.053)	0.536 (0.026)	0.496	0.519	0.970	128	0.6	(0.2, 1.0)
24	Central Hardwoods	10	690	0.345 (0.024)	0.915 (0.014)	(0.888, 0.943)	0.432 (0.038)	0.483	0.472	0.239	120	-2.3	(-3.3, -1.4)
27	Southeastern Coastal Plain	7	146	0.256 (0.050)	0.980 (0.031)	(0.922, 1.042)	0.370 (0.088)	0.610	0.377	0.289	206	-1.4	(-2.7, 0.0)
28	Appalachian Mountains	20	1511	0.422 (0.017)	0.961 (0.010)	(0.943, 0.980)	0.496 (0.024)	0.466	0.516	0.534	331	0.0	(-0.4, 0.5)
29	Piedmont	9	1339	0.519 (0.016)	1.003 (0.008)	(0.987, 1.019)	0.590 (0.021)	0.413	0.588	0.333	127	1.0	(-0.3, 2.2)
30	New England/Mid-Atlantic Coast	22	2521	0.423 (0.013)	0.975 (0.007)	(0.961, 0.989)	0.511 (0.019)	0.464	0.524	0.424	129	-0.1	(-0.7, 0.6)

Species		MAPS 1992-2003									BBS 1966-2007		
					Pradel model		Transient CJS model						
BCR no.	BCR name	No. stations ^{a}	No. individ. ^{b}	$\hat{\phi}_{BCR}$ (SE) ^{c}	$\hat{\lambda}_{BCR}$ (SE) ^{d}	$\hat{\lambda}_{BCR}$ 95% CI ^{e}	$\hat{\phi}^{tr}_{BCR}$(SE) ^{f}	$\hat{f}^{tr}_{BCR}$ ^{g}	$\hat{\gamma}^{tr}_{BCR}$ ^{h}	RI_{BCR} ^{i}	No. routes ^{j}	Trend est. ^{k}	Trend 95% CI ^{l}
Blue-winged Warbler													
23	Prairie Hardwood Transition	3	138	0.512 (0.062)	1.037 (0.032)	(0.977, 1.101)	0.579 (0.044)	0.458	0.558	0.404	61	0.8	(-2.5, 4.2)
24	Central Hardwoods	13	586	0.472 (0.033)	0.959 (0.014)	(0.931, 0.987)	0.566 (0.034)	0.392	0.591	0.292	67	-3.3	(-5.8, -0.9)
28	Appalachian Mountains	7	123	0.361 (0.099)	0.977 (0.033)	(0.914, 1.044)	0.559 (0.051)	0.418	0.572	0.445	175	-0.5	(-1.3, 0.3)
Orange-crowned Warbler													
4	Northwestern Interior Forest	11	539	0.332 (0.030)	0.977 (0.018)	(0.942, 1.014)	0.438 (0.020)	0.539	0.448	0.905	75	-1.3	(-3.2, 0.5)
5	Northern Pacific Rainforest	24	1572	0.373 (0.023)	0.952 (0.009)	(0.935, 0.969)	0.439 (0.020)	0.513	0.461	0.629	128	-2.6	(-3.8, -1.3)
10	Northern Rockies	12	333	0.339 (0.037)	0.963 (0.017)	(0.931, 0.996)	0.437 (0.021)	0.526	0.454	0.458	128	0.1	(-1.4, 1.6)
16	Southern Rockies/Colorado Plateau	4	165	0.435 (0.075)	1.045 (0.034)	(0.980, 1.114)	0.440 (0.024)	0.605	0.421	0.220	59	3.4	(1.2, 5.5)
32	Coastal California	16	1434	0.301 (0.029)	1.032 (0.009)	(1.014, 1.050)	0.437 (0.021)	0.595	0.423	0.628	60	-1.8	(-3.1, -0.4)
Yellow Warbler													
4	Northwestern Interior Forest	5	566	0.293 (0.024)	0.879 (0.019)	(0.843, 0.917)	0.417 (0.041)	0.463	0.474	0.726	75	-2.7	(-6.0, 0.6)
5	Northern Pacific Rainforest	14	880	0.431 (0.023)	1.026 (0.011)	(1.005, 1.048)	0.527 (0.032)	0.499	0.513	0.279	103	-1.5	(-3.1, 0.0)
9	Great Basin	21	1588	0.450 (0.019)	1.012 (0.013)	(0.987, 1.037)	0.575 (0.026)	0.436	0.569	0.375	161	-0.2	(-1.9, 1.5)
10	Northern Rockies	14	1215	0.440 (0.018)	1.074 (0.011)	(1.053, 1.095)	0.550 (0.023)	0.524	0.512	0.494	200	-1.1	(-2.0, -0.3)
11	Prairie Potholes	7	786	0.497 (0.020)	0.986 (0.011)	(0.965, 1.007)	0.548 (0.026)	0.438	0.556	0.696	231	1.5	(0.7, 2.2)
12	Boreal Hardwood Transition	4	125	0.284 (0.051)	1.001 (0.035)	(0.934, 1.073)	0.439 (0.090)	0.562	0.439	0.453	196	-0.4	(-1.2, 0.5)
13	Lower Great Lakes/St. Lawrence Plain	9	1112	0.510 (0.020)	0.917 (0.013)	(0.891, 0.943)	0.586 (0.028)	0.330	0.639	0.532	165	0.4	(-0.2, 0.9)
14	Atlantic Northern Forest	5	162	0.298 (0.053)	0.950 (0.029)	(0.895, 1.009)	0.390 (0.091)	0.560	0.410	0.414	230	-0.8	(-1.5, -0.1)
15	Sierra Nevada	9	641	0.442 (0.021)	0.989 (0.013)	(0.965, 1.014)	0.599 (0.029)	0.390	0.606	0.452	31	-1.7	(-4.3, 0.8)
16	Southern Rockies/Colorado Plateau	15	2678	0.514 (0.014)	1.067 (0.008)	(1.050, 1.083)	0.597 (0.018)	0.470	0.560	0.454	133	0.5	(-0.7, 1.7)
22	Eastern Tallgrass Prairie	6	838	0.485 (0.023)	0.984 (0.011)	(0.963, 1.005)	0.535 (0.032)	0.449	0.544	0.406	190	1.2	(-0.1, 2.6)
23	Prairie Hardwood Transition	7	219	0.418 (0.052)	1.016 (0.028)	(0.962, 1.072)	0.495 (0.095)	0.521	0.487	0.310	129	1.8	(1.0, 2.7)
28	Appalachian Mountains	8	248	0.388 (0.044)	0.879 (0.024)	(0.833, 0.927)	0.410 (0.073)	0.469	0.466	0.352	304	-0.3	(-0.9, 0.2)
30	New England/Mid-Atlantic Coast	8	233	0.386 (0.051)	0.976 (0.025)	(0.929, 1.025)	0.471 (0.088)	0.505	0.482	0.206	107	0.8	(0.1, 1.4)
32	Coastal California	6	201	0.404 (0.065)	1.146 (0.046)	(1.060, 1.239)	0.342 (0.093)	0.804	0.298	0.155	57	-0.9	(-5.1, 3.4)
Chestnut-sided Warbler													
12	Boreal Hardwood Transition	5	426	0.372 (0.037)	0.969 (0.016)	(0.938, 1.002)	0.435 (0.047)	0.534	0.449	0.236	220	-0.4	(-1.0, 0.2)
14	Atlantic Northern Forest	4	148	0.236 (0.056)	0.979 (0.023)	(0.934, 1.026)	0.342 (0.096)	0.637	0.350	0.340	232	-1.1	(-1.9, -0.3)
28	Appalachian Mountains	7	254	0.469 (0.040)	0.959 (0.020)	(0.921, 0.999)	0.511 (0.048)	0.449	0.532	0.390	167	1.4	(0.2, 2.5)

Species		MAPS 1992-2003									BBS 1966-2007		
				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations [a]	No. individ. [b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est. [k]	Trend 95% CI [l]
Prairie Warbler													
24	Central Hardwoods	13	374	0.486 (0.057)	1.010 (0.017)	(0.978, 1.043)	0.517 (0.057)	0.493	0.512	0.314	99	-2.5	(-3.2, -1.7)
27	Southeastern Coastal Plain	4	168	0.424 (0.076)	1.008 (0.019)	(0.970, 1.046)	0.491 (0.069)	0.517	0.487	0.251	192	-1.0	(-2.3, 0.3)
Black-and-white Warbler													
12	Boreal Hardwood Transition	6	141	0.451 (0.061)	0.933 (0.026)	(0.884, 0.985)	0.553 (0.051)	0.380	0.593	0.409	209	-0.5	(-1.3, 0.3)
14	Atlantic Northern Forest	11	241	0.486 (0.043)	0.944 (0.023)	(0.900, 0.989)	0.539 (0.045)	0.405	0.571	0.455	236	-1.7	(-2.4, -1.0)
28	Appalachian Mountains	15	224	0.457 (0.055)	1.062 (0.023)	(1.018, 1.109)	0.517 (0.065)	0.546	0.486	0.933	255	-2.6	(-3.7, -1.5)
30	New England/Mid-Atlantic Coast	12	235	0.542 (0.067)	0.909 (0.024)	(0.863, 0.958)	0.578 (0.066)	0.331	0.635	0.206	100	-3.0	(-4.9, -1.1)
American Redstart													
10	Northern Rockies	8	388	0.370 (0.034)	1.007 (0.016)	(0.977, 1.039)	0.497 (0.025)	0.510	0.493	0.290	76	-1.4	(-2.9, 0.1)
12	Boreal Hardwood Transition	7	540	0.400 (0.034)	0.981 (0.014)	(0.953, 1.010)	0.499 (0.023)	0.482	0.509	0.152	221	-1.3	(-3.3, 0.7)
13	Lower Great Lakes/St. Lawrence Plain	7	207	0.397 (0.056)	0.944 (0.030)	(0.887, 1.005)	0.499 (0.029)	0.445	0.529	0.180	138	0.6	(-0.3, 1.5)
14	Atlantic Northern Forest	10	503	0.395 (0.032)	0.973 (0.017)	(0.941, 1.006)	0.493 (0.028)	0.480	0.507	0.332	242	-1.8	(-2.7, -0.9)
22	Eastern Tallgrass Prairie	5	162	0.328 (0.072)	1.049 (0.035)	(0.982, 1.121)	0.501 (0.035)	0.549	0.477	0.105	38	-3.3	(-8.9, 2.2)
28	Appalachian Mountains	16	1436	0.503 (0.024)	0.993 (0.008)	(0.977, 1.009)	0.510 (0.025)	0.483	0.514	0.751	254	0.2	(-1.1, 1.5)
30	New England/Mid-Atlantic Coast	7	185	0.411 (0.047)	0.947 (0.026)	(0.898, 0.998)	0.498 (0.028)	0.449	0.526	0.438	82	0.4	(-1.1, 2.0)
Prothonotary Warbler													
26	Mississippi Alluvial Valley	5	254	0.464 (0.063)	0.993 (0.026)	(0.944, 1.045)	0.487 (0.065)	0.506	0.490	0.177	39	-2.4	(-5.3, 0.4)
27	Southeastern Coastal Plain	7	313	0.475 (0.060)	1.030 (0.020)	(0.991, 1.070)	0.501 (0.063)	0.529	0.487	0.685	221	-0.9	(-2.1, 0.3)
Worm-eating Warbler													
24	Central Hardwoods	8	224	0.466 (0.050)	0.989 (0.026)	(0.940, 1.041)	0.552 (0.058)	0.437	0.558	0.381	48	1.9	(-0.4, 4.1)
28	Appalachian Mountains	10	338	0.385 (0.051)	1.027 (0.022)	(0.984, 1.071)	0.548 (0.062)	0.479	0.534	0.664	189	-1.7	(-3.0, -0.4)
30	New England/Mid-Atlantic Coast	8	280	0.521 (0.043)	1.009 (0.016)	(0.977, 1.042)	0.601 (0.052)	0.407	0.596	0.355	54	0.1	(-2.8, 2.9)

Species		MAPS 1992-2003									BBS 1966-2007		
				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations [a]	No. individ.[b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est.[k]	Trend 95% CI [l]
Ovenbird													
12	Boreal Hardwood Transition	7	364	0.474 (0.014)	0.989 (0.019)	(0.951, 1.027)	0.573 (0.015)	0.416	0.580	0.371	226	-0.1	(-0.4, 0.3)
13	Lower Great Lakes/St. Lawrence Plain	8	168	0.473 (0.014)	0.966 (0.027)	(0.914, 1.020)	0.573 (0.015)	0.393	0.593	0.337	142	0.2	(-0.5, 1.0)
14	Atlantic Northern Forest	10	306	0.473 (0.014)	0.949 (0.021)	(0.908, 0.991)	0.573 (0.015)	0.376	0.604	0.450	239	0.1	(-0.5, 0.7)
24	Central Hardwoods	21	572	0.472 (0.015)	1.022 (0.015)	(0.993, 1.053)	0.573 (0.015)	0.450	0.560	0.483	61	0.7	(-1.2, 2.7)
27	Southeastern Coastal Plain	13	732	0.473 (0.014)	1.036 (0.015)	(1.008, 1.065)	0.573 (0.015)	0.463	0.553	0.613	63	1.2	(-0.7, 3.1)
28	Appalachian Mountains	25	1054	0.474 (0.014)	1.013 (0.011)	(0.992, 1.034)	0.573 (0.015)	0.440	0.566	0.502	315	1.5	(0.8, 2.2)
29	Piedmont	10	416	0.473 (0.014)	0.982 (0.016)	(0.951, 1.013)	0.573 (0.015)	0.409	0.584	0.667	95	1.8	(0.3, 3.4)
30	New England/Mid-Atlantic Coast	24	828	0.474 (0.014)	0.975 (0.011)	(0.953, 0.997)	0.573 (0.015)	0.402	0.588	0.496	122	-0.3	(-1.0, 0.3)
Louisiana Waterthrush													
24	Central Hardwoods	11	272	0.385 (0.039)	0.999 (0.018)	(0.965, 1.035)	0.520 (0.042)	0.479	0.521	0.663	72	2.7	(0.6, 4.8)
30	New England/Mid-Atlantic Coast	6	183	0.408 (0.037)	0.995 (0.018)	(0.960, 1.031)	0.529 (0.041)	0.466	0.532	1.153	55	1.0	(-1.8, 3.8)
Kentucky Warbler													
22	Eastern Tallgrass Prairie	9	263	0.510 (0.039)	1.087 (0.023)	(1.044, 1.133)	0.587 (0.048)	0.501	0.540	0.222	54	1.2	(-1.2, 3.6)
24	Central Hardwoods	29	1333	0.439 (0.017)	0.989 (0.010)	(0.970, 1.007)	0.539 (0.020)	0.449	0.546	0.411	115	0.0	(-0.9, 0.9)
26	Mississippi Alluvial Valley	5	165	0.359 (0.051)	0.903 (0.025)	(0.856, 0.953)	0.552 (0.053)	0.352	0.611	0.251	18	-2.8	(-7.2, 1.7)
30	New England/Mid-Atlantic Coast	5	126	0.443 (0.040)	0.936 (0.024)	(0.889, 0.985)	0.559 (0.048)	0.377	0.597	0.287	52	-3.2	(-4.2, -2.1)
MacGillivray's Warbler													
5	Northern Pacific Rainforest	29	2092	0.353 (0.013)	0.985 (0.007)	(0.971, 0.999)	0.454 (0.022)	0.531	0.461	0.670	114	-1.4	(-2.7, -0.1)
9	Great Basin	21	1534	0.380 (0.015)	1.003 (0.008)	(0.987, 1.019)	0.478 (0.019)	0.525	0.477	0.374	86	-1.6	(-2.9, -0.2)
10	Northern Rockies	22	1930	0.414 (0.014)	1.002 (0.007)	(0.988, 1.016)	0.501 (0.018)	0.500	0.500	0.302	146	0.8	(-0.3, 1.9)
15	Sierra Nevada	15	1241	0.385 (0.015)	1.022 (0.009)	(1.004, 1.041)	0.497 (0.020)	0.525	0.487	0.547	28	-0.6	(-5.0, 3.7)
16	Southern Rockies/Colorado Plateau	11	616	0.477 (0.030)	1.031 (0.017)	(0.998, 1.066)	0.540 (0.047)	0.491	0.524	0.168	90	-0.4	(-1.9, 1.1)

		MAPS 1992-2003											
Species				Pradel model			Transient CJS model				BBS 1966-2007		
BCR no.	BCR name	No. stations [a]	No. individ. [b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est. [k]	Trend 95% CI [l]
<u>Common Yellowthroat</u>													
5	Northern Pacific Rainforest	8	476	0.368 (0.026)	1.026 (0.015)	(0.997, 1.057)	0.451 (0.035)	0.575	0.440	0.612	88	0.9	(-0.4, 2.2)
9	Great Basin	9	479	0.337 (0.035)	0.926 (0.017)	(0.893, 0.961)	0.494 (0.059)	0.432	0.534	0.610	86	1.7	(-1.5, 4.8)
10	Northern Rockies	13	1092	0.453 (0.016)	0.987 (0.009)	(0.969, 1.005)	0.515 (0.021)	0.471	0.522	0.248	137	1.4	(0.3, 2.5)
11	Prairie Potholes	5	275	0.371 (0.043)	1.019 (0.040)	(0.943, 1.101)	0.412 (0.069)	0.607	0.404	0.233	211	0.0	(-0.6, 0.7)
12	Boreal Hardwood Transition	8	379	0.504 (0.035)	1.113 (0.025)	(1.065, 1.164)	0.522 (0.049)	0.592	0.469	0.379	231	-0.6	(-1.1, 0.0)
13	Lower Great Lakes/St. Lawrence Plain	10	487	0.375 (0.028)	0.926 (0.018)	(0.892, 0.961)	0.438 (0.042)	0.488	0.473	0.516	164	0.4	(0.0, 0.8)
14	Atlantic Northern Forest	11	455	0.363 (0.031)	0.948 (0.017)	(0.915, 0.982)	0.506 (0.050)	0.441	0.534	0.503	244	-0.8	(-1.4, -0.2)
22	Eastern Tallgrass Prairie	20	1063	0.394 (0.021)	1.011 (0.011)	(0.990, 1.032)	0.495 (0.030)	0.516	0.490	0.294	255	-0.7	(-1.2, -0.3)
23	Prairie Hardwood Transition	9	687	0.280 (0.021)	0.933 (0.014)	(0.906, 0.961)	0.416 (0.036)	0.517	0.446	0.740	130	0.3	(-0.1, 0.7)
24	Central Hardwoods	21	930	0.412 (0.020)	0.939 (0.011)	(0.917, 0.962)	0.465 (0.027)	0.474	0.495	0.266	130	-1.0	(-1.5, -0.6)
27	Southeastern Coastal Plain	11	427	0.232 (0.025)	0.965 (0.018)	(0.932, 1.000)	0.358 (0.042)	0.607	0.371	0.588	260	-1.0	(-1.7, -0.3)
28	Appalachian Mountains	16	542	0.422 (0.028)	0.950 (0.018)	(0.916, 0.985)	0.519 (0.041)	0.431	0.546	0.332	334	-0.5	(-1.0, -0.1)
29	Piedmont	10	524	0.442 (0.027)	0.965 (0.013)	(0.940, 0.991)	0.452 (0.038)	0.513	0.469	0.329	131	-0.3	(-1.1, 0.5)
30	New England/Mid-Atlantic Coast	24	1042	0.449 (0.022)	0.988 (0.011)	(0.967, 1.009)	0.598 (0.033)	0.390	0.605	0.321	130	-1.9	(-2.6, -1.2)
32	Coastal California	22	1971	0.469 (0.017)	0.995 (0.011)	(0.974, 1.016)	0.542 (0.023)	0.452	0.545	0.749	35	9.5	(2.5, 16.4)
33	Sonoran and Mojave Deserts	3	147	0.244 (0.053)	1.204 (0.057)	(1.097, 1.320)	0.432 (0.101)	0.771	0.359	0.261	16	1.3	(-0.6, 3.1)
34	Sierra Madre Occidental	3	223	0.370 (0.050)	0.999 (0.046)	(0.913, 1.092)	0.434 (0.073)	0.565	0.434	0.067	7	-1.9	(-12.3, 8.6)
<u>Hooded Warbler</u>													
26	Mississippi Alluvial Valley	4	134	0.380 (0.025)	1.009 (0.033)	(0.946, 1.076)	0.483 (0.033)	0.526	0.479	0.279	16	0.5	(-10.4, 11.5)
27	Southeastern Coastal Plain	12	390	0.381 (0.023)	0.938 (0.018)	(0.904, 0.974)	0.489 (0.027)	0.449	0.521	0.175	213	0.6	(-0.7, 1.9)
28	Appalachian Mountains	13	519	0.381 (0.023)	0.985 (0.016)	(0.955, 1.017)	0.485 (0.027)	0.500	0.492	0.332	231	1.5	(0.1, 2.8)
30	New England/Mid-Atlantic Coast	8	229	0.380 (0.024)	0.916 (0.020)	(0.878, 0.956)	0.492 (0.029)	0.424	0.537	0.325	36	-1.6	(-4.3, 1.1)
<u>Wilson's Warbler</u>													
4	Northwestern Interior Forest	9	890	0.204 (0.018)	0.957 (0.012)	(0.933, 0.981)	0.307 (0.031)	0.650	0.321	1.361	71	-1.6	(-4.2, 0.9)
5	Northern Pacific Rainforest	36	2948	0.383 (0.015)	0.979 (0.006)	(0.967, 0.991)	0.437 (0.019)	0.542	0.446	0.453	124	-1.2	(-2.0, -0.3)
9	Great Basin	6	153	0.216 (0.048)	0.986 (0.025)	(0.939, 1.036)	0.301 (0.074)	0.685	0.305	0.404	68	-1.8	(-5.1, 1.4)
10	Northern Rockies	6	374	0.273 (0.028)	0.961 (0.016)	(0.931, 0.992)	0.439 (0.046)	0.522	0.456	0.256	113	-5.2	(-7.9, -2.6)
15	Sierra Nevada	12	1341	0.335 (0.017)	0.981 (0.008)	(0.965, 0.998)	0.444 (0.024)	0.537	0.453	0.393	22	-7.7	(-12.4, -3.0)
32	Coastal California	12	3548	0.359 (0.019)	1.032 (0.005)	(1.021, 1.042)	0.469 (0.025)	0.563	0.455	0.913	47	-1.1	(-3.8, 1.6)

Species		MAPS 1992-2003									BBS 1966-2007		
				Pradel model			Transient CJS model						
BCR no.	BCR name	No. stations [a]	No. individ.[b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est.[k]	Trend 95% CI [l]
Yellow-breasted Chat													
5	Northern Pacific Rainforest	9	770	0.409 (0.023)	0.959 (0.011)	(0.939, 0.980)	0.509 (0.024)	0.451	0.530	0.424	45	-0.1	(-1.5, 1.4)
9	Great Basin	4	166	0.491 (0.043)	0.977 (0.027)	(0.925, 1.031)	0.527 (0.046)	0.450	0.540	0.204	55	0.0	(-1.7, 1.6)
16	Southern Rockies/Colorado Plateau	8	261	0.439 (0.039)	1.020 (0.028)	(0.967, 1.077)	0.505 (0.042)	0.515	0.495	0.142	48	1.3	(-2.1, 4.6)
22	Eastern Tallgrass Prairie	4	272	0.313 (0.042)	1.048 (0.020)	(1.010, 1.087)	0.439 (0.068)	0.609	0.419	0.151	132	-2.0	(-3.7, -0.3)
24	Central Hardwoods	18	700	0.464 (0.024)	0.946 (0.013)	(0.921, 0.971)	0.508 (0.026)	0.438	0.537	0.140	131	-1.4	(-2.2, -0.5)
26	Mississippi Alluvial Valley	3	229	0.501 (0.045)	0.989 (0.028)	(0.936, 1.046)	0.529 (0.054)	0.461	0.534	0.114	40	-3.1	(-5.3, -0.8)
28	Appalachian Mountains	7	252	0.377 (0.041)	0.806 (0.028)	(0.753, 0.863)	0.458 (0.057)	0.348	0.568	0.109	254	-3.7	(-4.4, -3.0)
32	Coastal California	6	330	0.425 (0.034)	0.913 (0.025)	(0.866, 0.963)	0.490 (0.039)	0.423	0.536	0.136	28	-1.3	(-3.1, 0.5)
Chipping Sparrow													
9	Great Basin	9	253	0.425 (0.042)	1.086 (0.023)	(1.041, 1.133)	0.439 (0.040)	0.648	0.404	0.379	143	-1.8	(-3.3, -0.4)
10	Northern Rockies	20	436	0.430 (0.039)	0.940 (0.014)	(0.913, 0.968)	0.439 (0.040)	0.501	0.467	0.223	196	-1.3	(-2.5, -0.1)
15	Sierra Nevada	10	279	0.427 (0.040)	0.855 (0.017)	(0.822, 0.890)	0.439 (0.040)	0.416	0.513	0.375	35	-3.5	(-5.4, -1.7)
16	Southern Rockies/Colorado Plateau	6	173	0.436 (0.044)	1.062 (0.035)	(0.997, 1.132)	0.439 (0.040)	0.624	0.413	0.460	171	-0.8	(-2.1, 0.5)
30	New England/Mid-Atlantic Coast	9	171	0.434 (0.042)	1.022 (0.031)	(0.964, 1.084)	0.439 (0.040)	0.583	0.429	0.293	127	0.0	(-0.7, 0.7)
Black-headed Grosbeak													
5	Northern Pacific Rainforest	34	1163	0.492 (0.024)	0.938 (0.009)	(0.920, 0.956)	0.555 (0.028)	0.383	0.592	0.679	123	0.6	(-0.5, 1.7)
9	Great Basin	19	694	0.521 (0.037)	1.000 (0.016)	(0.970, 1.031)	0.578 (0.031)	0.422	0.578	0.187	115	3.2	(2.0, 4.4)
10	Northern Rockies	11	239	0.487 (0.039)	1.015 (0.023)	(0.971, 1.060)	0.524 (0.066)	0.490	0.517	0.173	105	6.3	(2.9, 9.7)
15	Sierra Nevada	6	447	0.504 (0.022)	0.955 (0.016)	(0.925, 0.986)	0.573 (0.032)	0.382	0.600	0.182	34	2.2	(-1.3, 5.7)
16	Southern Rockies/Colorado Plateau	14	539	0.500 (0.022)	0.943 (0.019)	(0.907, 0.981)	0.584 (0.043)	0.359	0.619	0.233	128	0.7	(-1.5, 2.9)
32	Coastal California	25	1564	0.492 (0.023)	0.940 (0.008)	(0.924, 0.957)	0.553 (0.026)	0.387	0.589	0.424	88	-1.3	(-2.4, -0.3)
34	Sierra Madre Occidental	6	185	0.459 (0.071)	0.832 (0.037)	(0.762, 0.908)	0.507 (0.094)	0.324	0.610	0.116	27	-1.0	(-4.9, 2.9)
Lazuli Bunting													
5	Northern Pacific Rainforest	10	224	0.423 (0.056)	0.938 (0.023)	(0.895, 0.984)	0.673 (0.089)	0.265	0.718	0.312	67	-0.6	(-2.8, 1.5)
9	Great Basin	11	592	0.439 (0.045)	0.983 (0.017)	(0.951, 1.016)	0.483 (0.050)	0.500	0.492	0.227	121	-0.2	(-1.6, 1.2)
10	Northern Rockies	4	182	0.450 (0.059)	0.956 (0.025)	(0.908, 1.007)	0.375 (0.075)	0.581	0.392	0.168	114	2.9	(0.5, 5.2)
16	Southern Rockies/Colorado Plateau	9	331	0.366 (0.060)	1.039 (0.029)	(0.984, 1.098)	0.469 (0.085)	0.571	0.451	0.175	75	-1.5	(-4.2, 1.2)
32	Coastal California	13	437	0.340 (0.078)	0.958 (0.017)	(0.926, 0.991)	0.407 (0.099)	0.551	0.425	0.207	68	-2.0	(-5.1, 1.1)

		MAPS 1992-2003											
Species				Pradel model			Transient CJS model				BBS 1966-2007		
BCR no.	BCR name	No. stations [a]	No. individ.[b]	$\hat{\phi}_{BCR}$ (SE) [c]	$\hat{\lambda}_{BCR}$ (SE) [d]	$\hat{\lambda}_{BCR}$ 95% CI [e]	$\hat{\phi}^{tr}_{BCR}$(SE) [f]	$\hat{f}^{tr}_{BCR}$ [g]	$\hat{\gamma}^{tr}_{BCR}$ [h]	RI_{BCR} [i]	No. routes [j]	Trend est.[k]	Trend 95% CI [l]
Indigo Bunting													
22	Eastern Tallgrass Prairie	24	1332	0.399 (0.022)	1.031 (0.010)	(1.012, 1.051)	0.439 (0.034)	0.592	0.426	0.068	259	-0.2	(-0.6, 0.3)
23	Prairie Hardwood Transition	9	266	0.397 (0.044)	0.967 (0.021)	(0.927, 1.009)	0.539 (0.066)	0.428	0.557	0.141	130	-0.3	(-0.7, 0.1)
24	Central Hardwoods	30	1606	0.465 (0.019)	0.989 (0.009)	(0.973, 1.006)	0.503 (0.023)	0.486	0.509	0.086	131	-1.2	(-1.7, -0.8)
25	West Gulf Coastal Plain/Ouachitas	3	265	0.475 (0.041)	1.041 (0.023)	(0.997, 1.087)	0.590 (0.063)	0.451	0.566	0.075	82	-0.4	(-1.2, 0.4)
26	Mississippi Alluvial Valley	5	437	0.350 (0.033)	0.990 (0.019)	(0.953, 1.028)	0.534 (0.050)	0.456	0.539	0.056	42	-0.7	(-2.1, 0.8)
27	Southeastern Coastal Plain	10	120	0.457 (0.069)	0.978 (0.039)	(0.905, 1.057)	0.575 (0.116)	0.403	0.588	0.132	261	-0.9	(-1.5, -0.2)
28	Appalachian Mountains	23	554	0.367 (0.031)	0.893 (0.016)	(0.863, 0.925)	0.441 (0.048)	0.452	0.494	0.221	338	-1.2	(-1.5, -0.9)
29	Piedmont	9	193	0.483 (0.055)	0.945 (0.031)	(0.886, 1.007)	0.516 (0.082)	0.428	0.547	0.142	134	-0.5	(-1.0, -0.1)
Painted Bunting													
20	Edwards Plateau	8	366	0.417 (0.040)	1.038 (0.021)	(0.997, 1.081)	0.568 (0.034)	0.471	0.547	0.319	18	-1.1	(-3.5, 1.2)
21	Oaks and Prairies	14	855	0.487 (0.027)	1.020 (0.012)	(0.997, 1.044)	0.578 (0.027)	0.442	0.567	0.310	67	-0.5	(-2.6, 1.7)
36	Tamaulipan Brushlands	3	562	0.359 (0.058)	1.029 (0.017)	(0.997, 1.061)	0.564 (0.042)	0.465	0.548	0.345	22	-3.7	(-5.8, -1.6)
Bullock's Oriole													
5	Northern Pacific Rainforest	7	274	0.354 (0.067)	1.003 (0.022)	(0.962, 1.047)	0.482 (0.099)	0.521	0.481	0.362	59	-2.7	(-4.6, -0.9)
9	Great Basin	13	518	0.515 (0.047)	1.032 (0.019)	(0.995, 1.070)	0.568 (0.051)	0.464	0.550	0.357	160	1.2	(-1.0, 3.5)
32	Coastal California	14	398	0.421 (0.065)	0.933 (0.020)	(0.895, 0.973)	0.554 (0.076)	0.379	0.594	0.292	95	-1.8	(-2.9, -0.7)
Baltimore Oriole													
13	Lower Great Lakes/St. Lawrence Plain	12	207	0.242 (0.105)	0.943 (0.035)	(0.876, 1.015)	0.097 (0.093)	0.847	0.102	0.281	163	-1.0	(-1.7, -0.3)
22	Eastern Tallgrass Prairie	15	292	0.423 (0.075)	1.010 (0.023)	(0.965, 1.057)	0.374 (0.086)	0.636	0.370	0.266	256	0.4	(-0.6, 1.3)
23	Prairie Hardwood Transition	6	132	0.606 (0.092)	0.938 (0.031)	(0.880, 1.001)	0.761 (0.089)	0.177	0.811	0.503	129	-0.5	(-1.1, 0.0)

[a] Number of MAPS 'superstations'; a superstation includes multiple stations if station centroids < 1.3 km apart.

[b] Number of birds banded and released.

[c] Time-constant adult apparent survival-rate estimate from Pradel (1996) reverse-time capture-recapture models. (SE = standard error)

[d] Time-constant population growth rate estimate (i.e., trend) from Pradel (1996) reverse-time capture-recapture models. (SE = standard error)

[e] 95% confidence interval on time-constant population growth rate estimate.

[f] Time-constant adult apparent survival-rate estimate from ad hoc transient Cormack-Jolly Seber (CJS) model (Hines et al. 2003)

[g] Recruitment-rate estimate derived by subtracting transient adult apparent survival-rate estimate from the time-constant population growth-rate estimate.

[h] "Seniority" parameter derived by dividing the transient adult apparent surviva-rate estimate by the time-constant population growth-rate estimate. It measures relative contribution of adult apparent survival to population change. Its complement 1- seniority represents relative contribution of recruitment.

[i] Productivity index calculated as the ratio of young birds summed across years to year-unique adult birds summed across years in the constant-effort catch.

[j] Number of BBS routes surveyed.

[k] Estimate of population trend (Sauer et al. 2008).

[l] 95% confidence interval on BBS trend estimate.