

**EFFECTIVENESS OF BIRD INVENTORY
PROTOCOLS IN NATIONAL PARKS IN THE
EASTERN UNITED STATES BASED ON
ESTIMATION OF SPECIES RICHNESS**

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Table of Contents

List of Figures	iii
List of Tables	iv
List of Appendices	vii
Acknowledgments	viii
Executive Summary	ix
Chapter 1. Introduction	1
Chapter 2. Definitions	3
Chapter 3. Data Description	4
Chapter 4. Hopewell Furnace National Historic Site, Gettysburg National Military Park, Eisenhower National Historic Site, and Valley Forge National Historical Park	6
Methods	6
Hopewell Furnace National Historic Site	6
Gettysburg National Military Park and Eisenhower National Historic Site	7
Valley Forge National Historical Park	9
Results	9
Hopewell Furnace National Historic Site	9
Gettysburg National Military Park and Eisenhower National Historic Site	16
Valley Forge National Historical Park	26
Comparison of results from HOFU, GETT-EISE, and VAFO	26
Discussion	28
Chapter 5. Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial	33
Methods	33
Results	34
Discussion	34
Chapter 6. Shenandoah National Park	40

Methods.....	40
Results	40
Discussion.....	48
Chapter 7. Conclusions and Applications.....	49
Literature Cited.....	52
Appendix A. Number of bird species listed on the Valley Forge National Historical Park bird sighting list (Wolf 1996).	55

List of Figures

Figure

1. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on spring transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997..... 36
2. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997..... 37
3. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1995. 43
4. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1996. 44
5. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1997. 45

List of Tables

Table

1. HOFU One Visit: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, and calculated using the model M_h with the Web-based program COMDYN4.	10
2. HOFU Two Visits: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, and calculated using the model M_h with the Web-based program COMDYN4.	13
3. HOFU Model Selection: Estimates of species richness ($S_E \pm SE$) for the model selected as most appropriate and the model selected based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, calculated using program CAPTURE.	15
4. GETT-EISE One Visit: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories in Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4.	17
5. GETT-EISE Two Visits: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4.	20
6. GETT-EISE Model Selection: Estimates of species richness ($S_E \pm SE$) for the model selected as most appropriate and the model selected based on bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, calculated using program CAPTURE.	22
7. GETT-EISE 1993 and 1994: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on breeding season bird inventories at Gettysburg National Military Park and Eisenhower National	

Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4.	24
8. Lincoln-Petersen Index Estimates. Estimates of species richness based on transect bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site in 1993-94 and at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial in 1997, and calculated using the Lincoln-Petersen index.	25
9. VAFO Vehicular Inventories: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on vehicular bird inventories at Valley Forge National Historical Park, 1996, and calculated using the model M_h with the Web-based program COMDYN4.....	27
10. ALPO-JOFL: Transects: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997, and calculated using the model M_h with the Web-based program COMDYN4.....	35
11. ALPO-JOFL: Sectioned transects. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997, and calculated using the model M_h with the Web-based program COMDYN4.....	38
12. SHEN: Three Inventory Methods, 1995-97: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on three bird inventory methods in the breeding season at Shenandoah National Park, 1995-97, and calculated using the model M_h with the Web-based program COMDYN4	41
13. SHEN: Single Visit Mist Nets, 1995-96. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS mist netting inventories in the breeding season at Shenandoah National Park, 1995-96, and calculated using the model M_h with the Web-based program COMDYN4.....	42
14. SHEN: Multiple Visits Mist Nets, 1995-97. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS mist	

netting inventories in the breeding season at Shenandoah National Park, 1995-97, and calculated using the model M_h with the Web-based program COMDYN4.	46
15. SHEN: MAPS Point Counts, Time and Distance, 1995. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS point count inventories in the breeding season at Shenandoah National Park, 1995, and calculated using the model M_h with the Web-based program COMDYN4.	47

List of Appendices

Appendix A. Number of bird species listed on the Valley Forge National Historical Park bird sighting list (Wolf 1996)	55
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Executive Summary

Inventory and monitoring programs for flora and fauna have been developed in many national parks in response to policies of the National Park Service (NPS) that require park managers to know the nature and condition of the natural resources in parks (U.S. Department of the Interior 1992). Our objectives in this investigation were to (1) examine the extent to which an inventory for a given taxon accurately detects the actual number of species of the given taxon in a specified area or time period (species richness), and (2) determine what level of sampling effort (i.e., how many visits or surveys) is required of an inventory in order to document a desired proportion of the total species richness. Statistical models estimating species richness were applied to various sets of bird inventories obtained from previous studies in seven national parks, and the results were compared among inventory methods, number of visits, and sampling regimes.

The most consistent estimates of bird species richness and the highest observed species counts were obtained by unlimited-distance radius point counts. Vehicular surveys also provided efficient and apparently reliable estimates of species richness. Estimates of species richness were most robust when the sampling design included several study areas throughout a park, inclusive of multiple habitat types. Observed species counts and estimates of species richness increased from one to two visits within a season, but more than two visits per season was not efficient and allowed the sampled community to change with emigration (migration or mortality). The most important season to inventory birds was the breeding season when birds were most vocal and sedentary and thereby easier to detect.

Estimation models of species richness, in particular model M_h (available on the World Wide Web), can be used to determine if an inventory has accounted for a sufficient proportion of the actual bird species present. We recommend that for birds at least 75% of the estimated species richness be obtained before inventory efforts are terminated. However, the design of the inventory should be such that the estimate of species richness is reasonably reliable. The total number of study sites should be greater than five; data should be combined over multiple habitats; and at least two visits per season and year should be used. Priority should be given to inventories in the breeding season. The use of the species richness models for evaluation of amphibian and mammal inventory data is not recommended unless the inventories are comprehensive for the taxa, because of the low numbers of species accounted for in most amphibian and mammal inventories.

Chapter 1

Introduction

Inventory and monitoring programs for flora and fauna have been developed in many national parks in response to policies of the National Park Service (NPS) that require park managers to know the nature and condition of the natural resources in parks (U.S. Department of the Interior 1992). Many of these programs are labor- and money-intensive. A question often asked is at what point in an inventory program has enough information been gathered to make further inventories unnecessary? An inventory rarely is a complete census of all species, and some species may be undetected (Nichols and Conroy 1996). Many undetected species are rare, secretive, or occur occasionally, thereby requiring intensive or extensive inventory efforts. The objectives of this investigation were to (1) examine the extent to which an inventory for a given taxon accurately detects the actual number of species of the given taxon in a specified area or time period (species richness), and (2) determine what level of sampling effort (i.e., how many visits or surveys) is required of an inventory in order to document a desired proportion of the total species richness.

Unfortunately, actual species richness for a given taxon in a prescribed area or time period is difficult to measure because of biological, logistical, or other limitations. Nevertheless, statistical procedures for estimating species richness that account for individuals or species not detected in sampling efforts have been developed and applied to ecological data (Nichols et al. in press). Boulinier et al. (1998) have demonstrated the use of capture-recapture models for closed populations (i.e., no immigration or emigration) to estimate species richness from bird inventory data. Data from species inventories replicated over time, location, or investigator can be used to estimate species richness of a given community using these models (Nichols and Conroy 1996). The assumption that a population is closed dictates that the models be applied to inventory data sets taken within a limited-time frame or area (Burnham and Overton 1979, Nichols and Conroy 1996).

Capture-recapture models developed for estimating species richness have incorporated differences in the ability of investigators to detect individuals or species (Otis et al. 1978, Nichols and Conroy 1996). The probabilities of detection usually will differ among species, with some species being more common or more conspicuous than rarer or more secretive species (Nichols and Conroy 1996). One of the capture-recapture models, model M_h , assumes that detection probabilities vary among species (Boulinier et al. 1998). This model should be the most appropriate of the various models for application to inventory data based on a stratified sampling design (Nichols and Conroy 1996).

The application of the capture-recapture models is available through the computer software CAPTURE (Rexstad and Burnham 1991). Additionally, a World Wide Web-based program called COMDYN4, developed by researchers at the U.S.G.S. Patuxent Wildlife Research Center, makes model M_h available for Web-based calculations (<http://www.mbr-pwrc.usgs.gov/comdyn.html>) (Hines et al. in press). COMDYN4 uses a jackknife-estimation procedure for estimating species richness (Burnham and Overton 1979) and requires input in the form of $f(i)$ ($i = \{1, 2, \dots, n\}$, where $f(i)$ = the number of species observed at exactly i sites and n = total number of sites) and $s(i)$ ($i = \{1, 2, \dots, n\}$, where $s(i)$ = the number of species observed at site i and n = total number of sites). Output of COMDYN4 include an estimate of species

richness based on standard jackknife estimators, a 95% confidence interval estimate using a bootstrap approach, a goodness-of-fit test of the data to the model, and the average detection probabilities of species (referred to in this report as the percent of estimated species observed) (Hines et al. in press).

Throughout this report, the term species richness is not comprehensive for all species in a park, but will refer to the true number of species *in the sampled community*. A goal of park inventories is to determine the species richness of an entire taxon, such as birds, and we will discuss applications towards this goal in the conclusion. The estimates of species richness output by the models used in this investigation, however, must be understood to be merely of the species that could have been sampled by the given inventory. For example, data from an inventory of four woodlots in a park can yield an estimate of the true number of diurnal species present in those woodlots in the sampled season, but this estimate will not account for waterfowl in a nearby pond, nocturnal birds, or birds that migrate through in another season.

Chapter 2

Definitions

Species richness --- the actual number of species of a given taxon in a specified area or time period

Estimate of species richness (S_E) --- the estimated value of species richness calculated by a capture-recapture model

Observed species count (S_A) --- the number of species recorded by an observer during a given survey

Percent of estimated species richness observed (S_P) --- $(S_A \div S_E) \times 100\%$; this value is equivalent to the average species detection probability output by the capture-recapture models

Model M_0 --- closed population model that assumes species detection probability varies neither among species nor among sampling units, or that every species has the same probability of being detected in every sampling unit (Boulinier et al. 1998)

Model M_h --- closed population model that assumes species detection probability varies with individual species, or that each species has a specific detection probability which is constant for all sampling units (Boulinier et al. 1998)

Model M_t --- closed population model that assumes species detection probability varies with sampling unit but not with individual species within each unit (Boulinier et al. 1998)

Model M_b --- closed population model that assumes species detection probability varies with behavioral response to detection, or that the detectability of a species is affected by the fact that the observer has already recorded it on a previous occasion or in a previous sampling unit (Boulinier et al. 1998)

Model M_{th} --- closed population model that assumes species detection probability varies with individual species and with sampling unit (Boulinier et al. 1998)

Model M_{tb} --- closed population model that assumes species detection probability varies with both sampling unit and with behavioral response to detection (Boulinier et al. 1998)

Model M_{bh} --- closed population model that assumes species detection probability varies with individual species and with behavioral response to detection (Boulinier et al. 1998)

Model M_{tbh} --- closed population model that assumes species detection probability varies with individual species, with different sampling units, and with a behavioral response to detection (Boulinier et al. 1998)

Chapter 3

Data Description

Data used in this investigation were from bird inventories conducted at seven national parks in the Northeast Region (Yahner et al. 1998a; Yahner and Keller, unpubl. data; Atkinson, unpubl. data). These parks were Hopewell Furnace National Historic Site (HOFU), Gettysburg National Military Park and Eisenhower National Historic Site (GETT-EISE), Valley Forge National Historical Park (VAFO), Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial (ALPO-JOFL), and Shenandoah National Park (SHEN).

The data from HOFU, GETT-EISE, and VAFO were collected as part of a study comparing the effectiveness of different inventory methods for mammals, birds, reptiles, and amphibians (Yahner et al. 1998a). Study areas were selected within three habitat types (old-field, lowland forest, and upland forest) in each park. One transect (ranging from 200-800 m long) was established per habitat in each study area. Birds were inventoried using 3-minute point counts at 150-m intervals along the transects (recorded with both a 30-m fixed radius and an unlimited distance radius; hereafter termed the point-count method), non-stop transect surveys (hereafter termed the transect method), and both Breeding Bird Survey-style (BBS) vehicular surveys and non-stop vehicular surveys along a route traversing the park. For BBS-style vehicular surveys, two observers would stop at regular intervals (0.8-km) for a 3-minute point count to record birds seen or heard; for non-stop vehicular surveys, two observers tabulated birds continuously while driving and recording distance traveled every 0.8 km.

Birds at HOFU and GETT-EISE were sampled in four seasons, and each inventory was conducted 2-3 times per season in the same year (fall inventories at HOFU and vehicular inventories in winter at GETT-EISE were conducted only once). The sampling seasons at HOFU were spring (15 April-20 May 1994), breeding (20 May-15 July 1994), fall (1 September-10 October 1994), and winter (1 November 1994-15 March 1995). Vehicular surveys at HOFU were not conducted in fall. The sampling seasons at GETT-EISE were breeding (20 May-15 July 1993 and 1994), fall (1 September-10 October 1993), winter (1 November 1993-15 March 1994), and spring (15 April-20 May 1994). Fall inventories and breeding inventories in 1993 at GETT-EISE were conducted at a subset of study areas; thus, fewer areas were inventoried in fall and breeding seasons in 1993 than in winter, spring, or breeding (1994) seasons. Unless otherwise stated, data from GETT-EISE in the breeding season were from the 1994 inventories. Vehicular surveys at GETT-EISE were conducted in only winter (one visit) and spring (two visits). Birds at VAFO were inventoried in winter 1995-96 (one visit) and spring 1996 (two visits) using the two vehicular methods (see Yahner et al. [1998a] for more detailed descriptions of the inventory protocols and sampling periods).

Bird inventories were conducted in ALPO-JOFL during spring migration (May 1997) and the breeding season (June-July 1997) (Yahner and Keller, unpubl. data). Three 1-km transects were established to cover the two park units with non-stop transect surveys. Transects included most cover types represented in the parks. All birds observed or heard were recorded while an observer walked along the transect; the location along the transect and perpendicular distance of the bird from the transect were noted. Inventories were conducted four times each season.

Bird inventories were conducted at SHEN in breeding seasons (30 May-30 August, 1995-97) (Atkinson, unpubl. data). Bird inventory methods at SHEN included the North American

Breeding Bird Survey (BBS), mist netting for the Monitoring Avian Productivity and Survivorship Program (MAPS), and MAPS point counts (1995 only). The BBS was conducted once each year on four routes in the park. Each route consisted of 50 points (every 0.8 km) along paved and unpaved roads; the observer conducted a 3-minute unlimited distance point count at each point along the vehicular route. MAPS is a nation-wide monitoring effort designed to provide annual indices of adult population size and post-fledgling productivity for landbird species (DeSante et al. 1996). Six MAPS stations were operated at SHEN; two were in chestnut oak (*Quercus prinus*) habitat, two in cove hardwood habitat, and two in northern red oak (*Quercus rubra*) habitat. At each station, 10 mist nets were monitored for 6 hours per day on 1 day during each 10-day period for nine consecutive 10-day periods between 31 May and 28 August 1995-97. In June 1995, point counts were conducted on two separate visits at nine points per MAPS station. Species recorded after counts of 3, 5, and 10 minutes were recorded using both a 50-m fixed-radius and an unlimited distance radius.

The majority of this report was organized by groups of parks where comparable inventory methods were used. Because inventory methods, numbers of study sites, and seasons of the year differed among parks, comparisons of bird data among parks was difficult. Often comparisons were made among groups of data with unequal parameters (e.g., sample sizes) with the understanding that these inequalities may weaken the strength of any conclusions drawn. Results of this report were based on existing data sets; no resources were available to design or conduct surveys expressly for the purpose of this study.

Chapter 4

Hopewell Furnace National Historic Site, Gettysburg National Military Park, Eisenhower National Historic Site and Valley Forge National Historical Park

Methods

Hopewell Furnace National Historic Site

Analyses based on one visit

Before obtaining estimates of species richness, we compiled the inventory data into the format needed for application of the capture-recapture models to the data. A species list was obtained for each sampling point, site, or distance along a route. For the duration of this report, we define a “data set” as the set of survey results compiled for a particular inventory method, season, and habitat type. For example, there was one data set for transect surveys in spring in old-field habitats, and another data set for transect surveys in spring in lowland forest habitats.

We segregated the data by habitat type for comparisons among habitats within a park as well as combined the data from each habitat for a park-wide analysis. For the point-count method, each sampling point was used as a “site” for the model ($n = 10, 20$, and 10 sites for old-field, lowland forest, and upland forest habitats, respectively). Point-count data were combined on a given transect for a park-wide analysis, whereby the transect was the “site” ($n = 8$ sites). Estimates of species richness from point counts were based on both an unlimited-distance radius (hereafter termed point-count-UL) and a 30-m fixed-radius (hereafter termed point-count-30). For transect surveys, each transect was a “site” for the model ($n = 2, 4, 2$, and 8 sites for old-field, lowland forest, upland forest, and park-wide habitats, respectively). For BBS-style vehicular surveys, each stopping point along the vehicular route was a “site” ($n = 9$ park-wide sites). For non-stop vehicular surveys, each 0.8-km segment along the route was used as a “site” ($n = 9$ park-wide sites). Vehicular surveys were not conducted in fall. Estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals (obtained from a bootstrap algorithm) were obtained for each data set from calculations on the Web-based program COMDYN4 (<http://www.mbr-pwrc.usgs.gov/comdyn4.html>). When there was more than one visit per season, survey data from the second visit in a given season were used in these calculations.

The estimated species richness (S_E) as calculated by the model was compared to the observed species count (S_A , the number of species recorded during a given survey) by calculating the percent of estimated species richness observed (S_P):

$$S_P = (S_A \div S_E) \times 100\%$$

Analyses based on two visits

We next combined species lists from two visits in order to examine the effect of multiple visits within a season on the observed species counts and estimated species richness. Because fall inventories were only conducted once, they were excluded from this analysis. We used the same procedures as described above, with the only exception being that data were combined from two visits per season. Bird species observed at each “site” were pooled over the two visits prior to entry into the model. Species richness estimates, standard errors ($\pm SE$), and 95% confidence

intervals were obtained from calculations on the program COMDYN4. Percent of estimated species richness observed also was calculated using the data from two visits.

We entered the inventory data (compiled over two visits) into the program CAPTURE in order to examine the potential for another estimation model to fit the data better than M_h . CAPTURE has eight capture-recapture models, and the output is compared among models, with the model that best fits the data being selected. We recorded the model selected by CAPTURE for each data set and the estimate of species richness calculated by that chosen model if available.

The eight models differ in assumptions about the sources of variation in detection probabilities of species (Pollock et al. 1990). Models with a t -component permit variation among sampling sites; those with an h -component permit variation among species; and those with a b -component permit variation among behavioral response to detection (Pollock et al. 1990; see Chapter 2, Definitions). The version of CAPTURE used in our analyses was not yet programmed to compute estimates for two models, M_{tb} and M_{tth} , although these models were considered in the selection procedure.

Comparison of inventory methods

As part of this investigation, we also were interested in comparing both estimates of species richness and observed species counts among inventory methods. James Nichols of the Patuxent Wildlife Research Center was consulted (4 November 1997) to discuss approaches to this comparison. A four-step evaluation was suggested for examining model outputs to determine the inventory method that provided the most precise and unbiased species richness estimate. Bias is defined as the difference between the expected value of an estimator and the true parameter being estimated (Otis et al. 1978); precision is the degree of repeatability of the estimate, irrespective of accuracy (Verner 1985). Data used, unless otherwise noted, were based on two site visits and model M_h . Data for the fall season were based on one visit and model M_h . The four steps of this evaluation were as follows:

- 1) Did the confidence intervals of estimates of species richness within the same season and habitat (i.e., group of inventory methods that measure the same community) overlap?

Estimates with frequently non-overlapping confidence intervals may indicate bias.

- 2) Were any of the standard errors ($\pm SE$) within a group of inventory methods that measure the same community consistently smaller than the others? The precision of an estimate is indicated by the SE .

- 3) Which method caused the model selection program to select M_h more often? The use of a t component (models such as M_t , M_{th}) gives less precision in the estimate and should not be necessary with the design of this study.

- 4) Which method resulted in the highest percent of estimated species richness observed (S_p)? If methods were similar in parts 1-3 above, the method yielding the highest percent of estimated species richness observed would be preferred.

Gettysburg National Military Park and Eisenhower National Historic Site

Analyses based on one visit

We compiled the GETT-EISE inventory data into the format needed for application of the capture-recapture models. We segregated the GETT-EISE data by habitat type as well as combined the data from each habitat for a park-wide analysis. For the point-count method, each

sampling point was used as a “site” for the model ($n = 11, 10$, and 10 sites for old-field, lowland forest, and upland forest habitats, respectively in spring, breeding, and winter seasons) to compare among habitat types. Point-count data were combined on a given transect for a park-wide analysis, whereby the transect was the “site” ($n = 8$ park-wide sites in spring, breeding, and winter seasons). Fewer areas and, hence, fewer points were surveyed in the fall season than in spring, breeding, or winter seasons ($n = 6, 5, 6$, and 4 sites for old-field, lowland forest, upland forest, and park-wide habitats, respectively). Estimates of species richness from point counts were based on both point-count-UL and point-count-30. For transect surveys, each transect was a “site” for the model ($n = 4, 2, 2$, and 8 sites for old-field, lowland forest, upland forest, and park-wide habitats, respectively in spring, breeding, and winter seasons). Only four transects were surveyed park-wide in the fall season ($n = 4$ park-wide sites), and fall inventory data were not analyzed by habitat type. For non-stop vehicular surveys in winter and spring, each 1.6-km segment along the driving route was a “site” ($n = 14$ park-wide sites). Estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals were obtained for each data set from calculations on the program COMDYN4. We also calculated the percent of estimated species richness observed for each data set. When there was more than one visit per season, inventory data from only the second visit in a given season were used in all calculations.

Analyses based on two visits

We repeated these procedures using data combined from two visits in order to examine the effect on the observed species counts and estimated species richness of multiple visits within a season. Bird species observed at each “site” were pooled over the two visits prior to entry into the model. Estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals were obtained for each data set from calculations based on the program COMDYN4. Percent of estimated species richness observed also was calculated using the data from two visits.

We entered the GETT-EISE inventory data (compiled over two visits) into the program CAPTURE in order to examine the potential for another estimation model to fit the data more significantly than M_h . We recorded the model selected by CAPTURE for each data set and the estimate of species richness calculated by that chosen model when available.

Comparison of inventory methods

We repeated the four-step procedure for comparing the bias and precision of the various inventory methods. Data used, unless otherwise noted, were based on two site visits and model M_h at GETT-EISE.

1993 and 1994 breeding seasons

Breeding season inventories were conducted in both 1993 and 1994 at GETT-EISE, allowing for a comparison of species richness results between years. Inventory methods included point-count-UL (two visits per year) and transects (one visit per year). Some data from 1994 were eliminated, because fewer study areas were sampled in 1993. Data were entered into COMDYN4 using the same procedures described for one and two visit data ($n = 6, 5, 6$, and 4 sites for old-field, lowland forest, upland forest, and park-wide habitats, respectively). We recorded estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals calculated by the model M_h on COMDYN4 and percent of estimated species richness observed.

A procedure within COMDYN4 compares data from 2 years and determines the amount of change and differences in detectability of species from year-to-year.

Lincoln-Petersen Index

A simple species richness estimator, the Lincoln-Petersen Index (LPI), has been suggested for estimating species richness from two independent lists of bird species (Pollock et al. 1990). This estimator does not incorporate the differences in detectability that the capture-recapture models include, but it may be useful as a “quick-and-dirty” approach to a species inventory (Geissler 1998). The LPI uses ratios of the number of species recorded during each of two inventories and the number of species in common between the two inventories.

LPI estimates were calculated using data from GETT-EISE. For each of four seasons, LPI estimates were calculated using point count data as the first inventory and transect data as the second inventory. Two estimates were obtained for each season by using both point count-UL and point count-30 data.

Valley Forge National Historical Park

Vehicular surveys

Estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals for VAFO vehicular surveys were obtained from the program COMDYN4 for each combination of inventory method and season. For BBS-style vehicular surveys, each point was designated a “site” for the model ($n = 8$ sites); whereas for non-stop vehicular surveys, each 0.8 km segment along the route was a “site” ($n = 11$ sites). Calculations were based on both one and two visits. Percent of estimated species richness observed also was recorded.

Results

Hopewell Furnace National Historic Site

Analyses based on one visit

Fifty-four data sets were examined from HOFU inventories. Estimates of species richness (S_E) from point-count-UL methods were greater than those from point-count-30 methods in 13 (81%) of 16 pairs of data sets (Table 1). Estimates generally were consistent among the different methods within a season, except in fall and winter, when the observed species count was often low, causing the estimates to vary greatly among the methods.

In 27 (50%) of 54 data sets, the observed species count (S_A) accounted for at least 75% of the estimated species richness (S_E) (Table 1). Nine of these data sets were breeding season inventories, eight were winter inventories, six were spring inventories, and four were fall inventories. In nine (50%) of 18 data sets on a park-wide basis, the observed species count accounted for more than 75% of the estimated species richness. Additionally, both estimates and observed species counts yielded similar values among the methods, particularly when compiled on a park-wide basis.

The model M_h did not fit the data in 25 (46%) of the 54 data sets (chi-square goodness-of-fit test; $P < 0.05$). These data sets were primarily park-wide and fall inventories. Another model

Table 1. HOFU One Visit: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, and calculated using the model M_h with the Web-based program COMDYN4. Data from only one visit were used for each calculation.

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	$S_E \pm SE$	33 ± 3.9	47 ± 5.3	9 ± 2.7	78 ± 5.4^a
		(95% CI)	(18 - 69)	(37 - 97)	(8 - 16)	(45 - 121)
		S_A ($S_P\%$)	18 (54%)	35 (75%)	8 (89%)	42 (54%)
	Point-count-30	$S_E \pm SE$	40 ± 3.9^a	45 ± 5.4	11 ± 2.9	62 ± 6.1^a
		(95% CI)	(12 - 65)	(30 - 81)	(6 - 19)	(42 - 107)
		S_A ($S_P\%$)	12 (30%)	27 (60%)	6 (54%)	35 (56%)
	Transect	$S_E \pm SE$	20 ± 3.2	32 ± 4.0^a	10 ± 2.4	50 ± 5.3^a
		(95% CI)	(15 - 27)	(24 - 48)	(8 - 14)	(36 - 96)
		S_A ($S_P\%$)	15 (75%)	24 (75%)	8 (80%)	33 (66%)
	BBS-style Vehicular	$S_E \pm SE$				45 ± 4.4
		(95% CI)				(38 - 55)
		S_A ($S_P\%$)				38 (84%)
Breeding	Point-count-UL	$S_E \pm SE$	21 ± 3.4	26 ± 3.7	20 ± 3.7^a	37 ± 4.2^a
		(95% CI)	(15 - 66)	(23 - 34)	(15 - 36)	(31 - 48)
		S_A ($S_P\%$)	15 (71%)	23 (88%)	15 (75%)	31 (84%)
	Point-count-30	$S_E \pm SE$	17 ± 3.2	19 ± 4.1	7 ± 2.7^a	29 ± 4.2
		(95% CI)	(8 - 46)	(14 - 35)	(6 - 17)	(22 - 48)
		S_A ($S_P\%$)	8 (47%)	14 (74%)	6 (86%)	22 (76%)
	Transect	$S_E \pm SE$	21 ± 2.7	36 ± 4.1	6 ± 1.5	40 ± 4.8^a
		(95% CI)	(18 - 26)	(22 - 54)	(6 - 7)	(31 - 53)
		S_A ($S_P\%$)	18 (86%)	22 (61%)	6 (100%)	31 (77%)
	BBS-style Vehicular	$S_E \pm SE$				40 ± 4.5
		(95% CI)				(31 - 85)
		S_A ($S_P\%$)				31 (77%)
	Non-stop Vehicular	$S_E \pm SE$				34 ± 4.7
		(95% CI)				(25 - 67)
		S_A ($S_P\%$)				24 (71%)

Table 1 (cont.)

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Fall	Point-count-UL	$S_E \pm SE$	45 ± 4.5^a	29 ± 4.1	20 ± 3.7^a	34 ± 4.0^a
		(95% CI)	(17 - 79)	(17 - 71)	(11 - 49)	(27 - 70)
		$S_A (S_P\%)$	17 (38%)	17 (59%)	11 (55%)	27 (79%)
	Point-count-30	$S_E \pm SE$	16 ± 3.5^a	46 ± 3.8	15 ± 3.2^a	27 ± 4.3^a
		(95% CI)	(10 - 42)	(24 - 55)	(7 - 32)	(19 - 49)
		$S_A (S_P\%)$	10 (63%)	9 (20%)	7 (47%)	19 (70%)
	Transect	$S_E \pm SE$	12 ± 2.3	37 ± 4.1^a	7 ± 1.9	31 ± 4.0^a
		(95% CI)	(10 - 16)	(24 - 55)	(6 - 9)	(26 - 46)
		$S_A (S_P\%)$	10 (83%)	24 (65%)	6 (86%)	26 (84%)
Winter	Point-count-UL	$S_E \pm SE$	16 ± 3.4^a	33 ± 3.8^a	13 ± 3.2	21 ± 3.0^a
		(95% CI)	(7 - 32)	(18 - 62)	(9 - 38)	(20 - 27)
		$S_A (S_P\%)$	7 (44%)	18 (54%)	9 (69%)	20 (95%)
	Point-count-30	$S_E \pm SE$	0 ± 1.0	12 ± 2.9^a	2 ± 1.4	15 ± 3.0^a
		(95% CI)	(0 - 1)	(13 - 43)	(2 - 4)	(14 - 22)
		$S_A (S_P\%)$	1 (100%)	12 (100%)	2 (100%)	14 (93%)
	Transect	$S_E \pm SE$	4 ± 1.5	11 ± 2.6	6 ± 1.9	23 ± 3.6
		(95% CI)	(4 - 5)	(9 - 22)	(5 - 8)	(13 - 27)
		$S_A (S_P\%)$	4 (100%)	9 (82%)	5 (83%)	13 (56%)
	BBS-style Vehicular	$S_E \pm SE$				26 ± 4.2^a
		(95% CI)				(15 - 53)
		$S_A (S_P\%)$				15 (58%)
	Non-stop Vehicular	$S_E \pm SE$				36 ± 3.4^a
		(95% CI)				(10 - 58)
		$S_A (S_P\%)$				10 (28%)

^a Significant chi-square value from goodness-of-fit tests of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

with different assumptions about the heterogeneity of species detectability may more appropriately fit the data and was examined later using the program CAPTURE.

Analyses based on two visits

Forty-two data sets were examined from HOFU inventories. Estimates of species richness (S_E) from point-count-UL methods were greater than those from point-count-30 methods in 10 (83%) of 12 pairs of data sets (Table 2). Estimates generally were consistent among the different methods within a season except in winter, when the observed species count was often low, causing the estimates to vary greatly among the methods. Additionally, both estimates and observed species counts appeared more consistent among the methods when compiled on a park-wide basis rather than separately by habitat type. Estimates of species richness from non-stop vehicular methods, however, were not consistent with estimates from other methods.

In 29 (69%) of 42 data sets, the observed species count (S_A) accounted for at least 75% of the estimated species richness (S_E) (Table 2). Eleven of these data sets were breeding season inventories, nine were spring inventories, and nine were winter inventories. Observed species counts from all but three inventories on a park-wide basis accounted for more than 75% of the estimated species richness.

The model M_h did not fit the data in 18 (43%) of the 42 data sets (chi-square goodness-of-fit test; $P < 0.05$) (Table 2). These data sets were primarily park-wide inventories. Another model may more appropriately fit the data.

The observed species counts (S_A) in single-habitat inventories (data segregated by old-field, lowland forest, or upland forest habitat) increased an average of 6.9 species ($SE = 0.5$; 54% of the mean observed species count from one visit) from one visit to two visits for each method and season (Tables 1-2). For park-wide inventories, the mean increase in species observed was 8.3 species ($SE = 1.1$; 32% of the mean observed species count from one visit). Estimates of species richness (S_E) increased an average of 11.0 species ($SE = 1.8$; 58% of the mean estimated species richness from one visit) from one visit to two visits in single-habitat inventories. Estimates of species richness from park-wide inventories increased an average of 14.0 species ($SE = 4.7$; 36% of the mean estimated species richness from one visit) from one to two visits for those data sets when estimates of species richness increased from one to two visits. However, estimates from park-wide inventories decreased from one to two visits by 21 species (27% of the estimate of species richness for one visit) for spring point-count-UL, 11 species (18%) for spring point-count-30, and 22 (61%) for winter non-stop vehicular methods.

The model M_h was only selected for data sets using point-count methods (10 data sets using point-count-UL and 8 data sets using point-count-30, combining for 33% of all data sets), with the exception of winter non-stop vehicular methods (Table 3). M_{th} was the second most common model, having been selected for 13 (24%) of 54 data sets. M_{tth} was primarily selected for transect methods when only two sites were available (selected for 9 data sets, 17% of total). Other models selected were M_t (3 data sets, 6%), M_o (4 data sets, 7%), and M_b (1 data set, 2%). Estimates of species richness from models other than M_h (Table 3) were similar overall to those from M_h , except in the case of non-stop vehicular methods (Table 2). Estimates of species richness for non-stop vehicular data sets from the model selected by CAPTURE were much lower than the estimates from model M_h . Fourteen of 18 (78%) park-wide data sets failed to fit the model M_h significantly; nevertheless, M_h was selected by CAPTURE as the most appropriate

Table 2. HOFU Two Visits: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, and calculated using the model M_h with the Web-based program COMDYN4. Data from two visits were used for each calculation.

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	$S_E \pm SE$	40 ± 4.9^a	52 ± 4.7	24 ± 3.4	57 ± 4.6^a
		(95% CI)	(29 - 92)	(45 - 108)	(22 - 29)	(50 - 78)
		S_A ($S_P\%$)	28 (70%)	43 (83%)	22 (92%)	49 (86%)
	Point-count-30	$S_E \pm SE$	67 ± 5.4^a	46 ± 5.1	39 ± 3.9	51 ± 5.0^a
		(95% CI)	(26 - 100)	(38 - 104)	(13 - 68)	(45 - 71)
		S_A ($S_P\%$)	21 (31%)	35 (76%)	13 (33%)	42 (82%)
	Transect	$S_E \pm SE$	23 ± 3.0	56 ± 5.0^a	16 ± 2.7	53 ± 5.0^a
		(95% CI)	(19 - 29)	(39 - 74)	(13 - 21)	(44 - 95)
		S_A ($S_P\%$)	19 (83%)	35 (63%)	13 (81%)	42 (79%)
	BBS-style Vehicular	$S_E \pm SE$				48 ± 3.6^a
		(95% CI)				(45 - 54)
		S_A ($S_P\%$)				45 (94%)
	Non-stop Vehicular	$S_E \pm SE$				103 ± 5.2^a
		(95% CI)				(53 - 143)
		S_A ($S_P\%$)				50 (48%)
Breeding	Point-count-UL	$S_E \pm SE$	25 ± 3.6	38 ± 4.1	49 ± 3.9	47 ± 4.2^a
		(95% CI)	(22 - 48)	(32 - 73)	(20 - 84)	(39 - 85)
		S_A ($S_P\%$)	22 (88%)	32 (84%)	20 (41%)	40 (85%)
	Point-count-30	$S_E \pm SE$	19 ± 3.5^a	25 ± 3.3	17 ± 3.5	40 ± 4.6
		(95% CI)	(15 - 41)	(22 - 31)	(11 - 53)	(32 - 56)
		S_A ($S_P\%$)	15 (79%)	22 (88%)	11 (65%)	32 (80%)
	Transect	$S_E \pm SE$	26 ± 2.7	40 ± 4.3^a	15 ± 2.3^a	59 ± 5.1^a
		(95% CI)	(23 - 31)	(31 - 55)	(13 - 19)	(40 - 98)
		S_A ($S_P\%$)	23 (88%)	31 (78%)	13 (87%)	49 (83%)
	BBS-style Vehicular	$S_E \pm SE$				42 ± 4.3
		(95% CI)				(39 - 58)
		S_A ($S_P\%$)				36 (86%)
	Non-stop Vehicular	$S_E \pm SE$				64 ± 4.7
		(95% CI)				(32 - 99)
		S_A ($S_P\%$)				30 (47%)

Table 2 (cont.)

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Fall ^b						
Winter	Point-count-UL	$S_E \pm SE$	43 ± 3.7	45 ± 4.1	17 ± 3.5	36 ± 4.0
		(95% CI)	(14 - 71)	(23 - 88)	(13 - 50)	(28 - 77)
		$S_A (S_P\%)$	14 (32%)	23 (51%)	13 (76%)	28 (78%)
	Point-count-30	$S_E \pm SE$	16 ± 3.5	14 ± 2.9^a	4 ± 1.9	26 ± 3.8^a
		(95% CI)	(7 - 32)	(15 - 52)	(3 - 6)	(20 - 53)
		$S_A (S_P\%)$	7 (44%)	14 (100%)	3 (75%)	20 (77%)
	Transect	$S_E \pm SE$	12 ± 2.3	33 ± 3.8	14 ± 2.4	26 ± 3.5^a
		(95% CI)	(10 - 16)	(21 - 46)	(12 - 18)	(23 - 39)
		$S_A (S_P\%)$	10 (83%)	21 (64%)	12 (86%)	23 (88%)
	BBS-style Vehicular	$S_E \pm SE$				29 ± 4.1^a
		(95% CI)				(17 - 76)
		$S_A (S_P\%)$				17 (59%)
	Non-stop Vehicular	$S_E \pm SE$				14 ± 3.0^a
		(95% CI)				(13 - 23)
		$S_A (S_P\%)$				13 (93%)

^a Significant chi-square value from goodness-of-fit tests of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

^b Fall surveys were only conducted once at Hopewell Furnace National Historic Site.

Table 3. HOFU Model Selection: Estimates of species richness ($S_E \pm SE$) for the model selected as most appropriate and the model selected based on bird inventories at Hopewell Furnace National Historic Site, 1994-95, calculated using program CAPTURE. The program was not capable of calculating estimates for some of the models (e.g., M_{tth}). Data from all available visits were used for each case.

Season	Method	Community			
		Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	38 ± 6.5 M_{th}	52 ± 4.5 M_h	47 ± 7.2 M_{th}	63 ± 4.4 M_h
	Point-count-30	48 ± 11.4 M_{th}	47 ± 5.0 M_h	47 ± 13.0 M_h	61 ± 5.1 M_h
	Transect	not available M_{tth}	43 ± 5.6 M_{th}	not available M_{tth}	53 ± 3.9 M_{th}
	BBS-style Vehicular				49 ± 2.6 M_{th}
	Non-stop Vehicular				62 ± 6.4 M_{th}
Breeding	Point-count-UL	25 ± 3.6 M_h	not available M_{tth}	49 ± 3.9 M_h	47 ± 4.2 M_h
	Point-count-30	16 ± 1.4 M_t	25 ± 8.0 M_h	17 ± 3.5 M_h	39 ± 5.2 M_{th}
	Transect	28 ± 3.2 M_{bh}	39 ± 7.7 M_{th}	not available M_{tth}	56 ± 9.0 M_{th}
	BBS-style Vehicular				42 ± 4.3 M_h
	Non-stop Vehicular				31 ± 1.4 M_o
Fall	Point-count-UL	30 ± 6.8 M_o	30 ± 7.8 M_h	20 ± 6.1 M_h	36 ± 6.2 M_{th}
	Point-count-30	28 ± 18.9 M_{th}	46 ± 14.8 M_h	15 ± 5.8 M_h	29 ± 8.8 M_{th}
	Transect	not available M_{tth}	not available M_{tth}	not available M_{tth}	27 ± 1.3 M_t
Winter	Point-count-UL	43 ± 3.7 M_h	46 ± 12.6 M_h	18 ± 3.8 M_o	36 ± 4.0 M_h
	Point-count-30	Not enough data	15 ± 2.9 M_h	Not enough data	27 ± 5.6 M_{th}
	Transect	not available M_{tth}	24 ± 2.0 M_o	not available M_{tth}	26 ± 4.1 M_b
	BBS-style Vehicular				20 ± 2.5 M_t
	Non-stop Vehicular				14 ± 3.0 M_h

model for six of these data sets. The model selection procedure recommended M_{th} for eight of the remaining park-wide data sets.

Vehicular surveys

In five (83%) of six pairs of data sets using vehicular survey methods, observed species counts (S_A) were higher from BBS-style surveys than from non-stop surveys (Tables 1-2). In five (83%) of six pairs of data sets, the percent of estimated species richness observed (S_P) was higher from BBS-style surveys. Only two (33%) of six data sets using BBS-style surveys resulted in higher estimates of species richness than non-stop surveys. Estimates of species richness from BBS-style surveys in spring and breeding seasons using two visits, however, were more reasonable and consistent with estimates from other methods (Table 2). The estimates from non-stop surveys in spring in particular were higher than would be expected.

Comparison of inventory methods

We found the following non-overlapping confidence intervals within a given group: point-count-UL and transect surveys from spring upland forest inventories, point-count-30 survey from breeding lowland forest inventories, point-count-UL and transect surveys from breeding upland forest inventories, point-count-UL and transect surveys from fall old-field inventories, point-count-UL and transect surveys from fall upland forest inventories, point-count-30 survey from winter upland forest inventories, and point-count-UL and non-stop vehicular surveys from winter park-wide inventories (Tables 1-2).

All standard errors (SE s) from the estimates of species richness were similar (range 1.9-5.4), but the smallest among the methods were the following: among single-habitat inventories, seven (58%) of 12 of the data sets with the smallest SE were from transect surveys and four (33%) of 12 were from point-count-30 surveys (Tables 1-2). Among park-wide inventories, the BBS-style vehicular surveys had the smallest SE in spring, point-count-UL SE s were smallest in breeding and fall seasons, and the non-stop vehicular survey SE s were smallest in winter.

Only data sets using the point-count methods (and one non-stop vehicular data set) resulted in the selection of M_h by CAPTURE (Table 3). Point-count surveys resulted in the selection of M_h for 19 (56%) of 34 data sets using point counts.

Among single-habitat inventories, eight (67%) of 12 data sets with the highest percent of estimated species richness observed (S_P) were transect surveys, three (25%) of 12 were point-count-UL, and two (17%) of 12 were point-count-30 (the overlap was caused by equivalent S_P from two methods in one instance) (Tables 1-2). Among park-wide inventories, two (50%) of four data sets with the highest S_P were BBS-style vehicular surveys, one was transect surveys, and one was non-stop vehicular surveys.

Gettysburg National Military Park and Eisenhower National Historic Site

Analyses based on one visit

Forty-seven data sets were examined from GETT-EISE inventories. Estimates of species richness (S_E) from point-count-UL methods were greater than those from point-count-30 in 12 (75%) of 16 pairs of data sets (Table 4). Estimates were similar among the different methods, except in winter, when the observed species count was often low, causing the estimates to vary greatly from among the methods.

Table 4. GETT-EISE One Visit: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories in Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4. Data from only one visit were used for each calculation.

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	$S_E \pm SE$	46 ± 5.3	63 ± 4.3	25 ± 3.9	66 ± 5.9
		(95% CI)	(36 - 96)	(24 - 100)	(17 - 63)	(55 - 102)
		S_A ($S_P\%$)	33 (72%)	24 (38%)	17 (68%)	49 (74%)
	Point-count-30	$S_E \pm SE$	58 ± 5.7	31 ± 4.3	23 ± 3.9	62 ± 5.9
		(95% CI)	(38 - 122)	(20 - 84)	(15 - 52)	(49 - 97)
		S_A ($S_P\%$)	31 (53%)	20 (64%)	15 (65%)	44 (71%)
	Transect	$S_E \pm SE$	55 ± 5.1	34 ± 3.9	14 ± 2.4	74 ± 6.1^a
		(95% CI)	(37 - 74)	(28 - 43)	(12 - 18)	(50 - 120)
		S_A ($S_P\%$)	29 (53%)	26 (76%)	12 (86%)	43 (58%)
	Non-stop Vehicular	$S_E \pm SE$				74 ± 5.7^a
		(95% CI)				(39 - 144)
		S_A ($S_P\%$)				36 (49%)
Breeding	Point-count-UL	$S_E \pm SE$	34 ± 4.2	28 ± 4.1	29 ± 4.1	53 ± 5.1^a
		(95% CI)	(26 - 93)	(23 - 46)	(15 - 65)	(41 - 99)
		S_A ($S_P\%$)	26 (76%)	23 (82%)	15 (52%)	39 (73%)
	Point-count-30	$S_E \pm SE$	39 ± 4.6^a	17 ± 3.6	17 ± 3.7	49 ± 5.1
		(95% CI)	(20 - 88)	(14 - 32)	(11 - 42)	(30 - 92)
		S_A ($S_P\%$)	19 (49%)	14 (82%)	11 (65%)	30 (61%)
	Transect	$S_E \pm SE$	27 ± 3.6^a	18 ± 2.6^a	19 ± 2.6	53 ± 4.8^a
		(95% CI)	(20 - 43)	(15 - 23)	(16 - 23)	(32 - 90)
		S_A ($S_P\%$)	20 (74%)	15 (83%)	16 (84%)	31 (58%)

Table 4 (cont.)

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Fall ^b	Point-count-UL	$S_E \pm SE$	38 ± 4.1^a	13 ± 2.9	37 ± 3.9	51 ± 4.9
		(95% CI)	(20 - 61)	(9 - 29)	(13 - 58)	(36 - 69)
		$S_A (S_P\%)$	18 (47%)	9 (69%)	12 (32%)	26 (51%)
	Point-count-30	$S_E \pm SE$	33 ± 3.9^a	13 ± 2.9	30 ± 3.7	47 ± 4.7
		(95% CI)	(17 - 56)	(9 - 27)	(11 - 46)	(33 - 64)
		$S_A (S_P\%)$	17 (51%)	9 (69%)	11 (37%)	25 (53%)
	Transect	$S_E \pm SE$	too few sites	too few sites	too few sites	39 ± 4.3
		(95% CI)				(23 - 56)
		$S_A (S_P\%)$				23 (59%)
Winter	Point-count-UL	$S_E \pm SE$	27 ± 4.2^a	30 ± 4.3^a	12 ± 11.2	80 ± 5.6^a
		(95% CI)	(22 - 66)	(19 - 79)	(8 - 32)	(43 - 119)
		$S_A (S_P\%)$	22 (81%)	19 (63%)	8 (67%)	33 (41%)
	Point-count-30	$S_E \pm SE$	30 ± 4.4^a	29 ± 4.3^a	5 ± 7.9	52 ± 5.4^a
		(95% CI)	(22 - 82)	(19 - 69)	(4 - 16)	(37 - 92)
		$S_A (S_P\%)$	22 (73%)	18 (62%)	4 (80%)	31 (60%)
	Transect	$S_E \pm SE$	29 ± 3.8	14 ± 2.6	6 ± 1.7	29 ± 4.0
		(95% CI)	(17 - 45)	(11 - 18)	(6 - 8)	(22 - 59)
		$S_A (S_P\%)$	16 (55%)	11 (78%)	6 (100%)	22 (76%)
	Non-stop Vehicular	$S_E \pm SE$				30 ± 4.4
		(95% CI)				(19 - 78)
		$S_A (S_P\%)$				19 (63%)

^a Significant chi-square value from goodness-of-fit test of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

^b Fewer sites were surveyed in fall than in spring, breeding, and winter.

The observed species count (S_A) accounted for more than 75% of the estimated species richness (S_E) in only 12 (25%) of 47 data sets (Table 4). Five of these data sets were breeding season inventories and five were winter inventories. Six of the data sets accounting for more than 75% of the estimated species richness were transect surveys. Only one data set accounting for more than 75% of the estimate was an inventory on a park-wide basis.

The model M_h did not fit the data in 15 (32%) of the 47 data sets (chi-square goodness-of-fit test; $P < 0.05$) (Table 4). These data sets were primarily park-wide and old-field habitat inventories. Another model with different assumptions about the heterogeneity of species detectability may more appropriately fit the data.

Analyses based on two visits

Forty-six data sets were examined from GETT-EISE inventories. Estimates of species richness (S_E) from point-count-UL surveys were greater than those from point-count-30 in 11 (69%) of 16 pairs of data sets (Table 5). Estimates generally were similar among the different methods except in park-wide inventories and in winter inventories.

The observed species count (S_A) accounted for at least 75% of the estimated species richness (S_E) in 24 (52%) of 46 data sets (Table 5). Nine of these data sets were breeding season inventories and nine were winter inventories. Eight of the total data sets for which the observed species count accounted for more than 75% of the estimate were point-count-UL surveys, eight were point-count-30 surveys, and seven were transect surveys. Seven (54%) of 13 park-wide data sets accounted for at least 75% of the estimated species richness.

The M_h model did not fit the data in 17 (37%) of the 46 data sets (chi-square goodness-of-fit test; $P < 0.05$) (Table 5). These data sets were primarily from winter or park-wide inventories.

The observed species count (S_A) in single-habitat inventories (data segregated by old-field, lowland forest, or upland forest habitat) increased an average of 8.8 species ($SE = 0.6$; 51% of the mean observed species count from one visit) from one visit to two visits for all methods and seasons. For park-wide inventories, the mean increase in species observed was 12.5 species ($SE = 1.7$; 39% of the mean observed species count from one visit). Estimates of species richness (S_E) increased an average of 11.3 species ($SE = 1.8$; 42% of the mean estimated species richness from one visit) from one visit to two visits in single-habitat inventories. For those data sets from park-wide inventories when estimates of species richness increased from one visit to two visits, the estimates increased an average of 17.8 species ($SE = 4.1$; 33% of the mean estimated species richness from one visit). However, estimates from park-wide inventories decreased from one to two visits for fall point-count-30, winter point-count-UL, winter point-count-30, and winter vehicular.

The model M_h was selected for a greater percentage of data sets using point-count surveys than for those using transect surveys (Table 6). M_h was selected for point-count-UL in 10 (63%) of 16 data sets; for point-count-30 in nine (56%) of 16 data sets, and for transects in three (25%) of 12 data sets. Among park-wide inventories, the model M_h was selected more often (11 [79%] of 14 data sets) than among single-habitat inventories (13 [39%] of 33 data sets). Of the other models selected, M_{tbb} was selected for nine data sets (18% of total), primarily when only two sites were used for the inventory. Other models selected included M_o (5 data sets, 10%), M_{th} (3 data sets, 6%), M_b (2 data sets, 4%), M_{th} (2 data sets, 4%), M_t (1 data set, 2%), and M_{bh} (1 data set, 2%). Estimates of species richness from M_h (Table 5) were similar to those from other models

Table 5. GETT-EISE Two Visits: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4. Data from two visits were used for each calculation.

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	$S_E \pm SE$	52 $\pm$ 5.2	63 $\pm$ 5.5	38 $\pm$ 4.5	97 $\pm$ 6.4
		(95% CI)	(42 - 75)	(41 - 116)	(28 - 81)	(74 - 159)
		S_A ($S_P\%$)	42 (81%)	38 (60%)	27 (71%)	66 (68%)
	Point-count-30	$S_E \pm SE$	47 $\pm$ 5.0	75 $\pm$ 4.9	36 $\pm$ 4.5 ^a	69 $\pm$ 5.9
		(95% CI)	(39 - 59)	(30 - 117)	(22 - 86)	(59 - 97)
		S_A ($S_P\%$)	38 (81%)	30 (40%)	22 (61%)	55 (80%)
	Transect	$S_E \pm SE$	67 $\pm$ 5.4 ^a	52 $\pm$ 4.6	27 $\pm$ 3.2	78 $\pm$ 6.2 ^a
		(95% CI)	(47 - 87)	(43 - 63)	(22 - 33)	(67 - 100)
		S_A ($S_P\%$)	41 (61%)	40 (77%)	22 (81%)	62 (79%)
Breeding	Point-count-UL	$S_E \pm SE$	39 $\pm$ 3.6	38 $\pm$ 4.1	24 $\pm$ 3.2	58 $\pm$ 4.6 ^a
		(95% CI)	(36 - 46)	(33 - 86)	(21 - 68)	(49 - 108)
		S_A ($S_P\%$)	36 (92%)	33 (87%)	21 (88%)	47 (81%)
	Point-count-30	$S_E \pm SE$	42 $\pm$ 4.7	31 $\pm$ 4.1	16 $\pm$ 3.0	47 $\pm$ 4.4 ^a
		(95% CI)	(27 - 101)	(26 - 70)	(15 - 24)	(38 - 81)
		S_A ($S_P\%$)	27 (64%)	26 (84%)	15 (94%)	38 (81%)
	Transect	$S_E \pm SE$	52 $\pm$ 4.7	37 $\pm$ 3.5	27 $\pm$ 3.0	83 $\pm$ 6.1
		(95% CI)	(36 - 69)	(31 - 45)	(23 - 33)	(59 - 135)
		S_A ($S_P\%$)	35 (67%)	31 (84%)	23 (85%)	53 (64%)

Table 5 (cont.)

Season	Method	Variable	Community			
			Old-Field	Lowland Forest	Upland Forest	Park-Wide
Fall ^b	Point-count-UL	$S_E \pm SE$	48 ± 5.1	33 ± 3.4	39 ± 4.1	74 ± 5.8
		(95% CI)	(31 - 77)	(16 - 47)	(15 - 58)	(57 - 95)
		S_A (S _P %)	30 (63%)	16 (48%)	15 (38%)	40 (54%)
	Point-count-30	$S_E \pm SE$	53 ± 5.2	27 ± 3.4	36 ± 3.9	33 ± 4.4 ^a
		(95% CI)	(34 - 95)	(15 - 43)	(14 - 56)	(27 - 69)
		S_A (S _P %)	30 (57%)	15 (56%)	14 (39%)	40 (53%)
	Transect	$S_E \pm SE$	too few sites	too few sites	too few sites	85 ± 6.4 ^a
		(95% CI)				(68 - 108)
		S_A (S _P %)				42 (49%)
Winter	Point-count-UL	$S_E \pm SE$	34 ± 4.4 ^a	61 ± 4.9 ^a	15 ± 3.0 ^a	44 ± 4.6 ^a
		(95% CI)	(28 - 58)	(26 - 98)	(14 - 21)	(38 - 56)
		S_A (S _P %)	28 (82%)	25 (41%)	14 (93%)	37 (84%)
	Point-count-30	$S_E \pm SE$	33 ± 4.4 ^a	37 ± 4.7 ^a	17 ± 3.5 ^a	48 ± 5.0 ^a
		(95% CI)	(27 - 69)	(23 - 88)	(13 - 45)	(38 - 82)
		S_A (S _P %)	27 (82%)	23 (62%)	13 (76%)	36 (75%)
	Transect	$S_E \pm SE$	55 ± 5.1	24 ± 3.2 ^a	20 ± 3.1	55 ± 5.3
		(95% CI)	(37 - 74)	(19 - 30)	(15 - 25)	(42 - 100)
		S_A (S _P %)	29 (53%)	19 (79%)	15 (75%)	38 (69%)
	Non-stop Vehicular	$S_E \pm SE$				28 ± 4.0 ^a
		(95% CI)				(24 - 40)
		S_A (S _P %)				24 (86%)

^a Significant chi-square value from goodness-of-fit test of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

^b Fewer sites were surveyed in fall than in spring, breeding, and winter.

Table 6. GETT-EISE Model Selection: Estimates of species richness ($S_E \pm SE$) for the model selected as most appropriate and the model selected based on bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, calculated using program CAPTURE. The program was not capable of calculating estimates for some of the models (e.g., M_{tth}). Data from all available visits were used for each case.

Season	Method	Community			
		Old-Field	Lowland Forest	Upland Forest	Park-Wide
Spring	Point-count-UL	53 ± 9.1 M_{bh}	63 ± 11.6 M_h	38 ± 7.1 M_h	97 ± 13.7 M_h
	Point-count-30	not available M_{tth}	71 ± 16.9 M_h	not available M_{tb}	69 ± 5.8 M_h
	Transect	84 ± 50.8 M_b	not available M_{tth}	not available M_{tth}	not available M_{tb}
	Non-stop Vehicular				74 ± 17.5^a M_h
Breeding	Point-count-UL	39 ± 3.6 M_h	38 ± 4.1 M_h	24 ± 5.1 M_h	57 ± 6.3 M_h
	Point-count-30	42 ± 9.3 M_h	28 ± 1.8 M_0	16 ± 1.6 M_0	47 ± 5.4 M_h
	Transect	52 ± 7.1 M_h	not available M_{tth}	not available M_{tth}	83 ± 12.6 M_h
Fall	Point-count-UL	48 ± 8.4 M_h	17 ± 1.6 M_0	39 ± 9.5 M_h	74 ± 9.8 M_h
	Point-count-30	53 ± 9.6 M_h	16 ± 1.6 M_0	36 ± 9.3 M_h	76 ± 10.0 M_h
	Transect	too few sites	too few sites	too few sites	58 ± 7.6 M_t
Winter	Point-count-UL	not available M_{tth}	62 ± 65.9 M_b	not available M_{tb}	44 ± 4.6 M_h
	Point-count-30	not available M_{tth}	37 ± 7.8 M_h	20 ± 6.9 M_{th}	48 ± 6.9 M_h
	Transect	38 ± 5.2 M_0	not available M_{tth}	not available M_{tth}	55 ± 8.4 M_h
	Non-stop Vehicular				28 ± 4.0 M_{th}

^aOnly one visit conducted.

(Table 6) except in fall, when estimates calculated by model M_h were much higher than those calculated by models M_o and M_i .

Comparison of inventory methods

The only confidence intervals that did not overlap in a given group were vehicular and transect surveys from winter park-wide inventories (Table 5). All SE s were similar, but among single-habitat inventories, five (42%) of 12 of the data sets with the smallest SE were from transect surveys, five (42%) of 12 were from point-count-UL surveys, and four (33%) of 12 were from point-count-30 surveys (the overlap was caused by equivalent SE from two methods in three instances). Among park-wide inventories, vehicular surveys had the smallest SE in winter, and point-count-30 had the smallest in the spring, breeding, and fall seasons.

Point-count surveys resulted in the selection of M_h more often than transect surveys (Table 6). M_h was selected for point-count-UL in 10 (63%) of 16 data sets; for point-count-30 in nine (56%) of 16 data sets, and for transects in three (25%) of 12 data sets. Among park-wide inventories, the model M_h was selected more often (11 [79%] of 14 data sets) than among single-habitat inventories (13 [39%] of 33 data sets).

For single-habitat inventories, six (50%) of 12 data sets with the highest S_p were point-count-UL, five (42%) of 12 were point-count-30, and three (25%) of 12 were transect surveys (the overlap was caused by equivalent S_p from two methods in two instances) (Table 5). For park-wide inventories, point-count-30 and point-count-UL surveys had the highest S_p in three (75%) of four data sets; the highest for the fourth data set was from vehicular surveys. In three (75%) of four data sets, transect surveys yielded the lowest S_p within park-wide inventories.

1993 and 1994 breeding season

Nine data sets were examined for each year, where there was a data set for each combination of number of visits, method, and habitat type (Table 7). Both the observed species counts and the estimates of species richness were lower in 1994 than in 1993 in most data sets (6 [67%] of 9 paired data sets). However, the confidence intervals of the estimates all overlap from 1993 to 1994. The calculated values for species turnover and rate of change of species richness from COMDYN4 showed no statistical change in species richness or composition between the 2 years.

The use of data from two visits rather than one increased observed species counts and improved the percent of estimated species richness observed in all data sets (Table 7). The use of more study areas for 1994 breeding season inventories resulted in greater estimates of species richness, with a mean increase of 9.0 species in estimates of species richness for both one and two visits from few areas (Table 7) to many areas (Tables 4-5). Furthermore, the use of more study areas resulted in higher observed species counts, with a mean increase of 7.9 species for both one and two visits from few areas (Table 7) to many areas (Tables 4-5).

Lincoln-Petersen Index

All of the LPI estimates for GETT-EISE data were less than those calculated by model M_h (Table 8).

Table 7. GETT-EISE 1993 and 1994: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on breeding season bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site, 1993-94, and calculated using the model M_h with the Web-based program COMDYN4. Breeding season surveys were conducted in 1993 and 1994 at four study areas in the park.

Community and Method	Variable	Year	
		1993	1994
Old-Field one visit point-count-UL	$S_E \pm SE$	47 $\pm$ 4.4	22 $\pm$ 3.6
	(95% CI)	(22 - 69)	(18 - 41)
	S_A ($S_P\%$)	20 (42%)	18 (82%)
Old-Field two visits point-count-UL	$S_E \pm SE$	31 $\pm$ 3.8	28 $\pm$ 3.4
	(95% CI)	(26 - 41)	(25 - 43)
	S_A ($S_P\%$)	26 (84%)	25 (89%)
Lowland Forest one visit point-count-UL	$S_E \pm SE$	25 $\pm$ 3.8	14 $\pm$ 2.8
	(95% CI)	(18 - 43)	(13 - 21)
	S_A ($S_P\%$)	18 (72%)	13 (93%)
Lowland Forest two visits point-count-UL	$S_E \pm SE$	27 $\pm$ 3.6	26 $\pm$ 3.3
	(95% CI)	(22 - 40)	(23 - 35)
	S_A ($S_P\%$)	22 (81%)	23 (88%)
Upland Forest one visit point-count-UL	$S_E \pm SE$	25 $\pm$ 3.7	23 $\pm$ 3.7
	(95% CI)	(13 - 49)	(11 - 44)
	S_A ($S_P\%$)	13 (52%)	11 (48%)
Upland Forest two visits point-count-UL	$S_E \pm SE$	16 $\pm$ 2.8	25 $\pm$ 3.5
	(95% CI)	(15 - 21)	(19 - 48)
	S_A ($S_P\%$)	15 (94%)	19 (76%)
Park-wide one visit point-count-UL	$S_E \pm SE$	39 $\pm$ 4.1	48 $\pm$ 4.7
	(95% CI)	(30 - 55)	(32 - 64)
	S_A ($S_P\%$)	30 (77%)	28 (58%)
Park-wide two visits point-count-UL	$S_E \pm SE$	45 $\pm$ 4.3	50 $\pm$ 4.4
	(95% CI)	(36 - 61)	(40 - 67)
	S_A ($S_P\%$)	36 (80%)	38 (76%)
Park-wide one visit transect	$S_E \pm SE$	47 $\pm$ 4.6	35 $\pm$ 4.3
	(95% CI)	(31 - 65)	(26 - 51)
	S_A ($S_P\%$)	28 (59%)	25 (71%)

Table 8. Lincoln-Peterson Index Estimates. Estimates of species richness based on transect bird inventories at Gettysburg National Military Park and Eisenhower National Historic Site in 1993-94 and at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial in 1997, and calculated using the Lincoln-Peterson index. Estimates were calculated using data from two independent inventories and compared to estimates of species richness calculated from the same data using the model M_h .

Data Source	Estimates of Species Richness ^a						Mean	Mean from Model M_h Estimates ^b
GETT-EISE spring point counts and transects	58.5	55.6					57.0	67.3
GETT-EISE breeding point counts and transects	44.8	42.3					43.5	51.7
GETT-EISE fall point counts and transects	37.4	35.9					36.6	45.7
GETT-EISE winter point counts and transects	38.2	35.9					37.0	53.7
ALPO-JOFL spring transects	77.0	43.6	72.1	76.6	49.9	51.2	61.7	82.5

^a Multiple estimates were calculated from each combination of inventory visits.

^b Means calculated from Tables 4 and 10 using the comparable data source.

Valley Forge National Historical Park

Vehicular surveys

Both estimates of species richness and observed species counts increased from one to two visits for spring vehicular surveys (Table 9). Observed species counts did not differ greatly between BBS-style surveys and non-stop surveys in spring, but for two visits in spring, the estimate for the non-stop surveys was 12 species higher than the estimate for the BBS-style surveys. Observed species counts for two of the four spring data sets accounted for at least 75% of the estimated species richness (a third data set was close, at 73%). The observed species count for the winter data set was only 44% of the estimate of species richness.

Comparison of Results from HOFU, GETT-EISE, and VAFO

We were able to examine some direct comparisons among the results of the species richness investigation from these four parks because the system of inventories at each park was carried out as part of a central study design. The following section outlines similarities and differences in the results that have been presented separately in the above sections.

HOFU and GETT-EISE, analyses based on one visit (Tables 1 and 4)

Estimates of species richness from point-count-UL surveys were greater than those from point-count-30 for both parks. Estimates otherwise were similar among methods within a park, except in fall and winter, when numbers of species observed were low. Fewer data sets from GETT-EISE yielded observed species counts that were more than 75% of the estimated species richness, particularly in the park-wide inventories.

HOFU and GETT-EISE, analyses based on two visits (Tables 2 and 5)

At HOFU, park-wide estimates of species richness were more similar among the methods than the single-habitat estimates; whereas at GETT-EISE, park-wide estimates were some of the least similar among the methods.

Similar proportions of data sets from each park yielded observed species counts that were at least 75% of the estimates of species richness. The highest number of data sets with at least 75% of estimated species observed was from breeding season and park-wide inventories in both HOFU and GETT-EISE. Increases in observed species counts and estimates of species richness from one to two visits were similar for both parks.

HOFU and GETT-EISE, model selection (Tables 3 and 6)

For both parks, point-count surveys most often resulted in selection of model M_h , which was selected more for park-wide data sets at GETT-EISE than at HOFU. M_{th} was the second most common model selected at HOFU but was rarely selected at GETT-EISE.

HOFU and GETT-EISE, comparison of inventory methods (Tables 2-3 and 5-6)

There were more confidence intervals from the HOFU data that did not overlap among the methods than from the GETT-EISE data. For both parks, the smallest standard errors were primarily from transect surveys and point-count-30 surveys. More data sets from GETT-EISE selected model M_h than from HOFU; but with both parks, the point-count methods resulted in the

Table 9. VAFO Vehicular Inventories: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on vehicular bird inventories at Valley Forge National Historical Park, 1996, and calculated using the model M_h with the Web-based program COMDYN4. Vehicular inventories were conducted both with a BBS-style survey (point-counts at vehicular stops) and a non-stop survey (spring only). Inventories were conducted twice in spring season and only once in winter.

Season and Number of Visits	Variable	Vehicular Inventory Method	
		BBS-style	Non-stop
Spring one visit	$S_E \pm SE$	51 ± 5.1	50 ± 4.8
	(95% CI)	(41 - 80)	(43 - 98)
	S_A ($S_P\%$)	39 (76%)	42 (84%)
Spring two visits	$S_E \pm SE$	78 ± 6.0	91 ± 5.3
	(95% CI)	(62 - 129)	(56 - 141)
	S_A ($S_P\%$)	57 (73%)	53 (58%)
Winter one visit	$S_E \pm SE$	41 ± 4.6	
	(95% CI)	(20 - 78)	
	S_A ($S_P\%$)	18 (44%)	

selection of M_h more than other methods. The method yielding the highest percent of estimated species richness observed (S_p) at HOFU, transect surveys, was the method yielding the lowest S_p at GETT-EISE. Point-count methods gave higher S_p s at GETT-EISE than at HOFU.

HOFU and VAFO, vehicular surveys (Tables 1, 2, and 9)

At HOFU, BBS-style vehicular surveys consistently yielded higher observed species counts and percents of estimated species richness observed than non-stop vehicular surveys. Additionally, non-stop vehicular surveys at HOFU yielded estimates of species richness that were higher than would be expected. At VAFO, however, results did not differ greatly between BBS-style and non-stop surveys.

Discussion

The small number of species recorded in some habitats as well as the small number of sites used for some of the methods (esp. transect surveys) could explain the amount of disparity in estimates of species richness among methods on a single-habitat basis. Combining inventories over a whole park appeared to balance out low counts and high counts more evenly. The capture-recapture model estimators often fail to provide reliable estimates of species richness for small data sets (Otis et al. 1978, Menkens and Anderson 1988); the park-wide data sets were larger and may have been more effective for use of the models.

Estimates of species richness per habitat from fall and winter inventories were variable, probably due to the low numbers of species recorded in these seasons. Otis et al. (1978) recommended sample sizes of at least 20 species in order for model selection to operate reliably and provide a precise estimate of species richness. Bird species are less conspicuous in fall and winter because they are less territorial, potentially more mobile, and more susceptible to weather patterns than in summer, traveling in wide-ranging interspecific flocks (Verner and Milne 1989). The number of bird species counted in a single survey visit in fall or winter could, therefore, vary more from visit to visit and from method to method than in other seasons, e.g., breeding season, when birds are more vocal and sedentary. Estimates on a park-wide basis and from two visits in fall and winter were more consistent.

Habitat differences among study sites could account for some inconsistencies between estimates calculated on a single-habitat basis versus those compiled park-wide. Open habitats, e.g., fields, have less foliage or canopy than forested habitats, which could increase the detectability of birds by observers. Furthermore, the composition of bird species should vary among the habitats and cause the inventories to yield different results among habitat types. If such were the case, a species richness estimation model with a t -component should be used for park-wide data sets, assuming different detection probabilities among sites.

Many of the estimates of species richness for a single habitat were considerably higher than what the true species richness would be expected to be, based on species known to potentially occur in Pennsylvania (G. Keller, Penn State Univ., 15 March 1998). For example, it is unlikely that more than 50 species of birds would winter in old-fields or lowland forests at GETT-EISE (G. Keller, Penn State Univ., 15 March 1998), but the estimates of species richness and the 95% confidence intervals in some instances predicted from 60-100 bird species in a single habitat type. Estimates from data combined for a whole park and estimates from data with higher numbers of study sites were more in keeping with expected species richness values.

Two survey visits instead of one nearly doubled observed species counts of birds and greatly improved the percent of estimated species richness observed. Inventories based on only one visit would be more susceptible to inconsistent results from weather or other conditions that may cause birds to be less detectable, thus yielding unreliable results from the estimation models because of low numbers of species. Additionally, the chances of seeing less common species would be enhanced with more than one visit. Studies have shown the number of bird species and individuals recorded by point count inventories increased significantly with more than one visit (Buskirk and McDonald 1995, Petit et al. 1995). Furthermore, confidence in trends in species composition and abundance over time would increase with a greater sample size of species (Verner 1985). Sample sizes often can be increased either by increasing the number of sampling points or by increasing the number of visits (Ralph et al. 1995).

An important assumption of the species richness models and of most population estimates based on point-count surveys is that the sample community is closed. Particularly in the migratory seasons for birds (spring and fall), this assumption is most likely violated when more than one visit is used for a inventory. But neither the observed species counts nor the estimated species richness changed from one to two visits proportionally more in fall or spring than in winter or breeding seasons, which might be expected if the community was changing. The community may remain sufficiently similar and not violate the assumptions of the models if the survey visits are close together in time. Furthermore, because park personnel are probably more interested in recording a list of species occurring in the park than in the accuracy of the species richness estimate (a number only), we would recommend more than one visit per inventory regardless of season. There are capture-recapture estimators available for open communities (allows both immigration and emigration); however, these models do not account for heterogeneous species detection probabilities (Pollock et al. 1990). These models were not applied in the current investigation but could be considered for estimating species richness across seasons where the bird community is changing.

The model-selection procedure from program CAPTURE is not effective on small data sets (e.g., when there are only two study sites, as with transect surveys in old-field and upland forest habitats) or when numbers of species are low (e.g., winter inventories) (Otis et al. 1978, Menken and Anderson 1988, Pollock et al. 1990). Otis et al. (1978) recommended having at least five sites for application of the models. The model M_h was nevertheless capable of providing estimates of species richness for small data sets and could be used through the COMDYN4 Web site rather than through CAPTURE. Although the application of model M_h to park-wide inventory data from GETT-EISE often resulted in a poor fit of the model, M_h was most consistently selected by CAPTURE for park-wide inventory data. CAPTURE is more difficult to use than COMDYN4; if M_h is the best model for the majority of inventory data sets, then COMDYN4 could be used exclusively. However, the use of a model that does not adequately fit the data can lead to biased estimates and especially to large variance and confidence intervals (Otis et al. 1978).

The CAPTURE program selected models with a t component more often for transect and vehicular surveys than for point counts at HOFU, meaning that detection probabilities were assumed to vary among sites. This could be accounted for by the different habitat types where the transects were established and resulting detectability differences among sites. Point counts also were stratified among these habitats, but the number of sampling points was greater than with transect or vehicular surveys. Thus, detectability differences among habitat types may be less

distinguishable by models using point-count surveys. Because habitat variables associated with each sampling point or transect were not measured in conjunction with the inventories, there may have been microhabitat differences along transects or among sites within the same habitat type that affect detectability of birds.

Vehicular surveys on a park-wide basis appeared to be as effective as other methods for inventorying species and estimating species richness at HOFU, but were not as effective at GETT-EISE. When time is a constraint and roads enable most areas of a park to be accessible, the vehicular survey methods could be the most efficient means of obtaining an estimate of species richness of birds in the park. Two studies comparing point counts of birds from on-road to off-road points in the same habitat found that there was no significant difference between species counted at each location; in fact, more species and individuals were often recorded along roads than away from roads (Hutto et al. 1995, Keller and Fuller 1995).

Non-stop vehicular surveys were the least time-consuming and least labor-intensive inventory method analyzed in this investigation (Yahner et al. 1998a). At VAFO, the vehicular survey results did not differ between BBS-style and non-stop surveys; but at HOFU, BBS-style vehicular surveys improved the species list and the accuracy of the species richness estimate over the non-stop vehicular surveys. The BBS-style vehicular surveys may be more effective in forested habitats where detection of birds can be dependent more on sound (e.g., song) and amount of time spent at a point. As with other methods, repeating the survey at least twice within a season increased the counts.

Our analysis of inventory data from breeding seasons over 2 years illustrated how results can vary among years and sampling periods. Repeating inventories each year did not appear to alter significantly the observed species counts. It did alter the estimates of species richness, yet the confidence intervals of the estimates overlapped between years. The confidence intervals are important indicators of the range of possible values, and repeat sampling from year-to-year would not be expected to significantly alter the range of the estimate unless the community is changing. In order to monitor the community over time, inventories may instead be repeated on a greater time scale, such as every 10 or 20 years (Boulinier et al. 1998), although we would suggest intervals of 1 to 5 years for establishing a long-term data set.

Personnel at GETT-EISE and VAFO have compiled lists of bird species documented in each park over many years through various observation methods, including BBS data and personal observations by experienced birders frequenting the area (Yahner et al. 1998a). These lists contain nearly twice the total number of species estimated by methods tested in this investigation (Appendix A). Most of the additional species belong to taxa, such as waterfowl and shorebirds, that were not well documented by the inventories used in Yahner et al. (1998a). Because no inventory protocol is comprehensive, estimates of species richness can only be used as tools for probing the numbers of species in a park. In order to improve estimates of species richness, attention should be given to unique or underrepresented habitats (Howe et al. 1995) and to species requiring unique protocols (e.g., owls) (Ralph et al. 1995).

Based on the four-step examination of inventory methods presented in this report, the point-count-UL method appeared to yield more consistently precise results overall than the point-count-30 method. Point counts more consistently fit with the model M_h , whereas transect methods often yielded the highest percent of estimated species richness observed. In contrast, point-counts-UL yielded higher observed species counts than transects for 22 (79%) of 28 data sets. But in many cases, each method recorded some species that were not recorded by both

methods (e.g., the maximum coefficient of community similarity between point-count and transect methods was 0.84 and averaged 0.67). Therefore, for the purposes of compiling the most complete species list possible, a combination of methods might be most effective.

Observed species counts obtained from unlimited-distance point counts generally yielded higher values than fixed-radius point counts and required little extra effort on the part of the observer (Yahner et al. 1998a). Gates (1995) found that about 80% of all bird detections were recorded >30m from the counting point. However, if the investigator intends to calculate and compare indices of abundance or density, a fixed-radius provided more reliable figures (Gates 1995). Unlimited distance point counts can be conducted while recording distance to the birds for abundance or density calculations.

Park personnel inventorying birds may be more interested in the list of observed species than the estimated species richness. For this purpose, point-count-UL surveys yielded better results. Furthermore, when inventorying by specific habitats, the point-count surveys allowed for more effective use of the models, because the number of sites was higher for point-count surveys than for transect surveys. Within the given sampling design, the sample size of transects often was too small to be effective for single habitats (e.g., there were only two transects for two of the habitat types).

Park personnel may be more interested in species inventories across the entire park rather than within a certain habitat. On a park-wide basis, any of the four methods yielded similar estimates. Hence, we would recommend choosing an inventory method based on time and labor constraints. For instance, vehicular surveys are the least time-consuming and labor-intensive methods (Yahner et al. 1998a), and they consistently yielded observed species counts that accounted for over 80% of the estimated species richness. In winter, however, vehicular surveys were not as effective as transects or point counts, perhaps because birds tend to be more mobile than in the breeding season (Yahner 1989). Winter inventories may be improved by the use of additional methods, such as audio playback of bird songs to stimulate a response (Ralph et al. 1995). If time and labor constraints are not a limiting factor in an inventory, we would recommend conducting point counts.

The Lincoln Petersen Index has been found to be more effective than the capture-recapture models for data sets with small sample sizes, but it has not been found to be as effective when probabilities of detection varied among individual species rather than among sites (Menkens and Anderson 1988, Pollock et al. 1990). With the data sets in this study, detection probabilities were assumed primarily to vary among species, which may explain the difference between the LPI estimates and the M_h estimates. The effort required to apply the LPI was no different than that required for M_h , therefore, we recommend the use of the more robust capture-recapture models for these inventories. The LPI can be useful when inventories were not structured and when sites have not been designated.

Differences in effectiveness of the model application among GETT-EISE and HOFU may be attributable to differences in the extent of cover types between the two parks. Seventy-five percent of HOFU is forested, whereas only 36% of GETT-EISE is forested (Yahner et al. 1998a). Detectability of birds could vary between forested habitats and open habitats. Additionally, the effectiveness of each of the inventory methods could vary among habitat types. In particular, the prevalence of forest at HOFU may explain the improvement of vehicular survey results with the BBS-style method rather than the non-stop method. Forest birds are detected more readily by song rather than by visual sightings because of dense foliage; thus, investigators need to exit the

vehicle to enhance auditory detections of birds in forested cover types. The different extent of cover types between the parks also may explain the discrepancies among the precision of park-wide estimates between the parks.

Chapter 5

Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial

Methods

Transects

We compiled the ALPO-JOFL data into the format needed for application of the capture-recapture models. Initially, each transect was used as a “site” for the model ($n = 3$); the species list of birds was compiled for each transect. Data were compiled for each season and each additional survey visit, yielding data sets for both spring and breeding seasons from one, two, three, and four visits, respectively. For each additional visit, bird species recorded on previous visits were pooled with species newly recorded. Estimates of species richness, standard errors (SE), and 95% confidence intervals were obtained from calculations based on the Web-based program COMDYN4. We also calculated the percent of estimated species richness observed.

We subsequently entered the data into the model selection procedure in CAPTURE to determine if another model more accurately fit the data sets. We recorded the model selected by the procedure and the estimate of species richness provided by that model when available.

Sectioned transects

Secondly, each transect was divided into three equal-length sections prior to species compilation, and each section was a “site” for the model ($n = 9$); the species list of birds was compiled for each section. The use of more sites could improve the precision of the estimates and the reliability of the model selection procedure in CAPTURE (Otis et al. 1978). Data were compiled for each season and each additional survey visit, yielding data sets for both spring and breeding seasons from one, two, three, and four visits. For each additional visit, bird species recorded on previous visits were pooled with species newly recorded. Estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals were obtained from calculations based on the Web-based program COMDYN4. Percent of estimated species richness observed also was calculated using the sectioned data sets.

We subsequently entered the data into the model selection procedure in CAPTURE to determine if another model more accurately fit the data sets. We recorded the model selected by the procedure and the estimate of species richness provided by that model when available.

Lincoln-Petersen Index

We applied the LPI to ALPO-JOFL data sets using the spring season transect data. Each visit was considered an individual inventory, and LPI estimates were obtained for all combinations of two visits (e.g., first and second, first and third, first and fourth, second and third, etc.).

Results

Transects

Eight data sets were examined from ALPO-JOFL transect data (Table 10). In spring season, estimates of species richness increased with each additional visit, as did observed species counts (Fig. 1). The percent of estimated species richness observed increased from 70% (one visit) to 78% (four visits). The 95% confidence intervals for the estimates did not overlap from all four data sets, but they did overlap with the nearest two data sets.

In breeding season, the greatest change in both estimates of species richness and observed species counts was from one visit to two visits (increase of 13 species estimated and 11 species counted). Estimates of species richness hardly differed among two, three, and four visits; observed species counts increased by five species from two to four visits (Fig. 2). The percent of estimated species richness observed increased from 65% (one visit) to 73% (four visits). The 95% confidence intervals for the estimates overlapped for all four data sets. The model M_h did not fit the data for two of the eight data sets (spring three and four visits) by the chi-square goodness-of-fit test ($P < 0.05$). The model selection procedure in CAPTURE selected model M_i for these two data sets.

Sectioned transects

Using the sectioned data sets, estimates of species richness from the spring season increased dramatically from one to two visits, while the observed species counts only increased by 10 species (Table 11). With the exception of the two-visit data set, estimates of species richness from sectioned-transect data from spring were nearly identical to those from Table 10. Estimates of species richness from the breeding season were more consistent among different numbers of visits and among the two compilation methods (Table 10 vs. Table 11). The estimates of species richness from two, three, and four visits were two to four species less than those from Table 10.

The model M_h did not fit the data in all of the eight data sets from both spring and breeding seasons by the chi-square goodness-of-fit test ($P < 0.05$). CAPTURE instead selected the model M_{th} for all eight data sets. The estimate of species richness from model M_{th} for two visits in spring was more similar to the estimate using non-sectioned data (Table 10).

Lincoln-Petersen Index

The mean estimate of species richness from the LPI for ALPO-JOFL data was less than the mean estimate of species richness from model M_h (Table 8).

Discussion

During the spring migration of birds, additional survey visits continued to add to the ALPO-JOFL bird species list, and the estimates of species richness increased with each additional visit as well. Multiple visits in migratory seasons obviously are violating the assumption of a closed community that is required for application of the capture-recapture models. Additionally, there is the real problem of sampling multiple communities without bounds; population size,

Table 10. ALPO: Transects: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997, and calculated using the model M_h with the Web-based program COMDYN4. Variables were re-calculated using the program CAPTURE's model selection procedure, which selected model M_t for two cases. Surveys were conducted four times in each of two seasons, spring and breeding. Species of birds recorded on previous visits were combined with the species list from each additional visit.

Season and Model	Variable	Number of Visits			
		One	Two	Three	Four
Spring Model M_h	$S_E \pm SE$	76 ± 7.4	85 ± 7.2	104 ± 7.8^a	110 ± 7.8^a
	(95% CI)	(61 - 93)	(72 - 100)	(90 - 123)	(94 - 128)
	S_A ($S_P\%$)	54 (70%)	64 (75%)	80 (76%)	86 (78%)
Spring Model M_t	$S_E \pm SE$			87 ± 3.0	88 ± 2.5
	(95% CI)			(83 - 95)	(85 - 96)
	S_A ($S_P\%$)			80 (92%)	86 (98%)
Breeding Model M_h	$S_E \pm SE$	68 ± 7.2	81 ± 7.5	83 ± 7.4	83 ± 7.2
	(95% CI)	(52 - 87)	(67 - 97)	(67 - 99)	(71 - 97)
	S_A ($S_P\%$)	45 (65%)	56 (68%)	60 (72%)	61 (73%)

^aSignificant chi-square value from goodness-of-fit test of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

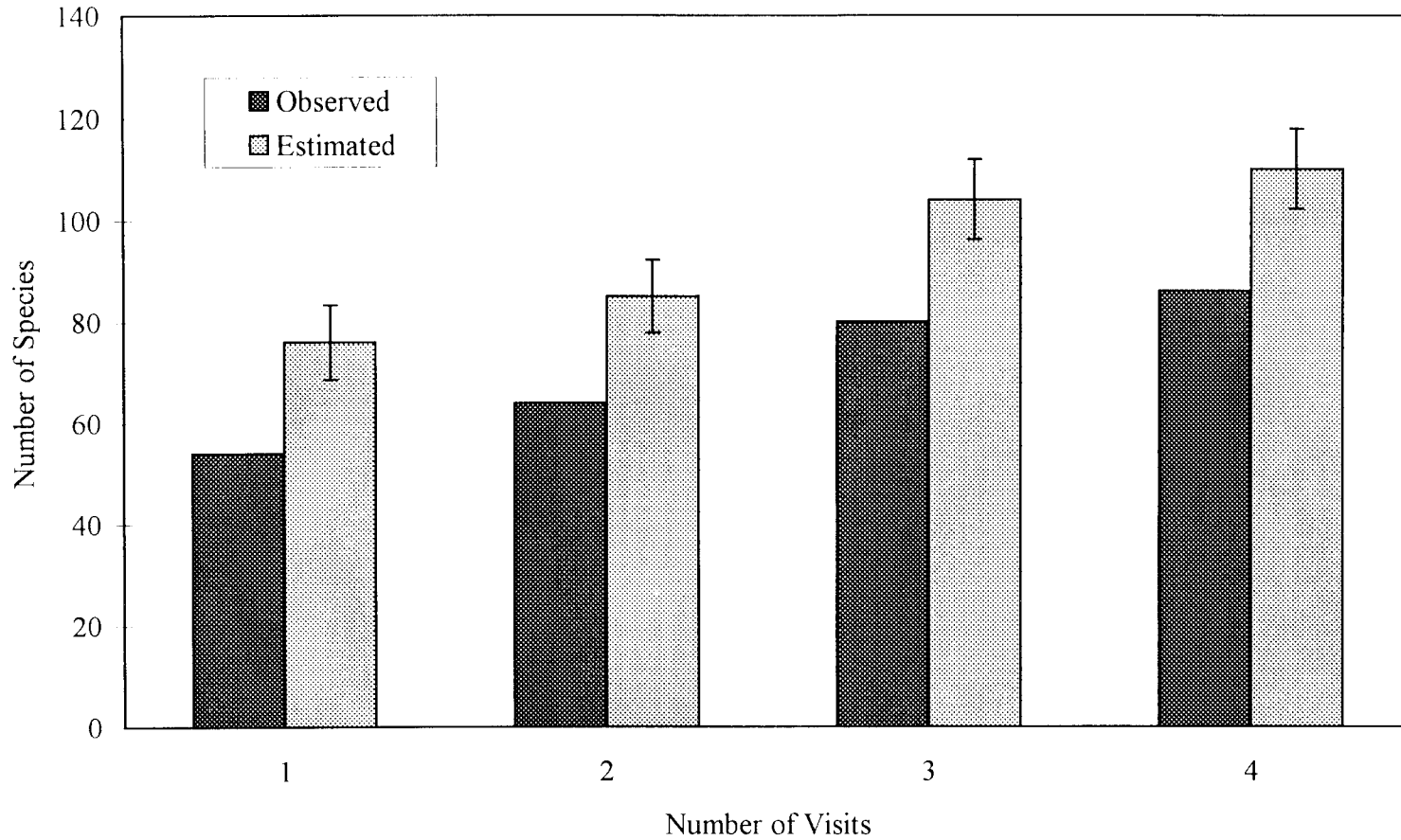


Figure 1. Observed species counts and estimates of species richness, including 95% confidence intervals, for each of four survey visits based on based on spring transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997. Species of birds recorded on previous visits were combined with the species list from each additional visit. Estimates of species richness were calculated using the model M_h with the Web-based program COMDYN4.

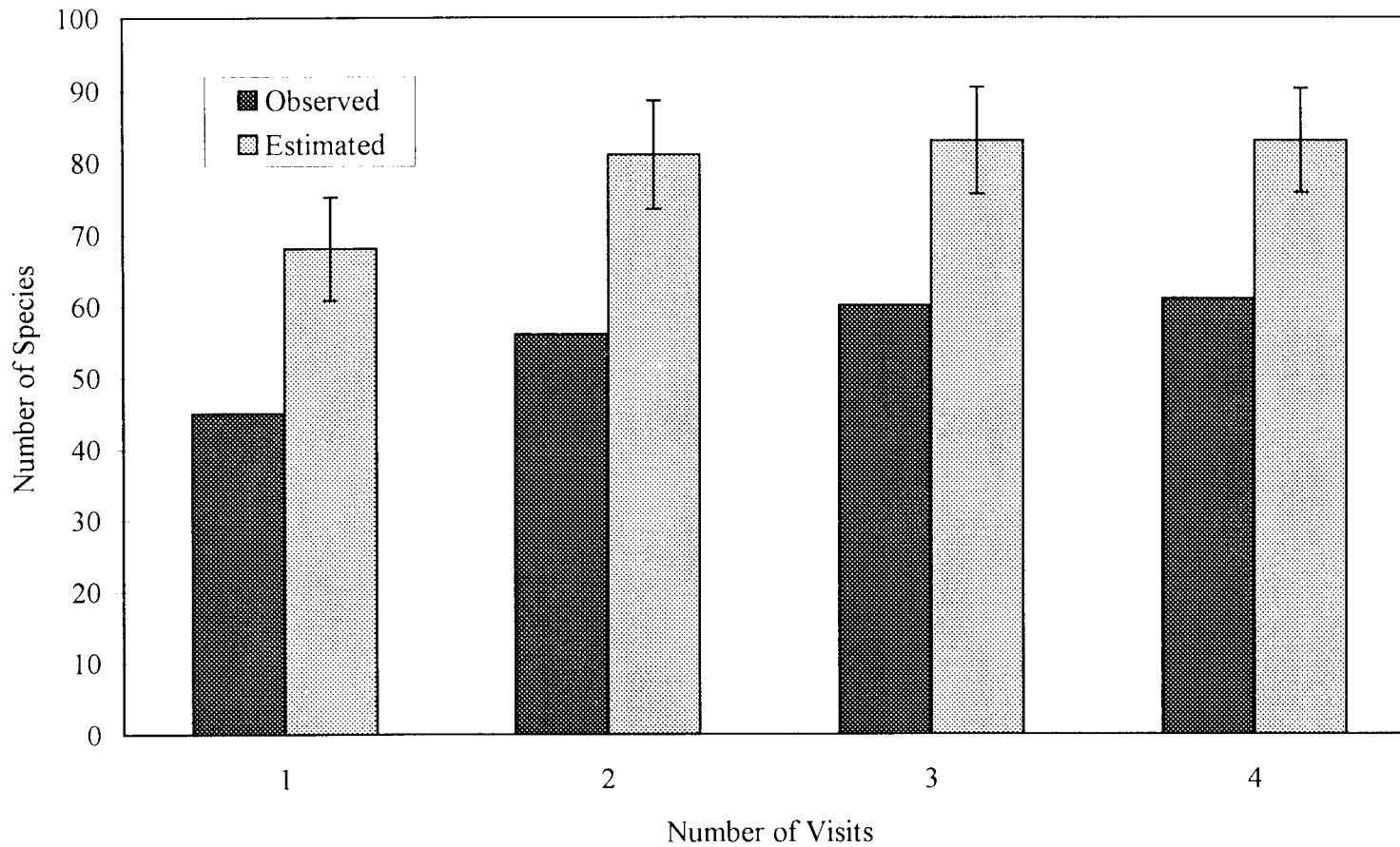


Figure 2. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997. Species of birds recorded on previous visits were combined with the species list from each additional visit. Estimates of species richness were calculated using the model M_h with the Web-based program COMDYN4.

Table 11. ALPO: Sectioned transects. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on transect bird inventories at Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, 1997, and calculated using the model M_h with the Web-based program COMDYN4. Variables were re-calculated using the program CAPTURE's model selection procedure, which selected model M_{th} for all cases. Surveys were conducted four times in each of two seasons, spring and breeding. Species of birds recorded on previous visits were combined with the species list from each additional visit. Each of three transects was divided into three sections prior to species compilation for this analysis.

Season and Model	Variable	Number of Visits			
		One	Two	Three	Four
Spring Model M_h	$S_E \pm SE$	73 ± 6.1^a	130 ± 6.3^a	108 ± 6.7^a	115 ± 6.6^a
	(95% CI)	(60 - 131)	(74 - 179)	(89 - 174)	(93 - 184)
	S_A ($S_P\%$)	54 (74%)	64 (49%)	80 (74%)	86 (75%)
Spring Model M_{th}	$S_E \pm SE$	72 ± 8.9	84 ± 8.9	101 ± 8.9	106 ± 8.2
	(95% CI)	(61 - 99)	(73 - 110)	(90 - 127)	(95 - 129)
	S_A ($S_P\%$)	54 (75%)	64 (76%)	80 (79%)	86 (81%)
Breeding Model M_h	$S_E \pm SE$	72 ± 6.2^a	79 ± 6.1^a	78 ± 5.9^a	79 ± 5.8^a
	(95% CI)	(52 - 125)	(62 - 127)	(67 - 134)	(67 - 124)
	S_A ($S_P\%$)	45 (63%)	56 (71%)	60 (77%)	61 (77%)
Breeding Model M_{th}	$S_E \pm SE$	75 ± 14.4	77 ± 9.5	78 ± 8.5	78 ± 7.8
	(95% CI)	(57 - 118)	(64 - 105)	(68 - 101)	(68 - 101)
	S_A ($S_P\%$)	45 (60%)	56 (73%)	60 (78%)	61 (78%)

^aSignificant chi-square value from goodness-of-fit test of model M_h , indicating that the data did not significantly fit the model ($P < 0.05$).

relative abundances, and species richness are constantly changing variables. Although it may be valuable to record the diversity of bird species migrating through a park, the reliability of the capture-recapture models is probably questionable beyond one or two survey visits in a migratory season. Models for open communities (e.g., Jolly-Seber open population model) instead could be used for migratory bird data (Pollock et al. 1990).

The estimate of species richness of birds at ALPO-JOFL appeared to reach an asymptote after two visits during the breeding season. The summer bird community is generally a closed community of resident species, because most are territorial, and the addition of a third and fourth visit appeared to be an unnecessary effort.

Otis et al. (1978) recommended the use of at least five sites for the best performance of the models. Although the estimates of species richness did not differ greatly between the use of three sites (non-sectioned data) or nine sites (sectioned data), the confidence intervals of the estimates were much narrower for the three site data. The use of the model M_{th} for the sectioned (nine sites) data sets improved the precision of the estimates over the results of M_h , but the estimates remained less precise than those from the non-sectioned (three sites) data.

The sectioning of the transects resulted in the selection of a model that assumed detection probabilities varied among sites as well as among individuals. By sectioning the transects, habitats that varied along the length of a transect were sectioned as well. For example, the first 100-400 m of two of the transects were characterized by open grasslands and shrubs. Detectability of bird species would likely vary from these open habitats to the more enclosed hardwood and hemlock forests that the rest of the transects covered.

The LPI has been found to be more effective than the capture-recapture models for data sets with small sample sizes, but it has not been found to be as effective when probabilities of detection varied among individual species rather than among sites (Menkens and Anderson 1988, Pollock et al. 1990). With the data sets in this study, detection probabilities were assumed primarily to vary among species, which may explain the difference between the LPI estimates and the M_h estimates. The effort required to apply the LPI was no different than that required for M_h , therefore, we recommend the use of the more robust capture-recapture models for these inventories. The LPI can be useful, however, when inventories were not structured and when sites have not been designated.

Chapter 6

Shenandoah National Park

Methods

We compiled inventory data from three methods in various combinations of data sets. BBS data from 1995-97 were compiled for each year by route, and each route was a "site" for the model ($n = 4$). MAPS mist-net data from 1995-96 were compiled for each year initially using only one visit, and each station was a "site" for the model ($n = 6$). Single-visit data sets were compiled for each of the first five visits. Data beyond the fifth visit were not used for this investigation. Secondly, the mist-net data from 1995-97 were compiled for each year and each cumulative visit, resulting in data sets from one, two, three, and four visits. For each additional visit, bird species recorded on previous visits were pooled with species newly recorded. MAPS point count data from 1995 were examined using each station of nine points as a "site" for the model ($n = 6$). Data sets were compiled for each combination of the following factors: count distance (50-m and unlimited), count duration (3- and 5-minute), and number of visits (one and two).

For each data set described above, estimates of species richness, standard errors ($\pm SE$), and 95% confidence intervals were obtained from calculations based on the Web site COMDYN4. Percent of estimated species richness observed was calculated for each data set as well.

Results

The results of the three inventory methods can be compared using the data sets for one visit. For MAPS point-count data, unlimited distance, 3-minute duration counts were used to facilitate comparison to the BBS methodology (Table 12). BBS estimates of species richness and observed species counts were significantly greater than those from either MAPS method for all years. MAPS point counts recorded more species than mist nets in 1995. All but one data set (mist nets 1996) yielded observed species counts that were at least 74% of the estimated species richness. Within a method, inventory results were very consistent among years.

The mean estimate of species richness from MAPS mist-net, single-visit data for five visits was 32.2 in 1995 and 33.0 in 1996 (Table 13). The mean observed species count was 25.4 and 24.4, respectively. Results from each individual visit did not vary widely from these means. For the 3 years combined, the estimate of species richness from MAPS mist-net data increased an average of 12.3 species ($SE = 4.8$, 37% of the mean estimate of species richness from one visit) from one to four visits; the observed species count increased an average of 12.3 species ($SE = 2.4$, 51% of the mean observed species count from one visit) from one to four visits (Figs 3-5, Table 14). The percent of estimated species richness observed declined (mean of 18%, $SE = 7$) from two to three visits in all 3 years. Eight (67%) of the 12 data sets in Table 14 resulted in percent of estimated species richness observed greater than 75%.

Neither observed species counts nor estimates of species richness increased significantly from 3-minute counts to 5-minute counts for MAPS point count data (Table 15). The use of an unlimited distance count versus a 50-m radius increased the observed species counts by an average of 4.0 species ($SE = 0.6$). The use of data from two visits instead of just one increased

Table 12. SHEN: Three Inventory Methods, 1995-97: Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on three bird inventory methods in the breeding season at Shenandoah National Park, 1995-97, and calculated using the model M_h with the Web-based program COMDYN4. Only one visit was used for each calculation. Methods of inventory are described in the text.

Year	Variable	Inventory Method		
		Breeding Bird Survey	MAPS Mist Nets	MAPS Point Counts ^a
1995	$S_E \pm SE$	68 ± 4.0	23 ± 2.9	47 ± 4.6
	(95% CI)	(62 - 81)	(22 - 28)	(35 - 80)
	S_A ($S_P\%$)	61 (90%)	22 (96%)	35 (74%)
1996	$S_E \pm SE$	68 ± 4.0	48 ± 3.9	
	(95% CI)	(60 - 84)	(26 - 68)	
	S_A ($S_P\%$)	60 (88%)	26 (54%)	
1997	$S_E \pm SE$	72 ± 4.6	29 ± 3.5	
	(95% CI)	(62 - 91)	(24 - 54)	
	S_A ($S_P\%$)	61 (85%)	24 (83%)	

^a Data used were from unlimited distance 3-minute point counts. MAPS point counts were not conducted after 1995.

Table 13. SHEN: Single Visit Mist Nets, 1995-96. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS mist netting in the breeding season at Shenandoah National Park, 1995-96, and calculated using the model M_h with the Web-based program COMDYN4. Data from only one visit were used for the calculations.

Visit Number	Variable	Year	
		1995	1996
First	$S_E \pm SE$	23 ± 2.9	48 ± 3.9
	(95% CI)	(22 - 28)	(26 - 68)
	S_A ($S_P\%$)	22 (96%)	26 (54%)
Second	$S_E \pm SE$	30 ± 3.7	29 ± 3.7
	(95% CI)	(25 - 52)	(23 - 57)
	S_A ($S_P\%$)	25 (83%)	23 (79%)
Third	$S_E \pm SE$	35 ± 4.1	32 ± 3.8
	(95% CI)	(27 - 63)	(27 - 43)
	S_A ($S_P\%$)	27 (77%)	27 (84%)
Fourth	$S_E \pm SE$	43 ± 4.5	29 ± 3.7
	(95% CI)	(28 - 76)	(23 - 58)
	S_A ($S_P\%$)	28 (65%)	23 (79%)
Fifth	$S_E \pm SE$	30 ± 3.9	27 ± 3.5
	(95% CI)	(25 - 51)	(23 - 50)
	S_A ($S_P\%$)	25 (83%)	23 (85%)
Mean	$S_E \pm SE$	32.2 ± 3.3	33.0 ± 3.8
	(95% CI)	(25.7 - 38.7)	(25.5 - 40.5)
	S_A ($S_P\%$)	25.4 ± 1.0 (79%)	24.4 ± 0.9 (74%)

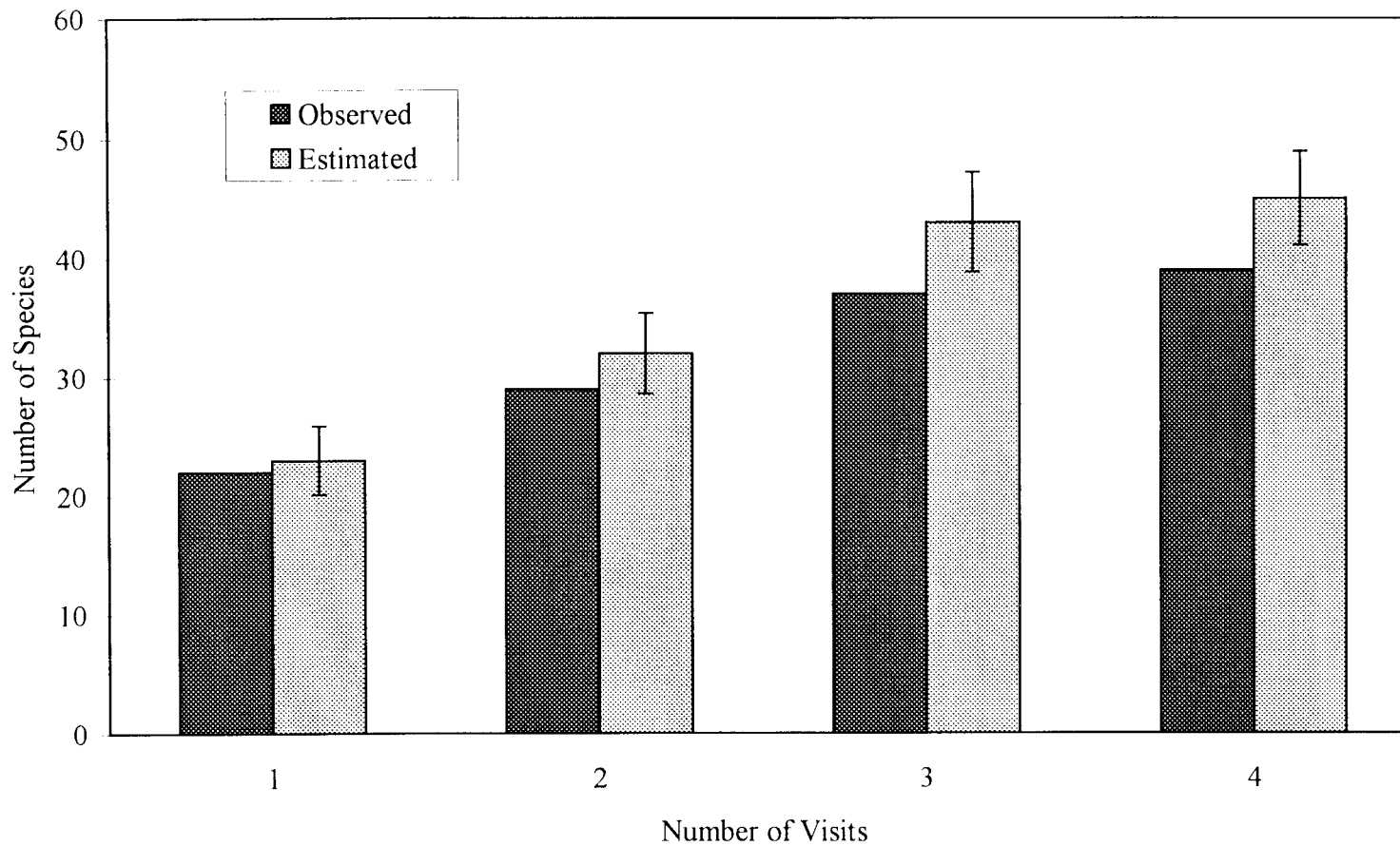


Figure 3. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1995. Species of birds recorded on previous visits were combined with the species list from each additional visit. Estimates of species richness were calculated using the model M_h with the Web-based program COMDYN4.

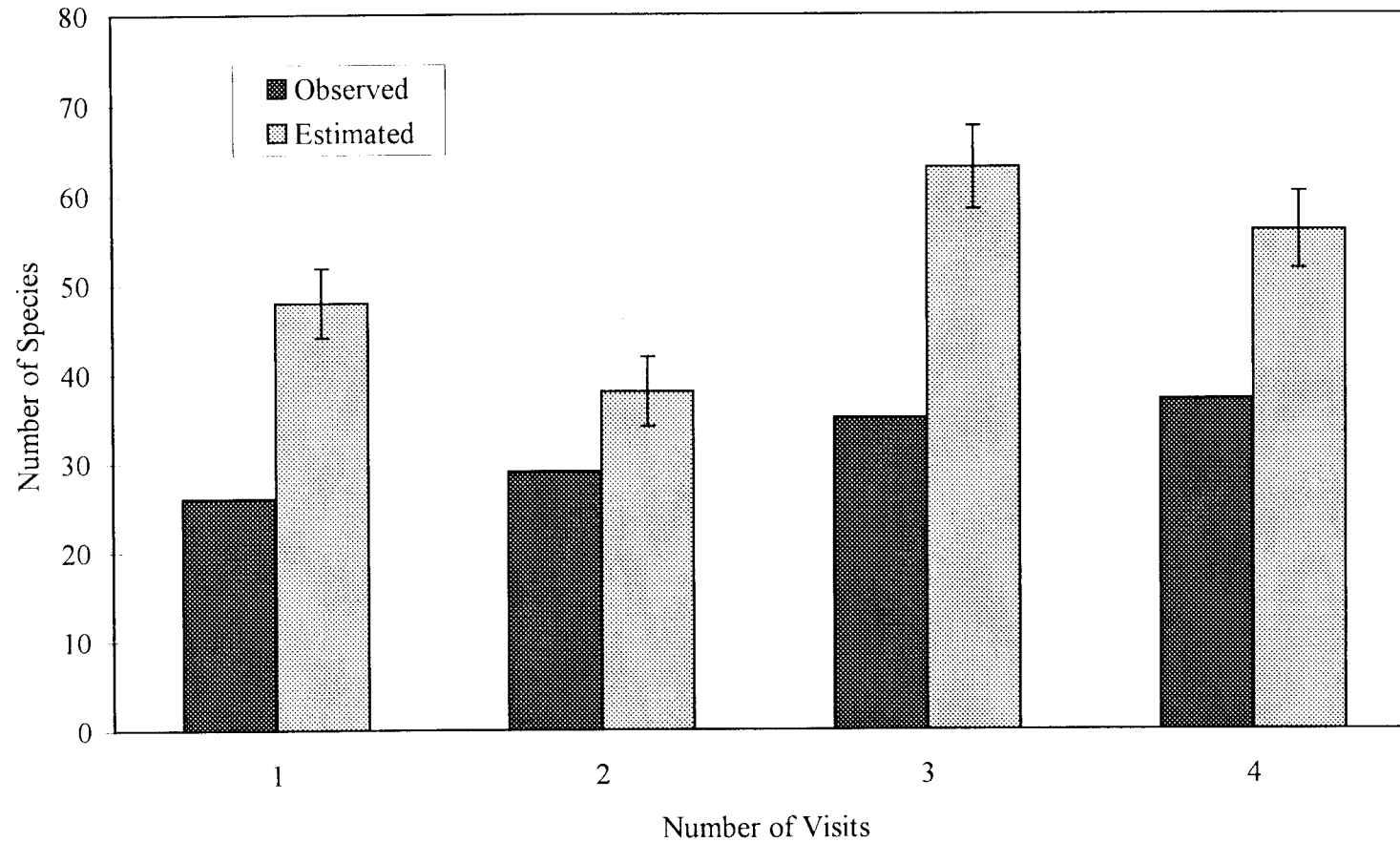


Figure 4. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1996. Species of birds recorded on previous visits were combined with the species list from each additional visit. Estimates of species richness were calculated using the model M_h with the Web-based program COMDYN4.

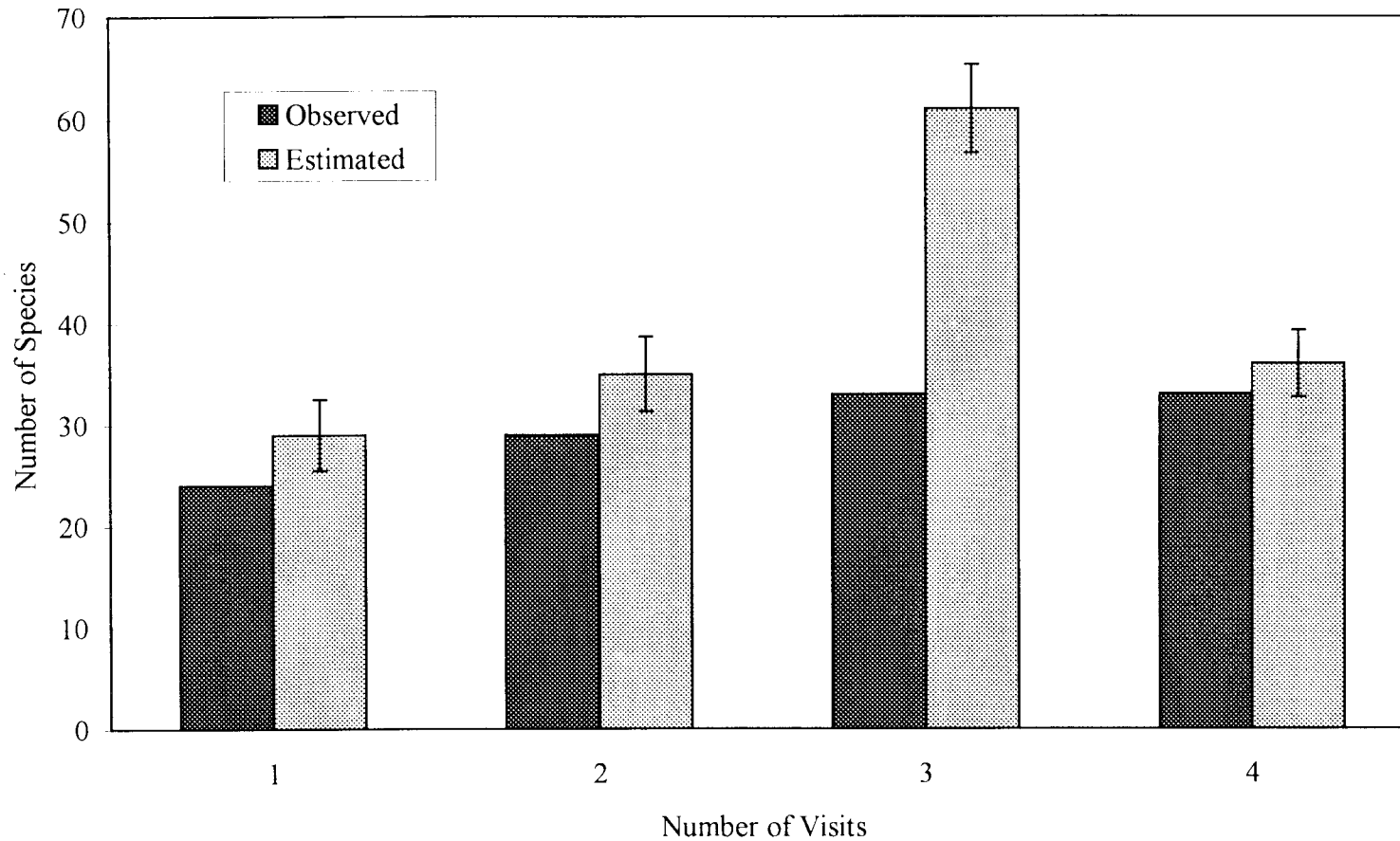


Figure 5. Estimates of species richness, including 95% confidence intervals, and observed species counts for each of four survey visits based on breeding season mist net inventories at Shenandoah National Park, 1997. Species of birds recorded on previous visits were combined with the species list from each additional visit. Estimates of species richness were calculated using the model M_h with the Web-based program COMDYN4.

Table 14. SHEN: Multiple Visits Mist Nets, 1995-97. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS mist netting in the breeding season at Shenandoah National Park, 1995-97, and calculated using the model M_h with the Web-based program COMDYN4. MAPS bird inventories were conducted at six sites in the park. Bird species recorded on previous visits were combined with species recorded on each additional visit.

Year	Variable	Number of Visits			
		One	Two	Three	Four
1995	$S_E \pm SE$	23 ± 2.9	32 ± 3.4	43 ± 4.2	45 ± 3.9
	(95% CI)	(22 - 28)	(29 - 39)	(37 - 54)	(39 - 76)
	S_A ($S_P\%$)	22 (96%)	29 (91%)	37 (86%)	39 (87%)
1996	$S_E \pm SE$	48 ± 3.9	38 ± 3.9	63 ± 4.6	56 ± 4.3
	(95% CI)	(26 - 68)	(29 - 68)	(38 - 86)	(37 - 83)
	S_A ($S_P\%$)	26 (54%)	29 (76%)	35 (56%)	37 (66%)
1997	$S_E \pm SE$	29 ± 3.5	35 ± 3.7	61 ± 4.3	36 ± 3.3
	(95% CI)	(24 - 54)	(29 - 62)	(33 - 85)	(33 - 58)
	S_A ($S_P\%$)	24 (83%)	29 (83%)	33 (54%)	33 (92%)

Table 15. SHEN: MAPS Point Counts, Time and Distance, 1995. Estimates of species richness ($S_E \pm SE$), 95% confidence intervals (CI), observed species counts (S_A), and percent of estimated species richness observed (S_P) based on MAPS point count inventories in the breeding season at Shenandoah National Park, 1995, and calculated using the model M_h with the Web-based program COMDYN4. Estimates were calculated from both one and two visits, with both a 50-m and an unlimited distance radius, and with both a 3-minute and a 5-minute count.

Number of Visits	Count Radius	Variable	Length of Count	
			3 Minutes	5 Minutes
One	50 m	$S_E \pm SE$	44 ± 4.5	43 ± 4.3
		(95% CI)	(34 - 75)	(32 - 73)
		S_A ($S_P\%$)	32 (73%)	32 (74%)
One	Unlimited	$S_E \pm SE$	47 ± 4.6	44 ± 4.1
		(95% CI)	(35 - 80)	(37 - 74)
		S_A ($S_P\%$)	35 (74%)	37 (84%)
Two	50 m	$S_E \pm SE$	42 ± 4.1	43 ± 4.1
		(95% CI)	(35 - 60)	(36 - 63)
		S_A ($S_P\%$)	35 (83%)	36 (84%)
Two	Unlimited	$S_E \pm SE$	43 ± 4.0	47 ± 4.3
		(95% CI)	(38 - 55)	(41 - 63)
		S_A ($S_P\%$)	38 (88%)	41 (87%)

the observed species counts by an average of 3.5 species ($SE = 0.3$) and decreased the estimates of species richness by an average of 0.8 species ($SE = 1.5$). The percent of estimated species richness observed was at least 73% for all eight data sets. All of the SHEN data fit the model M_h by the chi-square goodness-of-fit test.

Discussion

The BBS method accounted for more bird species observed in the park than either of the MAPS methods. This difference may merely be a factor of the different sampling schemes and the number of sampling points between the two methods. With 50 sampling points per route versus 10 net stations per MAPS site, the BBS had a larger number of sampling stations and, thus, is more statistically robust (Ralph et al. 1995). The different sample sizes (number of sites) between the two methods, however, undermine any direct comparison among results obtained from the various inventory methods. Furthermore, neither program was intended to be a thorough species inventory for the given area. MAPS was designed to gather data on bird productivity and return rate trends over the long term, and the BBS was designed to monitor global trends in species distributions and populations.

The MAPS point counts accounted for more species than the mist nets. Mist nets are dependent on a bird flying through an specific area of air space, whereas observers can record birds by either sight or sound within a larger area with a point count.

Mist netting did appear to be reliably consistent from visit-to-visit and from year-to-year. This method is not dependent on factors influencing birds to sing or be conspicuous, and it seems that a standard number of species was recorded each visit. The number of species observed from mist-net data increased with each visit from one to three visits but did not change markedly from three to four visits. Unlike the estimates of species richness from ALPO-JOFL data, the estimates of species richness from mist net data at SHEN continued to change beyond two visits. Estimates of species richness from three visits appeared to be the least similar to the number of species observed. Breeding season birds are resident and not migratory, and two visits may be sufficient to record most species.

Point counts conducted for more than 3 minutes was an unnecessary expenditure of survey effort according to the data from the MAPS point counts in 1995. Longer counts become inefficient and risk counting birds more than once; shorter counts allow for more sites to be visited and, thus, increase statistical power in hypothesis testing (Gates 1995). Howe et al. (1995) detected 63.5% of all bird species observed in a 10-minute count within the first 3 minutes. Ralph et al. (1995) recommend a 5-minute standard point count, however, because this is the most common duration used in other point-count studies. If the investigator wishes to compare results to other studies, the count duration should be at least as long as that used by others.

Using an unlimited distance radius also did not contribute greatly to the survey; however, this should require little additional effort on the part of the observer and occasionally may yield important observations. The distance to the observation should still be recorded, because many abundance and density calculations are dependent on fixed distance counts (Gates 1995).

Chapter 7

Conclusions And Applications

Method of inventory

Each of the inventory methods examined in this investigation yielded reasonably unbiased and precise estimates of species richness. If time and labor constraints are not a limiting factor, we recommend conducting unlimited-distance radius point counts, because this method yielded the most consistent results as well as often recorded a higher number of species than other methods. Distance to each bird observation should be estimated, particularly for birds within 50-m of the observation point, to allow density and abundance calculations. Additionally, for the most comprehensive list of species in a park, a combination of methods should be used and all habitats in the park should be targeted.

Vehicular surveys appear to offer a time and labor-efficient method of inventorying birds when infrastructure allow access to a representative sample of habitat types within a park. We recommend conducting BBS vehicular surveys rather than non-stop vehicular surveys. The BBS method not only accounts for more birds than non-stop surveys, but it is also less dependent on the expertise of the observer and the degree of cover by the habitat (Yahner et al. 1998a). Ralph et al. (1995) recommended the use of tertiary and secondary roads and trails rather than primary roads for vehicular surveys. Furthermore, if some habitats or areas of a park cannot be sampled from a road, other inventory methods could be employed in these areas to enhance a count (Ralph et al. 1995).

Sampling design

Most protocols for species inventories recommend establishing study areas randomly over the whole region to be sampled rather than stratifying by habitat type (Howe et al. 1995, Ralph et al. 1995). Small patches of unique habitats, which may be missed by this method, can be sampled separately from the standard inventory to record rare or unusual species occurring there (Howe et al. 1995, Ralph et al. 1995). If data specific to habitat types are sought, then study areas should be stratified by habitat, with care taken to include edge and transition zones. Statistical testing and application of the species richness models are more robust and reliable when study areas are randomly selected, however (Ralph et al. 1995).

Reliability of estimates of species richness also can be improved by maximizing the number of sites or points sampled by each inventory. At least five study sites should be sampled for application of the species richness models (Otis et al. 1978). More sites will improve the precision of counts and estimates of species richness, with the maximum number of sampling points being determined by time and labor constraints.

Season sampled

Birds should be inventoried during all seasons in order to compile the most complete list of species occurring in a park. Nevertheless, statistics based on inventory data, such as estimates of species richness and density estimates, will be most reliable from breeding season data. Ralph

et al. (1995) recommended that at least 70% of bird inventory efforts be spent on breeding season inventories. Estimates of species richness calculated from sparse fall or winter inventory data should be evaluated carefully before interpretation. Winter inventories may be improved by using multiple inventory methods, such as transects and tape playbacks.

Number of visits

We recommend two visits within a season for each inventory. Two visits rather than only one can increase species counts, improve the precision of estimates of species richness, and accommodate more variation in counts from day-to-day differences in sampling conditions. The visits should be conducted within a short-time interval (e.g., 2 weeks), which will vary according to the season, to improve the chances of the target community remaining closed from migration or deaths. Additional visits beyond two may contribute a few more species to the comprehensive list of birds but will be an unnecessary expenditure of effort in most cases. Alternatively to multiple visits, Petit et al. (1995) recommended extending the duration of a point count to increase the number of birds counted. Nevertheless, we consider that multiple visits are preferred to longer point counts, because effects of adverse weather or other conditions on a single visit can be reduced.

Use of model output

We recommend the application of the species richness estimation model M_h to bird inventory data for determining the actual number of species present in a given season. This model is the simplest of the capture-recapture models to apply because of the availability and ease of use of the Web-based program COMDYN4. Where another model more appropriately fit the data in our investigation, the estimates of species richness from M_h were nevertheless reasonably similar to those from the other models. The results of the models should be interpreted with caution, however, because natural populations cannot be controlled and are not easily modeled (Otis et al. 1978). Park managers can use the percent of estimated species richness observed as a guideline for determining the level of continued inventory effort necessary. We considered observation of 75% (arbitrarily determined) of the estimated species observed to be a reasonable cut-off level. This percentage was reached most commonly in the breeding season and for park-wide data. At least 75% of the estimated species richness was observed most often with two visits in an inventory and with at least five sites (i.e., when data was compiled park-wide).

Applications

An objective of the NPS inventory program is for each park to document the occurrence of at least 80% of the species present in the park. A question stemming from this goal is how the parks can combine all inventory efforts over time and habitat in order to be able to estimate the comprehensive species richness. In our investigation, we did not attempt to reach comprehensive numbers for a park; however, the species richness estimation models could be applied to a more comprehensive approach. Species richness could be estimated using data from multiple inventory methods and seasons (e.g., Breeding Bird Survey, Christmas Bird Count, and migratory season

surveys), but we recommend careful interpretation of the results and the use of an open population model, such as the Jolly-Seber model.

For more reliable information about species richness in a park, we recommend that the 80% documentation objective be examined for only resident bird populations. Surveys can be concentrated in the breeding season and the program COMDYN4 can be used to estimate species richness. Many areas have attempted comprehensive bird inventories in the summer by having birding fests, where experts and volunteers survey the park intensively, targeting all unique habitats as well as surveying for nocturnal birds.

Applications for other taxa

The inventories conducted at HOFU, GETT-EISE, and VAFO included inventories of reptiles and amphibians and small mammals (Yahner et al. 1997, Yahner et al. 1998b). We explored the potential for these data to be examined with the species richness models for a similar evaluation of effort required in an inventory. We concluded that estimates of species richness from these other inventories would be unreliable and difficult to obtain. For example, the inventories of salamanders primarily recorded one common species, with up to seven other species occurring only once or twice per survey. An estimate of species richness would reveal little because of low numbers of species sampled.

One of the problems for mammalian sampling is that each inventory method was only capable of targeting select species. For example, of 59 mammalian species potentially occurring at GETT-EISE, fewer than 20 would be expected to be sampled by pitfall and small-mammal traps (Yahner et al. 1997). In fact, only seven species were captured at GETT-EISE with pitfall or live traps. Other mammal species would need to be targeted by different inventory methods, such as mist nets (bats) or remote-sensing photographs (medium to large mammals). Comprehensive sampling of all mammal groups would require extensive effort and equipment. The models for species richness estimation would not be effective on small numbers of species observed by only one inventory method but could be applied to a compilation of these methods.

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Appendix A. Number of bird species listed on the Valley Forge National Historical Park bird sighting list (Wolf 1996). Categories for the likelihood of a species occurring are: C = common, U = uncommon, O = occasional, R = rare, and X = only one record.

Season	Likelihood of Occurrence				
	C	U	O	R	X
Spring	56	37	31	58	7
Cumulative totals ^a		93	124	182	189
Breeding	41	17	23	32	1
Cumulative totals		58	81	113	114
Fall	42	40	32	61	4
Cumulative totals		82	114	175	179
Winter	22	16	14	48	8
Cumulative totals		38	52	100	108

^a Cumulative totals are the sum of the cells above and to the left of the total cell.



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