Improving the Breeding Bird Survey[1]

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Abstract

We investigated increasing the number of Breeding Bird Survey (BBS) routes and reducing potential bias as ways to increase the number of species adequately monitored by the BBS in the Pacific Northwest. Estimates of place-to-place variance in trends were used to assess the effects of increasing the number of additional BBS routes. Increasing the number of BBS routes from the current number (149) to 210 would increase the number of adequately covered species, using a recently proposed standard, from 42 at present to 60. If potential bias was reduced from its estimated current value (0.008) to 0.003, then the number of adequately monitored species at present would be 75 and would increase to 84 with 210 BBS routes. Implementing effective waterbird, raptor and nocturnal species surveys would cover up to 45 more species resulting in adequate coverage for 121 (74 percent) of the 164 species that warrant monitoring. We recommend that all three approaches–increasing the number of BBS routes, reducing potential bias, and implementing new surveys–be considered in efforts to improve bird monitoring programs.

Key words: Breeding Bird Survey, optimization, sample size, birds, surveys, trend estimation, bias

Introduction

Bart et al. (2004) suggested an accuracy target for landbird monitoring programs and that expansion of the Breeding Bird Survey (BBS), or other similar surveys, would be an effective way to achieve the target for more species. They estimated how many BBS routes would be needed to achieve the accuracy target for 80 percent of the species suited to monitoring using the BBS. Their estimate was based on a single rangewide estimate of route-to-route variation in trend for each species that warrants monitoring, and they did not present any information about how many species would be adequately monitored with numbers of routes other than the number they recommended. In this paper, we explore optimal allocation of new BBS routes at the scale of a Bird Conservation Region using more detailed information on spatial variation in trend, and we estimate how many more species would be adequately monitored with different numbers of new routes. We also discuss the relative merits of adding BBS routes and other ways to increase the number of adequately monitored species.

Methods

The study area covered 254,240 km^2 and included portions of California, Oregon, Washington and British Columbia within the Northern Pacific Rainforest Bird Conservation Region (BCR 5) (*fig. 1*). Most of the study area is coniferous forest with small amounts of other habitats such as riparian, oak/prairie, agricultural, and residential/urban. The Alaskan portion of this BCR (southeast and south-coastal Alaska) was not included because the road network is extremely limited; this prevented us from evaluating the efficiency of additional routes in this area.

We defined species that warrant monitoring as those for which management action would be considered if it were known that their populations were seriously declining. To produce the list, we identified all species whose breeding range (as depicted in National Geographic Society [1999]) covered >10 percent of the study area. This list was then scrutinized to determine whether it excluded or included any species that clearly did or did not meet our general criteria. This process produced 164 species that warrant monitoring in the established. We used a guideline from Bart et al. (2003) that a species should be recorded ≥5 times, during a 20-year period, to calculate within-route trends. Trends cannot be reliably calculated from just a few routes. We used a guideline from Link and Sauer (1994) that trends should only be calculated for species

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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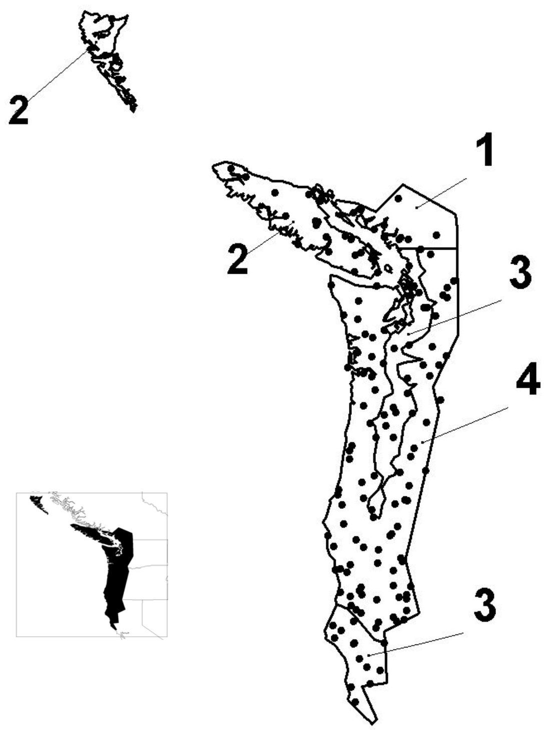

Figure 1— Study area, strata (numbers 1-4), and current BBS routes (dots).

recorded on ≥14 routes. Thus, we only considered species recorded ≥5 times on ≥14 routes as being suitable for coverage by the BBS. Under this rule, 103 species within our study were possibly suitable for monitoring with the BBS if the number of routes was increased.

The study area was stratified according to the distribution of BBS routes, major habitat features, and political boundaries. Four strata were delineated: mainland British Columbia, Vancouver and the Queen Charlotte islands, interior valleys and lowlands in the United States, and forested areas in the United States (*fig. 1*). The two strata in the United States were delineated using a USGS land use/land cover map.

The study area at present contains 149 official BBS routes. We added routes beyond this value in groups of 10 (except the first group which was 11) and determined how many species were adequately monitored (see below) with each new increment of routes.

We used procedures described by Bart et al. (2004) for determining whether species were adequately covered for monitoring purposes by the BBS. Specifically, Bart et al. (2004) recommended that species should be considered adequately monitored if a 20-year data set had 80 percent power to detect a 50 percent decline using a two-tailed test, a significance level of 0.10, and incorporating effects of potential bias in the analysis. They suggested that at present a reasonable value for potential bias with BBS data is 0.008, and they showed that under this assumption, the power objective is met if the standard error of the trend is <0.0073. They recommended various measures to reduce bias and suggested that implementing these measures would reduce potential bias to 0.003, in which case the standard error needed to meet the accuracy target is 0.0113. They also indicated that meeting the accuracy target in areas as small as our study area was probably not realistic. It can be shown that the accuracy target within one portion of an area, across which inferences will be made, is (target standard error for the entire area)/$\sqrt{p}$, where p is the proportion of the entire area covered by the study area. We illustrate the procedure for investigating whether to establish additional BBS routes by assuming that trends will be estimated across an area three times larger than our study area. Under this assumption, p is 0.33, and the target standard errors are $0.0073/0.33^{0.5} = 0.013$, under current conditions, and $0.0113/0.33^{0.5} = 0.020$ if potential bias is reduced to 0.003. We used these two values, 0.013 and 0.020, as the target standard errors for the trend estimate within our study region.

Trends were estimated using a simple form of route regression (Bart et al. 2003) in which the linear trend is calculated for each route and the mean of these trends is divided by the mean number of birds recorded on the routes. The result is an essentially unbiased estimate of the trend, defined as the rate of change of an exponential curve fit to the true population sizes using the method of least squares. With stratified sampling, the estimated variance of the trend estimate may be expressed as:

$$v(r) = \sum_{h}^{L} \frac{W_h^2 s_h^2}{f_h n_h}, \qquad (1)$$

where W_h is the proportion of the study area in stratum h, s^2_h is a function of the variance of the trends among routes in stratum h and does not depend on number of routes surveyed, f_h is the fraction of routes in stratum h on which the species is recorded frequently enough to estimate trends (i.e., ≥5 times) and n_h is the number of routes in stratum h. The f_h and s^2_h were calculated for each species with sufficient BBS data (species recorded ≥5 times on ≥14 routes). The $v(r)$, and from this the se(r), were then calculated for each sample size. In adding routes, we maintained proportional allocation (i.e., at each sample size, the fraction of routes in each stratum was approximately equal to the fraction of the study area in the stratum).

Results and Discussion

At present, the accuracy target is met for 42 species, or 41 percent of the 103 species suitable for coverage with the BBS. As the number of routes is increased, the number of adequately covered species rises (*fig. 2*; see *Appendix 1*). With 210 routes, it is 60, (58 percent of the 103 species suitable for coverage with the BBS) and at 300 routes it is 71 species (69 percent). The number of species added to the list increased very slowly beyond 300 routes. Adding routes beyond about 210 would not be very productive given the effort that would be required (see *fig. 2*). Of the 18 species that would be added by increasing the number of routes to 210, several are of conservation concern in the region including forest species, Black-throated Gray Warbler (see *Appendix 1* for scientific names, 160 routes) and Rufous Hummingbird (*Selasphorus rufus*, 190 routes); lowland riparian species, Yellow Warbler (160 routes) and Yellow-breasted Chat (190 routes); and a grassland associate, the Western Meadowlark (180 routes).

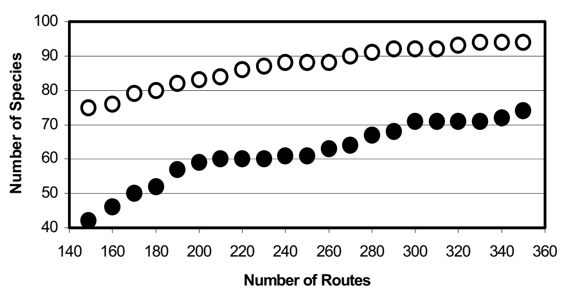

Figure 2— Number of adequately monitored species (out of 103 that are potentially suitable for monitoring with the BBS) as a function of number of BBS routes and potential bias (closed circles = bias of 0.008; open circles = bias of 0.003).

In contrast to the option of adding more BBS routes, our results showed the value of reducing potential bias. With a bias of 0.003, the current number of adequately monitored species would be 75, or 73 percent of the 103 species suitable for coverage with the BBS (*fig. 2*; see *Appendix 1*). With 210 routes, the number would be 84 (82 percent), and with 300 it would be 92 (89 percent). Of the 9 species that would be added by increasing the number of routes to 210, only 2 could be considered of conservation concern–Vaux's Swift (200 routes) with its association for large old-growth snags for nesting, and Chipping Sparrow (170 routes), a species associated with declining oak savannah and woodland habitats. Even with 350 routes, the number of adequately monitored species, with bias = 0.008, was less than the number that would be adequately monitored with the current sample size (149 routes) if potential bias could be reduced to 0.003 (*fig. 2*). At the species level, reducing potential bias to 0.003 without adding any routes would add 33 species to the adequately monitored list, including species of some conservation concern such as Rufous Hummingbird, Brown Creeper, Black-throated Gray Warbler, Yellow Warbler, Yellow-breasted Chat, and Western Meadowlark. Thus, measures discussed in Bart et al. (2004), such as training and evaluation, overlap in consecutive surveyors on a route (to identify inconsistencies between observers), off-road surveys, habitat-based models, and double sampling, might produce a greater increase in number of adequately monitored species than even doubling the current number of routes. Thus, reducing potential bias is an effective way to increase the number of species that are adequately monitored by the BBS.

Adding new BBS routes appears to be a reasonable strategy in most of the study area because of the significant and increasing human population to conduct the surveys, and a sufficiently developed road network in most of the area. Annual coverage of existing BBS routes is >90 percent, but it is unknown how successful recruitment might be for enlisting volunteers to conduct the additional routes indicated by our analysis. However, we recently learned that about 60 routes in British Columbia are being surveyed but are not included in the BBS data set. Adding 60 routes would increase the number of species adequately covered by the BBS to 60 (58 percent) under current conditions and to 84 (82 percent) if potential bias were reduced to 0.003.

A combination of bias reduction, increased BBS coverage, and supplemental monitoring may be most effective. For example, if potential bias were reduced to 0.003 and the number of routes increased to 170, then 95 species would be adequately monitored. We believe that 61 of the 164 species that warrant monitoring in our study area were not well suited to coverage using the BBS. Among these, 37 are aquatic species, 10 are raptors, 7 are nocturnal species, and the rest are other terrestrial species. Thus, if special surveys were instituted that covered most (e.g., 45) of the 54 aquatic species, raptors, and nocturnal species, then the number of adequately covered species would be 121 or 74 percent of the 164 target species (*Table 1*). Thus, adding routes, reducing potential bias, and implementing surveys for aquatic birds, raptors, and nocturnal species would result in adequate coverage for about three-quarters of the species that warrant monitoring. Some of the other species are more common in surrounding areas and thus might be covered adequately if similar strategies were used in surrounding areas. Others would require specialized surveys.

Table 1— *Strategies for improving the number of adequately monitored species.*

N of BBS routes[1]	Potential bias	Other surveys	N (%) of adequately monitored species
149	0.008	None	42 (26%)
200	0.008	None	51 (31%)
200	0.003	None	70 (48%)
250	0.003	None	86 (52%)
250	0.003	Aquatic species, raptors, and nocturnal species	121 (74%)

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Appendix 1— *Species currently covered by BBS effort (149 routes; bias = 0.008), or that would be adequately covered by reducing bias to 0.003 or by adding new routes with either level of bias. Adequate levels of coverage >350 total routes are not shown.*

Species	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
	0.008	0.003	0.008	0.003
Great Blue Heron, *Ardea herodias*		•	260	
Common Merganser, *Mergus merganser*		•	190	
Turkey Vulture, *Cathartes aura*		•		
Osprey, *Pandion haliaetus*		•		
Red-tailed Hawk, *Buteo jamaicensis*	•	•		
American Kestrel, *Falco sparverius*		•	290	
Ring-necked Pheasant, *Phasianus colchicus*				190
Blue Grouse, *Dendragapus obscurus*				270
California Quail, *Callipepla californica*	•	•		
Mountain Quail, *Oreortyx pictus*		•		
Killdeer, *Charadrius vociferus*		•	260	
Spotted Sandpiper, *Actitis macularia*		•	190	
Band-tailed Pigeon, *Columba fasciata*		•		
Rock Dove, *Columba livia*				270
Mourning Dove, *Zenaida macroura*		•	280	
Common Nighthawk, *Chordeiles minor*		•	350	
Vaux's Swift, *Chaetura vauxi*				200
Belted Kingfisher, *Ceryle alcyon*				280
Acorn Woodpecker, *Melanerpes formicivorus*		•	200	
Northern Flicker, *Colaptes auratus*	•	•		
Red-breasted Sapsucker, *Sphyrapicus ruber*	•	•		
Downy Woodpecker, *Picoides pubescens*		•	190	
Hairy Woodpecker, *Picoides villosus*		•	160	
Pileated Woodpecker, *Dryocopus pileatus*		•	170	
Olive-sided Flycatcher, *Contopus cooperi*	•	•		
Western Wood-Pewee, *Contopus sordidulus*	•	•		
Willow Flycatcher, *Empidonax traillii*	•	•		
Dusky Flycatcher, *Empidonax oberholseri*	•	•		

Appendix 1 (continued)

Species	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
	0.008	0.003	0.008	0.003
Pacific-slope Flycatcher, *Empidonax difficilis*	•	•		
Western Kingbird, *Tyrannus verticalis*				330
Hutton's Vireo, *Vireo huttoni*				190
Cassin's Vireo, *Vireo cassinii*	•	•		
Red-eyed Vireo, *Vireo olivaceus*		•	280	
Warbling Vireo, *Vireo gilvus*	•	•		
Steller's Jay, *Cyanocitta stelleri*	•	•		
Gray Jay, *Perisoreus canadensis*				240
Western Scrub-Jay, *Aphelocoma californica*		•	180	
American Crow, *Corvus brachyrhynchos*	•	•		
Northwestern Crow, *Corvus caurinus*	•	•		
Common Raven, *Corvus corax*	•	•		
Tree Swallow, *Tachycineta bicolor*			350	160
Violet-green Swallow, *Tachycineta thalassina*	•	•		
Cliff Swallow, *Petrochelidon pyrrhonota*	•	•		
Northern Rough-winged Swallow, *Stelgidopteryx serripennis*		•	300	
Barn Swallow, *Hirundo rustica*	•	•		
Black-capped Chickadee, *Poecile atricapilla*		•	300	
Chestnut-backed Chickadee, *Poecile rufescens*	•	•		
Bushtit, *Psaltriparus minimus*		•	340	
Brown Creeper, *Psaltriparus minimus*		•	240	
White-breasted Nuthatch, *Sitta carolinensis*				230
Red-breasted Nuthatch, *Sitta canadensis*	•	•		
House Wren, *Troglodytes aedon*		•	210	
Winter Wren, *Troglodytes troglodytes*	•	•		
Bewick's Wren, *Thryomanes bewickii*		•	270	
Marsh Wren, *Cistothorus palustris*				320
Golden-crowned Kinglet, *Regulus satrapa*		•	170	
Swainson's Thrush, *Catharus ustulatus*	•	•		
Hermit Thrush, *Catharus guttatus*	•	•		
Varied Thrush, *Ixoreus naevius*		•	280	
American Robin, *Turdus migratorius*	•	•		
European Starling, *Sturnus vulgaris*		•	200	
Cedar Waxwing, *Bombycilla cedrorum*	•	•		
Orange-crowned Warbler, *Vermivora celata*	•	•		
Yellow-rumped Warbler, *Dendroica coronata*	•	•		
Black-throated Gray Warbler, *Dendroica nigrescens*		•	160	
Townsend's Warbler, *Dendroica townsendi*				170
Hermit Warbler, *Dendroica occidentalis*	•	•		
Yellow Warbler, *Dendroica petechia*		•	160	
MacGillivray's Warbler, *Oporornis tolmiei*	•	•		
Wilson's Warbler, *Wilsonia pusilla*	•	•		
Common Yellowthroat, *Geothlypis trichas*	•	•		
Yellow-breasted Chat, *Icteria virens*		•	190	
Western Tanager, *Piranga ludoviciana*	•	•		
Spotted Towhee, *Pipilo maculatus*	•	•		
Chipping Sparrow, *Spizella passerina*				170

Appendix 1 (continued)

Species	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
	0.008	**0.003**	**0.008**	**0.003**
Savannah Sparrow, *Passerculus sandwichensis*				180
Song Sparrow, *Melospiza melodia*	•	•		
White-crowned Sparrow, *Zonotrichia leucophrys*	•	•		
Dark-eyed Junco, *Junco hyemalis*	•	•		
Black-headed Grosbeak, *Pheucticus melanocephalus*	•	•		
Lazuli Bunting, *Passerina amoena*		•	170	
Western Meadowlark, *Sturnella neglecta*		•	180	
Red-winged Blackbird, *Agelaius phoeniceus*				220
Brewer's Blackbird, *Euphagus cyanocephalus*	•	•		
Brown-headed Cowbird, *Molothrus ater*	•	•		
Bullock's Oriole, *Icterus bullockii*				220
Purple Finch, *Carpodacus purpureus*		•	160	
House Finch, *Carpodacus mexicanus*	•	•		
Red Crossbill, *Loxia curvirostra*		•		
Pine Siskin, *Carduelis pinus*		•	170	
American Goldfinch, *Carduelis tristis*	•	•		
Lesser Goldfinch, *Carduelis psaltria*	•	•		
Evening Grosbeak, *Coccothraustes vespertinus*				210
House Sparrow, *Passer domesticus*		•	300	