Detection Ratios of Riparian Songbirds[1]

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Abstract

This paper presents preliminary results from the first year of a two-year study designed to evaluate bias in a typical songbird survey by examining differences in detection ratios among species, cover types, and time of the season. Detection ratios, calculated as number of individuals detected during a 15-25 minute fixed-width transect survey divided by the number of individuals shown to be present through intensive nest searching and territory mapping, were obtained for riparian songbirds on 22, 1.5-ha plots in southeastern Oregon. During intensive territory mapping and nest finding, overall, 80 percent of territories were identified after 3 hours of effort per plot, the estimated number of territories stabilized after about 9 hours, and nests or probable nests were located on 204 (78 percent) of the 261 identified territories. The pooled detection ratio for all species was 0.46 (±0.03 se). Species-specific detection ratios ranged from 0.59 in Song Sparrows to 0.20 in MacGillivray's Warbler. The detection ratio was higher in willow/meadow cover type than in aspen, possibly due to the more frequent nest loss in willow/meadow and presumably higher detectability of re-nesting pairs, the higher density of individuals and species in aspen, and the greater structural complexity of aspen. Total detections were higher earlier in the season (17-22 May) than later (31 May-19 June), suggesting a decline in detectability with nesting phenology. Further study to understand the visual and auditory detectability of individual territory-holders as a function of distance from the observer, stage of nesting, paired status, date, time of day, and various other factors, will help evaluate potential sources of bias and aid in identifying rapid survey methods that are likely to be most efficient.

Key words: avian, density, detection ratios, double sampling, index, riparian

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Introduction

Point counts and other methods that use singing birds to monitor and assess avian abundance across time or habitats provide an index to abundance. Indices may lead to biased results if detectability varies systematically among subgroups being compared (e.g., among species, habitats, or years). Although a balanced and standardized design can reduce the effects of some sources of bias, other sources cannot be accounted for by design or specialized analyses (Bart and Schoultz 1984; Johnson 1995). As a result, doubling sampling (Bart and Earnst 2002) and other methods that estimate density are becoming more widely used (e.g., distance sampling, Buckland et al. 2001; double observer, Nichols et al. 2000; removal method, Farnsworth et al. 2002). In double sampling, a large number of plots is surveyed using a rapid survey method (point counts, distance methods, double observer), and the true 'number present' is determined on a subsample of these plots (Bart and Earnst 2002). We define 'number present' as those individuals whose first nest of the season or territory centroid (for those whose nest was not found) is within the plot. Other definitions can be used as long as each bird in the population of interest is assigned a single place by the definition. The number of individuals recorded on rapid surveys, averaged across observers, is used as the numerator in the detection ratio and the 'number present' is the denominator. This ratio is best conceptualized as an index ratio, or correction term, between the numbers recorded during rapid surveys and the parameter of biological interest (number of birds on territories). The correction term reflects errors caused by territory holders being absent, behaving in a non-detectable manner, or missed by the observer during rapid surveys.

Double sampling is being used to assess the density of riparian songbirds on Sheldon and Hart Mountain National Wildlife Refuges as part of a larger study (Earnst et al., this volume). Here we describe preliminary detection ratios obtained as part of that ongoing work. Understanding factors that affect detectability will help to evaluate potential sources of bias in songbird surveys and aid in identifying survey methods that are likely to be most efficient. Specifically, the aim of this paper is to describe the a) average or pooled detection ratio across all species; b) variation in detection ratios among species and habitats; and c) seasonal trend in overall detections on rapid surveys.

Methods

As part of the larger study, 106 riparian plots were placed systematically across perennial streams and cover types on Hart Mountain National Wildlife Refuge. Of those 106 plots, 22 were intensive plots in the 2001 field season and form the basis for all analyses in this paper. Another 11 of the 106 plots will be intensive plots in 2002, resulting in 33 percent of all plots being sampled with the intensive method. We chose intensive plots in representative patches of aspen, willow, and meadow cover types along five different drainages, but did not choose a true random sample of the 106 plots due to time constraints of traveling among plots. Each plot was 150 m long by 100 m wide, the center-line was marked at 50 m increments and ran near and parallel to the stream, and the width of the riparian vegetation was typically less than the width of the plot.

In this application of double sampling, we used a fixed-width transect method as the rapid survey method and we used nest searching and territory mapping to obtain the actual number present. Each of 4 observers conducted one rapid survey on each plot, with each plot surveyed once during 17-22 May, twice during 31 May - 9 June, and once during 15-19 June. During a rapid survey, the observer walked slowly along the center-line recording all birds seen or heard within the plot. Time spent on a rapid survey depended on cover type—25 minutes in aspen, 20 in willow, and 15 in meadow. We used the time constraints of Dobkin et al. (1988a,b) because one goal of the larger study was to compare avian abundance in 2000-2002 to that in 1991-1993 (Earnst et al., this volume). The time constraints were originally designed to allow more time in habitats with higher avian abundance (Dobkin et al. 1988b).

Nest searching and territory mapping were conducted by the 2 authors on 11 intensive plots each (11 aspen, 8 willow, and 3 meadow) from 17 May through 19 July. After each visit to a plot, we recorded number of hours on plot and number of nests and territories of each species. Territory mapping was a season-long iterative process; maps from previous visits were modified upon each subsequent visit. In addition to nests, we recorded 'probable nests' on known territories when a) a female repeatedly flushed from a single location in a species-specific manner characteristic of a nest; b) an adult of a ground-nesting species was observed feeding immobile young; or c) an adult of a shrub/tree nesting species was repeatedly observed taking food to one location during the nestling phase (see also Vickery et al. 1992, and Martin and Geupel 1993). These operational definitions represent cases in which the observer was confident of the location of the nest to within a few meters and thus confident that the nest was within the plot.

The detection ratio for a species was calculated as the average number of individuals recorded per rapid survey divided by the average number of nests or territory centroids discovered during intensive surveys. Standard formulas for ratio estimators were used (Cochran, 1977, Ch. 6), with plot as the sampling unit (N = 22). Pooled detection ratios for more than one species were calculated by first summing the numerator and denominator across species. The coefficient of variation (CV = standard error/$\bar{x}$) was used as a measure of precision. Standard errors (se) are given with means throughout and scientific names of species mentioned in text and figures are given in *table 1*. T-tests were used to compare detection ratios. The distribution of the test statistic (i.e., mean difference between ratios) is symmetrical and thus close to a t-distribution, under the null hypothesis of no difference, thus t-tests are valid.

Results

We monitored a total of 261 territories of 32 species (*table 1*). Cumulative hours spent per plot averaged 12.5 hours for meadow and willow plots, which had an average of 6.5 territories per plot, and 23.1 hours for aspen plots, which had a mean of 17.3 territories per plot (*table 2*). When data from all plots were pooled, it indicated that approximately 80 percent of territories were identified after only 3 hours of monitoring, and the estimated number of territories stabilized after about 9 hours (*fig.1*). Approximately 60 percent of nests or probable nests were found after an average of 18 hours per plot and 80 percent were found on those plots visited for 42 hours. Overall, nests were located on 70 percent of territories (183/261), and nests or probable nests were located on 78 percent of territories (204/261).

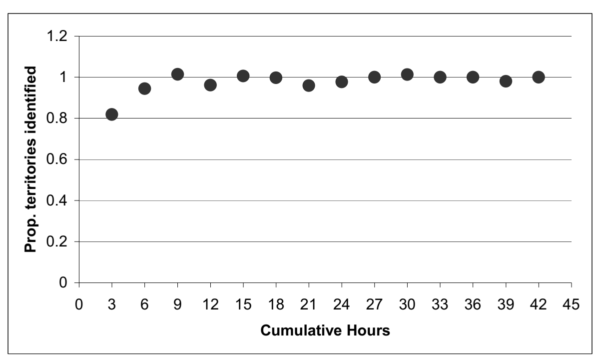

Figure 1— Proportion of territories identified within 3-45 cumulative hours of effort on plots. Cumulative effort and results were recorded at the end of each plot-day (effort per day varied from 1-8+ hrs per plot), thus each plot does not necessarily enter each cumulative category.

Table 1— *Number of territories and nests of species holding >5 territories within the 22 intensive plots on Hart Mountain, 2001. The 204 total nests include the 21 probable nests given in parentheses.*

Species	Scientific name[a]	AOU code	Territories	Total nests
Yellow Warbler	*Dendroica petechia*	YWAR	39	33 (2)
House Wren	*Troglodytes aedon*	HOWR	30	28 (2)
Dusky Flycatcher	*Empidonax oberholseri*	DUFL	27	23
American Robin	*Turdus migratorius*	AMRO	26	23 (1)
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	14	13 (3)
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	13	8 (1)
Song Sparrow	*Melospiza melodia*	SOSP	12	10 (3)
Tree Swallow	*Tachycineta bicolor*	TRES	12	10
Warbling Vireo	*Vireo gilvus*	WAVI	11	8
Northern Flicker	*Colaptes auratus*	NOFL	9	9 (2)
MacGillivray's Warbler	*Oporornis tolmiei*	MACW	8	4 (2)
Cassin's Finch	*Carpodacus cassinii*	CAFI	7	6 (1)
European Starling	*Sturnus vulgaris*	EUST	7	6 (1)
Green-tailed Towhee	*Pipilo chlorurus*	GTTO	7	1 (1)
Dark-eyed Junco	*Junco hyemalis*	DEJU	6	2
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	5	2
Other species			28	18 (2)
Grand Total			261	204 (21)

[a]Scientific names of species mentioned in the text but not in *table 1* are as follows: Barn Swallow (*Hirundo rustica*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Brewer's Blackbird (*Euphagus cyanocephalus*), Brewer's Sparrow (*Spizella breweri*), Bullock's Oriole (*Icterus bullockii*), Cliff Swallow (*Petrochelidon pyrrhonota*), Swainson's Thrush (*Catharus ustulatus),* Western Tanager (*Piranga ludoviciana*), Western Wood-Peewee (*Contopus sordidulus*), and Wilson's Warbler (*Wilsonia pusilla*).

Table 2— *Mean observer effort and mean number of territories, nests, and species holding territories by cover type on intensive plots on Hart Mountain, 2001 (N = 11 plots in aspen and 11 plots in willow/meadow).*

Cover type	Visits	Hours	Species	Territories	Nests	Probable Nests
Aspen	12.0 ± 1.0	23.1 ± 2.9	10.9 ± 1.1	17.3 ± 2.2	12.5 ± 1.9	1.4 ± 0.4
Willow/Meadow	8.4 ± 1.1	12.5 ± 2.2	4.5 ± 0.7	6.5 ± 0.9	4.0 ± 0.7	0.7 ± 0.2

The pooled detection ratio for all species was 0.46 (±0.03 se). Species-specific detection ratios, which were calculated for the 16 species having >5 territories present, ranged from 0.59 in Song Sparrows to 0.20 in MacGillivray's Warbler (closed bars, *fig.2*). A reasonably precise detection ratio was obtained for 11 of these species (CV < 0.25, see $\bar{x}$'s and se's in *figure 2*, closed bars) and the coefficient of variation was <0.40 for the other 5 species (Cassin's Finch, Dark-eyed Junco, Green-tailed Towhee, MacGillivray's Warbler, and Yellow-rumped Warbler). The precision of the species-specific detection ratios will increase with the addition of more plots (and thus more territories for each species) in the 2002 field season, and differences among species will be investigated more thoroughly then. In the final calculation of density, a pooled detection ratio will be used for groups of species having similar detection ratios.

A second detection ratio, which can be thought of as a maximum or 'potential' detection ratio, was based on 3-4 rapid surveys that each intensive surveyor performed on each of the plots on which she also mapped territories and found nests. We used the same rapid survey method (same time-constraints, stayed on the survey line), but we were familiar with the individuals on each plot, referred to our territory maps during the rapid survey, and specifically looked and listened for individuals on each known territory. This method of obtaining 'potential' detection ratios minimized the chance that an observer would overlook a territory owner that was present and behaving in a detectable manner. Thus, we interpret 'potential' detection ratios

<1 as being due primarily to territory owners being absent or undetectable (i.e., not singing and not visible) during the survey, rather than the observers failing to detect them. As expected, the 'potential' detection ratio tended to be higher than the regular detection ratio (i.e., that obtained by observers inexperienced with the plot) for all species combined ($\bar{x}$ = 0.56 ± 0.04 vs. $\bar{x}$ = 0.46 ± 0.03, t = 1.89, P = 0.07), and was significantly higher for Yellow Warbler, Dusky Flycatcher, and MacGillivray's Warbler (*fig.2*). More importantly, all 'potential' detection ratios were substantially less than 1.0 (open bars, *fig.2*), indicating for example that up to 20 percent of Warbling Vireos and 80 percent of Yellow-rumped Warblers were not detectable during transect surveys even when observers looked and listened for specific territory holders.

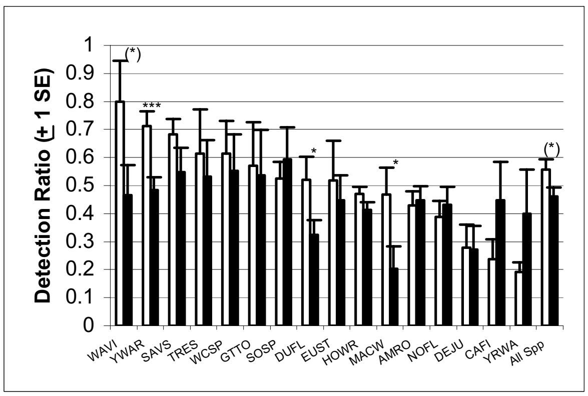

Figure 2— 'Potential' detection ratio (open bars) and observed detection ratio (dark bars) for 16 species with at least five territories present and for all species pooled. Potential detection ratio is the detection ratio by observers familiar with the territories and specifically trying to detect known territory holders. The observed detection ratio is the average of the detection ratio of four observers who had no previous experience with the plots (N = 22 plots). Statistical significance based on independent t-tests with asterisks indicating significance levels as follows: (*) P < 0.10, * P < 0.05, ** P < 0.01, *** P < 0.001. See *table 2* for four-letter species codes and number of territories present.

Detection ratios in the willow/meadow cover type were 28 percent higher than those in aspen for all species combined ($\bar{x}$ = 0.58 ± 0.05 vs. $\bar{x}$ = 0.42 ± 0.03, t = 2.49, P = 0.02, *fig.3*). Five species had at least three territories in each cover type (MacGillivray's Warbler, Yellow Warbler, Dusky Flycatcher, White-crowned Sparrow, and American Robin) and the pooled detection ratio for these five common species was also significantly higher in willow/meadow than in aspen ($\bar{x}$ = 0.52 ± 0.05 vs. $\bar{x}$ = 0.38 ± 0.03, t = 2.25, P = 0.03; *fig.3*).

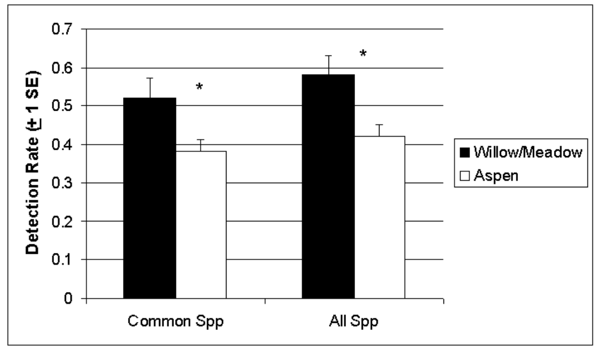

Figure 3— Pooled detection ratio on willow/meadow (N = 11) and aspen plots (N = 11) for 5 species that had at least three territories within each cover type and for all species pooled. Statistical significance based on independent t-tests, with asterisks indicating significance levels as follows: * P < 0.05; ** P < 0.01; *** P < 0.001.

To investigate whether detections varied over the course of the season, we calculated number of individuals detections per plot-survey in three calendar periods (17-22 May, 31 May-9 June, and 15-19 June). Detections per plot were higher in the first period (15.6 ± 1.5) than during the second (10.8 ± 0.9, paired t = 4.90, P < 0.001) or third (11.9 ± 1.0, paired t = 2.92, P = 0.008) for all species combined, excluding Brewer's Blackbirds. Brewer's Blackbirds were unusual in showing a 5-fold increase from the first to the third period (0.27, 0.63, and 1.35 individuals per plot) when flocks of parents and young moved into some plots. Similarly, a few relatively uncommon species that arrived later than others (Black-headed Grosbeak, Western Wood-Pewee, Swainson's Thrush) also had somewhat more detections in the last period than in earlier periods.

Discussion

The finding that 80 percent of territories were identified after only 3 hours of monitoring, and the estimated number of territories stabilized after about 9 hours, suggests that our territory-mapping method is a reliable and efficient method for determining total number of territories per plot. Nest finding also was useful in determining the number of territorial pairs present, especially for rare or secretive species, plots with high density, and edge territories. In addition, nest finding allowed a valuable ancillary study of nest success. It is possible that territory mapping alone would provide a reliable count of true number present for most territorial songbird species and thus be an appropriate intensive method, but this needs further study. The intensive method of repeated territory mapping and nest finding used here minimized the potential for problems inherent in less intensive methods such as spot mapping (e.g., Eagles 1981, and method, is an attractive sampling plan because it makes fewer assumptions than distance sampling, double-observer, or removal methods (see Bart and Earnst 2002).

Numerous authors during the past two decades have highlighted the pitfalls of interpreting indices of abundance (Burnham 1981, Bart and Earnst 2002, Farnsworth et al. 2002, Nichols et al. 2000, Rosenstock et al. 2002, Thompson 2002). Likewise, three findings from the current study demonstrate the value of estimating detection ratios and suggest caution in interpreting indices. First, the low 'potential' detection ratio ($\bar{x} = 0.56 \pm 0.04$), obtained by observers who knew the territories well and specifically listened for known territorial birds, is strong evidence that many breeding birds will not be detected by survey methods that rely primarily on auditory cues, such as point counts. This suggests the need for a rapid method, such as an area search, that would increase visual detections. The strip transect method used here resulted in almost identical detections per plot compared to fixed-radius point counts that sampled an equivalent area and time, and it resulted in somewhat fewer detections per plot than a single visit, medium-intensity, area-search/spot-map technique that required 45 minutes per meadow plot and 270 minutes per willow or aspen plot (Dobkin et al. 1998b).

Although a low detection ratio is not itself a problem, the lower the average ratio, the more potential for variation among subgroups of interest, such as species, habitats, or years. For example, in this study, the detection ratio was three times higher for Song Sparrows than MacGillivray's Warblers. Not surprisingly, two of the species with the lowest detection rates included one that sings sporadically (MacGillivray's Warbler) on our study site and one with a quiet, easily missed song (Dusky Flycatcher). Other field studies have also reported a low overall detectability and high variability among species (e.g., DeSante 1981), and tape-recording studies have shown that even experienced surveyors missed up to 35 percent of audible birds (Bart and Schoultz 1984) and were significantly less successful in detecting some species than others (Kepler and Scott 1981; Bart 1985).

Second, an important source of variation and potential bias, is the change in singing rate and visibility across stages of the nesting cycle (Wilson and Bart 1985). In our study, detections per plot dropped 24 percent from 17-22 May to 15 -19 June. This illustrates the need for plots to be surveyed at the same time each year relative to arrival and nesting phenology and for surveys to be completed within the window of relatively high detectability. This task is complicated by the likelihood that nesting phenology—timing of pair bond formation, nest initiation, incubation, nestling care, re-nesting after nest loss, or initiating a second clutch—varies by species and year and may not always be related to phenology of male arrival (B. Walker, pers. comm.) or other easily detected cues.

Third, detection ratios varied between cover types, thus complicating the use of indices to make inferences about the relative value of a cover type. The higher detection ratio in willow/meadow habitat compared to aspen habitat was expected based on the less complex vegetative structure and the fewer number of individuals and species present. Other studies have shown that observers are more efficient when density of species (Scott and Ramsey 1981) and conspecifics (Bart and Schoultz 1984) is lower. It is also possible that the higher detection ratio resulted from a higher detectability of pairs that were re-nesting after nest failure (in particular, a higher singing rate by re-nesting males), since nest failure was more common in willow /meadow than aspen habitat in 2001 (Heltzel and Earnst 2002). The difference in detectability in willow /meadow compared to aspen habitat was probably even higher than estimated here since our rapid survey method allowed 15 or 20 minutes in willow/meadow habitat and 25 minutes in aspen.

Our study was designed to allow comparison to a 1991-1993 study on the same areas, but not all aspects of the design are optimal for double sampling. For example, the small size of plots (1.5 ha) and their high edge-area ratio meant that several territories were on plot edges. Because edge birds were not always present on the plot, they added noise to the rapid estimate, and during intensive searches, required substantial effort to determine whether the nest or territory centroid was inside the plot. Plot size should be large relative to the territory size of species of interest. Our plot size was sufficient for many songbirds (Yellow Warblers, Warbling Vireos, Dusky Flycatchers) but larger plots would have been better for Bullock's Orioles, Black-headed Grosbeaks, and Western Tanagers, which have large territories and move widely among areas.

Our definition of number present worked well for most songbirds but not for those that used riparian areas during some periods or activities but rarely nested there. For example, some species nested in the uplands near plots and moved fledglings to riparian areas later in the summer (Brewer's Sparrows and Brewer's Blackbirds); others foraged widely away from nests (Cliff Swallows and Barn Swallows); and some migrants used plots for a week or more but did not nest there (Wilson's Warblers and Swainson's Thrushes). If these species are of particular interest, a definition of 'number present' other than location of nest or territory centroid is needed for them.

Further study to understand the visual and aural detectability of individual territory-holders as a function of distance from the observer, stage of nesting, paired status, date, time of day, and various other factors will help to evaluate potential sources of bias and aid in identifying rapid survey methods that are likely to be most efficient. Also, double sampling can be used to empirically evaluate the potential bias of the various rapid methods, including methods that estimate density (e.g., distance sampling, or double observer), and can be used to evaluate their efficiency (i.e., the standard error of the density estimate obtained from double sampling). The optimal intensive method should also be evaluated empirically, perhaps by conducting territory mapping and/or nest finding on a color-marked population.

Acknowledgments

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