

## AN INVESTIGATION OF THE EFFECT OF SEASONAL ACTIVITY LEVELS ON AVIAN CENSUSING

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**ABSTRACT.**—Intensive variable distance circular-plot censuses and timed activity budget data were used to compare the effects of conspicuousness upon census results. In six of ten species no correlation was found, suggesting that all birds within the "Effective Detection Distance" (EDD) were seen. In four species there were significant correlations. Multiple regression analyses confirmed these results. Generally larger correlations were found with the number of birds per station than with density per ha; the latter is presumed to correct for changes in conspicuousness, possibly through changes in the EDD. However, a completely unexpected result showed that the EDDs themselves, while showing cycles, did not correlate with the activity variables. This indicates that, although they probably have biological meaning and are relevant to censusing, EDDs are not simply related to obvious changes in conspicuousness as measured by activity patterns.

In dense forests censusing of birds is thought to have less reliability than in open habitats due to individuals being overlooked. This problem is probably greatest in a fixed distance transect. Theoretically, a variable distance count (e.g., J. T. Emlen 1971) corrects for the lessened visibility at greater distances. A researcher does this by calculating a distance at which all birds are detected, or a given proportion is detected. A species that is very conspicuous will have a larger detection distance, on the average, than inconspicuous species. However, variable distance methods assume that within some distance from the observer that is calculated from the data, all birds are detected. If this assumption does not hold, if a proportion of the birds close to the observer go undetected, the census will underestimate the density of birds.

The purpose of this paper is to investigate the problem of inconspicuous birds. That is, are the seasonal changes in abundances calculated from variable distance methods due to actual changes in density, or to changes in conspicuousness? Since it is difficult at best to measure the presence of the "invisible birds," I have used indirect measures to determine the effects of conspicuousness on censuses. I will test the efficacy of the count method by two analyses:

(1) I examined monthly trends in count results and compared them to measures of conspicuousness. Positive correlation would make us suspect the count results are responding to behavior. Lack of correlation can indicate a variety of things, among them the possibility that the population density is changing and the count method is measuring these changes.

(2) The factor in the variable distance count methods that responds to changes in conspicuousness is presumably the detection distance. Positive correlations between distance and con-

spicuousness would indicate that the method is satisfactorily compensating for changes in conspicuousness. That is, the seasonal changes in calculated density are due to actual changes in abundance, rather than to changes in conspicuousness.

### MATERIALS AND METHODS

Monthly censuses were conducted between July 1977 and April 1980 in a wet (ca. 1500 mm rain per year) forest at approximately 1600 m elevation on Keauhou Ranch, near Hawaii Volcanoes National Park on the island of Hawaii. On a 16-ha gridded plot, 8-minute variable distance station counts (Reynolds et al. 1980) were taken between dawn and about 10:00 on 25 stations, 100 m apart, usually three times each month, for a total of 50 to 100 station counts per month. The census data were analyzed using a method from Ramsey and Scott (1979) giving a density of birds per ha based on the assumption that all birds are detected within some minimum distance from the observer. For this study, I grouped all observation in 10 m increments, setting the minimum distance for calculation of density at 20 m. The census data also provided a measure of uncorrected abundance, the number of birds per station. This latter set of data should be responsive to conspicuousness, and the density data less so.

The conspicuousness of the species was determined by timed activity budgets taken throughout the day. Each month approximately 35 individuals of each species were followed for a minimum of 10 seconds (average 20 to 25) for each individual. We recorded the number of calls, hops, and flights, and the total length of song bouts, hops and flights. These are considered indices of conspicuousness. Data from three years were combined by month, and the resulting monthly averages of these activities were compared with the census data. Average sample size was between 150 to 250 individual budgets per species per month. The square roots of all quantities were used in the following analyses to correct for their non-normality.

### RESULTS

Although 10 species are presented in this study, for the sake of space, detailed analyses

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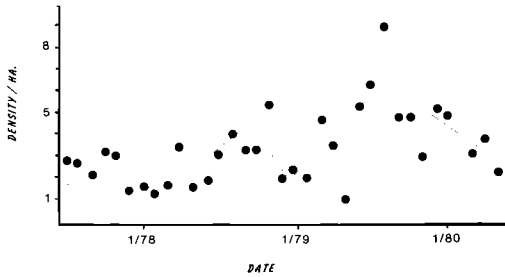


FIGURE 1. Calculated density of 'Elepaio, presumably corrected for effects of conspicuousness.

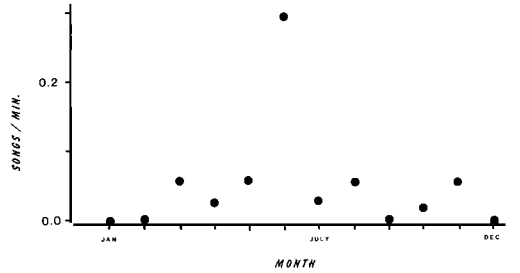


FIGURE 3. Monthly mean length of song bouts per minute of the 'Elepaio.

will be shown for only the 'Elepaio (*Chasiempis sandwichensis*).

RESULTS OF CENSUSES

Seasonal variations in both density (Fig. 1) and number per station (Fig. 2) are apparent for the 'Elepaio, differing in amplitude and somewhat in timing. The number observed per station varied from a low in the early part of the year to a high shortly after the breeding season. The density figures have a similar pattern, showing a pattern of gradually increasing density over the course of the three years.

CHANGES IN ACTIVITY LEVELS

*Vocalizations.*—This species has few prolonged song bouts. What few there are peaked in June (Fig. 3). Calls, on the other hand, are more evenly distributed throughout the year, being most frequent from April through October (Fig. 4). The average calling rate of between 0.75 and 2.0 calls per minute provides the observer with between four and ten opportunities to identify and record a bird during a single count period.

*Movements.*—The number of hops and flights showed a regular seasonal pattern (Fig. 5), peaking between December and June, and reaching

a low point in August. These movements are possibly related to food availability. In some of the other species studied, where food resources could be quantified, decreased food (e.g., fewer flowers with nectar) resulted in more and faster movements. The average distance flown per minute (Fig. 6) showed two peaks in the 'Elepaio, one in June and the other in early winter. Distance traveled in hops showed little trend, with only a minor peak in October.

CORRELATIONS BETWEEN ABUNDANCE AND ACTIVITY

I calculated Pearson correlation coefficients between the six activity variables and the 10 species' census data. Significant correlation might suggest that apparent changes in abundance merely reflect changes in activity levels. A low correlation could indicate, among other possibilities, that there is no linear relationship, and that variable distance counts are immune to changes in conspicuousness resulting from the birds' behavior. The analyses resulted in 34 significant correlations in the 120 comparisons (Table 1—"Dens" and "#/Sta" columns). In six species, the 'Amakihi (*Loxops virens*), Hawaiian Thrush (*Phaeornis obscurus*), 'Akiapola'au (*Hemignathus wilsoni*), Hawaiian Creeper (*Loxops maculatus*), Japanese White-eye (*Zosterops japonicus*), and Hawaiian 'Akepa (*Lox-*

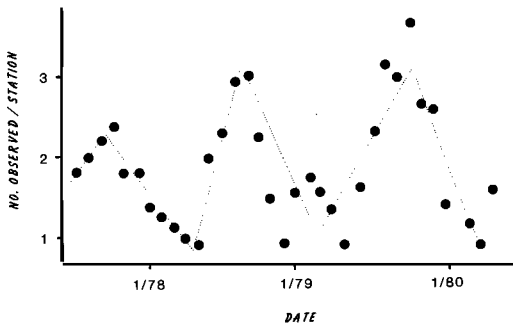


FIGURE 2. Number of individual 'Elepaio over three years per station censused.

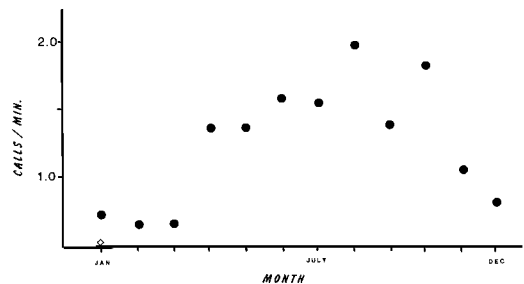


FIGURE 4. Monthly mean number of calls per minute of the 'Elepaio.

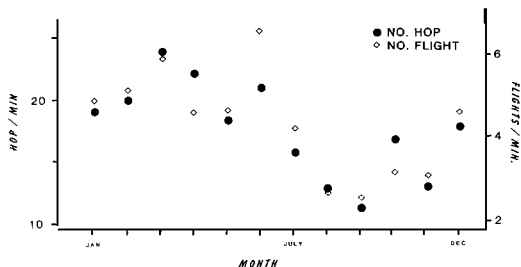


FIGURE 5. Monthly mean number of hops and flights per minute of the 'Elepaio.

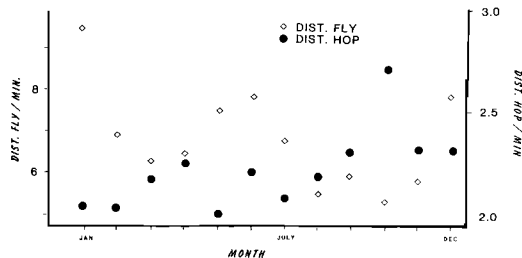


FIGURE 6. Monthly mean total distance of hops and flights per minute of the 'Elepaio.

*ops coccineus*), there were only two or fewer significant comparisons between activity levels and the two density measures, and these only at the 0.05 level.

However, in four species, 'Elepaio, 'Apapane (*Himatione sanguinea*), Red-billed Leiothrix (*Leiothrix lutea*), and 'Iwi (*Vestiaria coccinea*), there were several significant correlations. It can therefore be concluded that activity variables possibly influence population counts in these species. Since about half of the correlations are negative (19 of 34), it is apparent that no simple relationship exists. For instance, an increased number of hops could presumably make a bird more conspicuous, but it could also move a bird out of view more rapidly.

We can determine if the density figures are less correlated with the activity variables than are numbers per station, as we would expect if the former do indeed correct for conspicuousness. This was not clearly the case. Of the 60 comparisons between conspicuousness and one or both abundance measures, 20 had at least one significant correlation. Only in one of these (distance hopped in the thrush) was there actually a significant ( $P \leq 0.05$ ) difference between the sample correlations. A trend was, however, apparent. Of the 20 significant correlations of activity variables (Table 1): (1) in 12 cases there was a greater correlation with number per station than with density; (2) in six cases the level of significance was the same; and (3) in only two cases was there a more significant correlation with density than with number per station. One interpretation is that the density calculations (derived from the variable distance method) at least partially correct for changes in activity variables.

#### MULTIPLE REGRESSION ANALYSIS

Simple correlations may be insensitive to the underlying influences, so I did a multiple regression analysis. For this I first used a principal components analysis to define between one and three (e.g., Fig. 7) new variables from the orig-

inal six. The new variables (called factors 1–3), unlike the original, are independent and orthogonal, and therefore their order of entry into the statistical model does not alter their significance to the model. These were then used to predict the numbers of birds per station and the density. Factors 1–3 are linear combinations of the original six and have no immediate and simple biological meaning. They are best thought of as abstractions of the birds' behaviors. But, of course, the original variables are also abstractions—those that are easy to quantify. Moreover, the relationship between any specific behavior and detectability is not at issue; only whether behavior, in some abstract sense, contributes to differences in the numbers of birds observed.

This analysis showed that in five species relatively little of the variation in either the density or the number per station is explained by the activity patterns (Table 1—"Model" row,  $R^2$  value). The percent of the variation explained in these species ranges from only 0 to 8%. However, in five other species, the model explains significant amounts of the variation. As was expected, conspicuousness usually explains more of the variation in the number per station than in density.

#### VARIATION IN EFFECTIVE DETECTION DISTANCES

As a bird becomes more conspicuous, the average distance at which detections are made should increase, and vice versa. The "Effective Detection Distance" (EDD) is essentially this distance (calculated by the method in Ramsey and Scott 1979).

Of the 10 species studied, six showed definite annual cycles of EDDs (e.g., Fig. 8), while two were questionable, and two did not (Table 1). Because of their cycling, it appears that EDD is measuring (or is sensitive to) some aspect of the birds' behavior in many cases, perhaps some aspect of conspicuousness.

The next obvious analysis was to determine

TABLE I  
SIGNIFICANCE OF CORRELATION<sup>a</sup>

Species x̄ density/ha	'Arapane 14.4			White-Eye 5.3			Leiothrix 3.4			'Elepaio 3.3			Thrush 3.0			'I'iwi 2.8		
	Dens	#/Sta	EDD	Dens	#/Sta	EDD	Dens	#/Sta	EDD	Dens	#/Sta	EDD	Dens	#/Sta	EDD	Dens	#/Sta	EDD
Activity variables (x̄ per min)																		
Number calls	—	*	—	—	—	—	—	—	—	*	***	—	—	—	—	—	—	*
Length songs	—	****	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*
Number hops	**	**	—	—	—	—	XX	XX	—	X	XXX	—	—	—	—	*	**	—
Number flights	**	**	—	—	—	—	XX	X	—	XX	XXX	—	—	—	—	**	**	—
Dist. flown	—	—	—	—	—	—	X	X	—	X	X	—	—	—	—	—	—	—
Dist. hopped	X	XXX	—	—	—	—	X	X	—	*	**	—	—	—	X	—	X	—
Model { P	*	***	—	—	—	—	**	*	—	**	***	—	—	—	—	—	—	**
R <sup>2</sup>	.20	.40	.00	.00	.00	.00	.26	.24	Yes	.27	.44	?	.04	.08	.12	.22	.22	.22
EDD cycle?	—	Yes	—	—	Yes	—	—	—	Yes	—	—	—	—	—	Yes	—	—	Yes
Species x̄ density/ha																		
Activity variables (x̄ per min)																		
Number calls	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Length songs	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Number hops	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Number flights	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dist. flown	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dist. hopped	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Model { P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R <sup>2</sup>	.03	.07	.04	.04	.04	.04	.07	.04	No	.04	.03	?	.05	.13	.13	.13	.13	.13
EDD cycle?	—	No	—	—	—	—	—	—	No	—	—	—	—	—	—	—	—	Yes

<sup>a</sup> \* = positive correlation; x = negative correlation; \* and x = <0.5; \*\* and xx = <0.1; \*\*\* and xxx = <0.01; \*\*\*\* and xxxx = <0.0001.

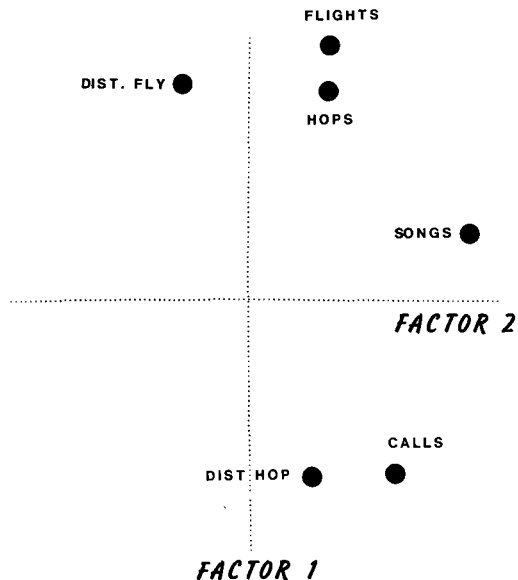


FIGURE 7. Result of two factor Principal Components Analysis on activity variables of the 'Elepaio.

if these changes in EDDs were related in any simple way to the activity variables. I predicted that many species would be highly correlated. Pearson correlation coefficients (Table 1—"EDD" columns) yielded, however, only two significant ( $P \leq 0.05$ ) relationships. By chance alone, one would have expected three. Multiple regression analyses yielded no significant models based upon the activity variables themselves predicting EDDs. This completely unexpected result throws some doubt upon a very basic tenant of variable distance methods: i.e., differences between species' conspicuousness are accounted for by differences in their detection distances.

DISCUSSION

In six of the 10 species, conspicuousness changing over the season had little relation either to the number of birds seen at each station or to the density calculated from the data. This indicates that these species are possibly active or vocal enough that rather few birds are missed during the 8-minute count period. Therefore, the census method probably accurately measures the population changes. However, in four species, conspicuousness possibly plays a role, since changes in abundance were correlated with activity variables. In these four species: (1) significant correlations exist between the birds' activity and their apparent abundance; and (2) a multiple regression model, based on their ac-

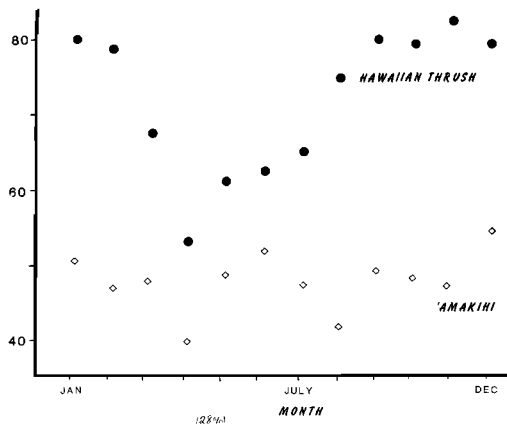


FIGURE 8. Monthly mean of Effective Detection Distances (EDD) for a cycling species (Hawaiian Thrush) and a non-cycling species ('Amakihi).

tivity, significantly predicted their abundance. However, on the bright side, even in these species the multiple regression analysis still only explained less than half of the variation. The rest of the variation was presumably due to other factors, paramount among them being, one would hope, actual changes in the birds' density.

It is suggestive that, in most cases, the level of significance of correlation (and the percent of the variation explained by the activity level changes) are greater when one is dealing with the number observed per station as opposed to density. That is, although one is likely to see and hear more birds when they are conspicuous, either empirical (J. T. Emlen 1971) or calculated (e.g., Ramsey and Scott 1979) densities do tend to remove the effects of conspicuousness.

However, an examination of the relation of the EDDs and the activity variables does not make it clear why these calculations do succeed. The fact that between six and eight of the species' EDDs cycle indicates that some aspect of the birds' behavior is being measured by the EDDs. However, the lack of relationship between the changes in EDDs and the activity measures indicates that EDDs reflect: (1) some abstraction of behavior; (2) an interplay of factors not easily measured; and/or (3) something irrelevant to detection of birds and, therefore, to censusing.

Although the distance measure used in the variable distance census methods provides an aesthetic and intuitively pleasing quantity, my data do not clearly show that changing EDDs reflect changes in conspicuousness. This is a very basic assumption in any variable distance method and quite obviously merits further investigation.

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