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A COMPARISON OF THE "FLUSH" AND SPOT-MAP METHODS FOR ESTIMATING THE SIZE OF VESPER SPARROW TERRITORIES

By J. Michael Reed

Spot-mapping, a common census method for birds (Williams 1936, Kendeigh 1944, Emlen 1977, Paul and Roth 1983), has also been used to delimit individual territories or "known use" areas (Zimmerman 1971). Spot-mapping involves mapping observation points throughout the day, or over a course of several days, so that territorial boundaries may be drawn. A faster method of mapping territories, especially suitable for grassland species, was developed by Wiens (1969). This, the "flush" method, involves repeatedly flushing an individual a minimum of 20 times, and recording its flight path and flush sites. These paths are assumed to fall within territorial boundaries. Both methods have been used in grassland research to estimate territory size (spot-map—Zimmerman 1971, 1982; flush—Wiens 1973, 1974, Whitmore 1979, 1981, Rotenberry and Wiens 1980). However, the methods have not been compared with respect to relative accuracy, consistency, or usefulness in estimating territory size.

Here I compare results from the spot-map and flush methods of mapping territories, using the Vesper Sparrow (*Pooecetes gramineus*). I used 4 standard techniques of delimiting territorial boundaries to examine the robustness of my results, i.e., whether the results are independent of boundary delimitation technique.

STUDY SITE AND METHODS

The study site, a 130 ha upland plot, was situated amid the grassy slopes located 0.5 km north of Missoula, Montana (114°00'W, 47°48'N, elevation 980 m). Dominant vegetation was Idaho fescue (*Festuca idahoensis*), rough fescue (*F. scabrella*), blue bunch wheatgrass (*Agropyron spicatum*), and spotted knapweed (*Centurea maculosa*).

I mapped 7 territories using an adaptation of the flush method, in which only flush points were used to delimit territories, rather than flush points plus flight paths (Wiens 1969). I excluded flight paths because flight paths of some individuals crossed known territorial boundaries, as indicated by observation of habitat use and territorial skirmishes. If another Vesper Sparrow territory was invaded during the flushing, the territory owner whose boundary was crossed chased out the encroacher. These chases never occurred when an individual landed at a flush point.

After flush mapping was completed, I set up a path for spot-mapping the individuals that occupied the same territories. Each time I traversed the territory, I recorded the location of any bird seen. This technique differs from the flush method because all points are generated from the

first sighting of an individual each time the path is walked. The International Standard for Mapping (Robbins 1970) recommends a minimum of 8 visits and 3 sightings for census work in open habitat. To get more information on territory sightings I repeated each systematic path 38 times and sighted each individual a minimum of 20 times.

From the points for flush and spot-map methods I estimated territory sizes using 4 different techniques:

(1) Minimum circle—The territory area was calculated by using the 2 most distant points as the diameter of a circle (Fitch 1958). Such a method may be reasonable for grassland species as evidenced by the fact that the territory of the Chestnut-collared Longspur (*Calcarius ornatus*) is approximately circular (Harris 1944).
(2) Maximum polygon—This was found by connecting the outermost of the cluster of points with straight lines (Odum and Kuenzler 1955, Ambrose 1969).
(3) Adjusted polygon—This was found in the same manner as the maximum polygon, except that areas that were not used or defended, for whatever reason, were not included (Mohr 1947 ["minimum home range"], Janes 1959 ["composite method"], Ambrose 1969 ["adjusted home range"], Seastedt and MacLean 1979). The decision about an area's exclusion was made through repeated observations of an individual's presence in different parts of the territory. If an area was consistently unused it was excluded.
(4) 90% polygon—A maximum polygon was found with the most isolated 10% of the points excluded. Stenger and Falls (1959) calculated a used territory, excluding the most isolated 5% of the points. I had smaller sample sizes than they had, and by excluding 10% I eliminated 2 points from each territory for both map methods.

To determine the variability in estimating territory size using the flush method, I chose 5 of the 7 territories that were initially mapped and remapped each 4 times during the following 15 days. I then compared the within- to between-territory variance in territory size. The method used for determining territorial boundaries for this part of the analysis was the adjusted polygon method (for reasons presented in the discussion).

The areas of the polygons were calculated using a graphics table and a program that calculated surface area based on the polygon outline drawn with an electronic pen.

RESULTS

The 7 territories that were found by flush and spot-mapping are shown in Fig. 1. (The adjusted polygon technique was used to define the territorial boundaries in the figure.) The flush method resulted in significantly larger territory sizes than spot-mapping (Sign test, $n = 7$ for each method, $P < 0.01$) regardless of the technique used to estimate territory size (Table 1).

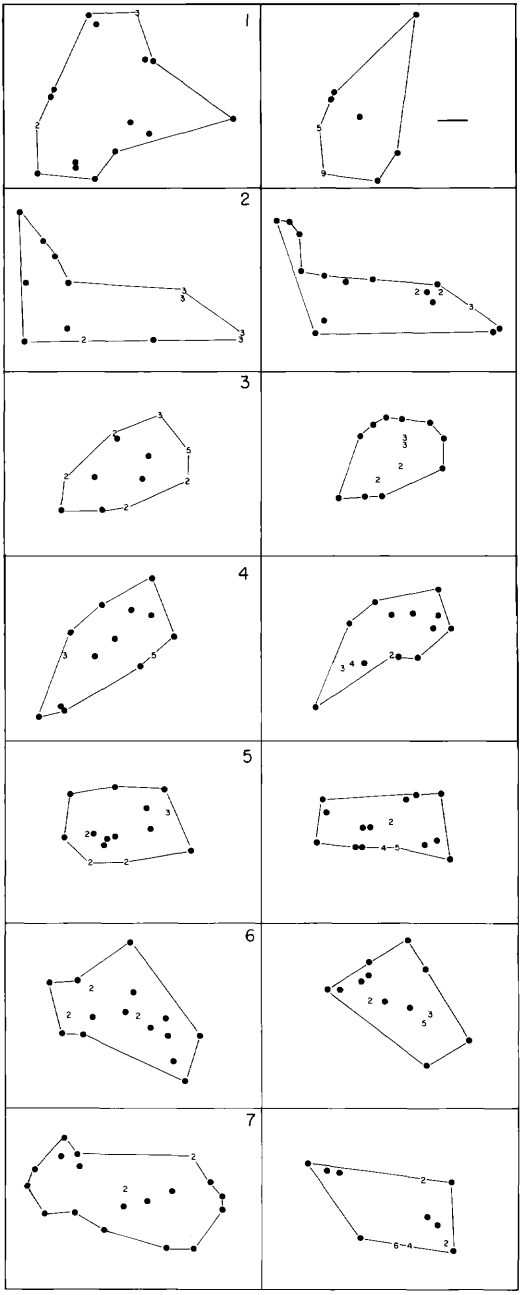

FIGURE 1. Flush points (left column) and spot-map points (right column) for the seven territories. Numbers represent multiple points. Territories are depicted using the adjusted polygon method. The bar in territory 1 represents 20 m.

TABLE 1. Calculated area (ha) of each of seven territories, using flush and spot-map methods for each of 4 techniques of territory size determination.

	Maximum polygon		Adjusted polygon		90% polygon		Minimum circle	
Territory	Flush	Spot	Flush	Spot	Flush	Spot	Flush	Spot
1	1.60	0.76	1.44	0.76	0.79	0.29	1.82	1.61
2	1.30	1.05	1.00	0.77	0.70	0.46	3.04	2.87
3	0.61	0.49	0.61	0.49	0.53	0.39	0.86	0.67
4	0.71	0.57	0.71	0.57	0.56	0.44	1.51	1.35
5	0.64	0.54	0.64	0.54	0.44	0.44	0.84	0.95
6	1.00	0.69	0.94	0.69	0.58	0.46	1.30	1.07
7	1.25	0.68	1.12	0.68	0.91	0.53	1.74	1.35
Mean	1.02	0.68	0.92	0.64	0.64	0.43	1.59	1.41
SD	0.38	0.19	0.30	0.11	0.16	0.07	0.75	0.71

Territory sizes ranged from 0.29 ha (90% polygon, spot-map, territory 1), to 3.04 ha (minimum circle, flush, territory 2). The 90% polygon method consistently resulted in the smallest territory sizes, while the minimum circle method resulted in the largest territory sizes (Table 1).

In the repeat-mapping portion of the study, territory sizes ranged from 0.53 ha (territory 3) to 1.13 ha (territory 5) (Table 2). I performed a nested analysis of variance (ANOVA) to determine where the variability in territory sizes was most prominent, and the most significant amount of variability occurred between territories (98.6%), rather than within territories (mean squares = 0.13, 0.05, $F = 2.60$, df = 4,20, $P > 0.05$).

DISCUSSION

I believe the adjusted polygon method was the most accurate and biologically sound of the techniques I used for interpretation of field data, such as exclusion of areas that the individual does not use (e.g., Ambrose 1969, Seastedt and MacLean 1979). Based upon additional field observations and flushing of individuals, I am fairly certain that the boundaries shown by the adjusted polygon technique are accurate. Territory borders often followed fence lines or trails for a distance, which altered the territory shape from the expected maximum polygon shape. For example, territory 2 was "L"-shaped. The area avoided by the individual, causing the unusual territory shape, was one of sudden vegetation structure change, from mixed grasses to a broad-leafed forb. Vesper Sparrows had difficulty perching on this vegetation, which may be why they avoided it.

Mapping methods.—The modified flush method (Wiens 1969) was better than spot-mapping for mapping territories for 2 reasons: accuracy and time. The first problem with the spot-map method is that the only way to see an individual is when it is perched or when it is flushed from the ground while walking the path. Vesper Sparrows are very secretive

TABLE 2. The area (ha) of 5 territories using the flush method to generate points and the adjusted polygon technique to estimate territory size for each of five sample dates.

Territory	Repetition date				
	6/25	6/28	6/30	7/6	7/10
3	0.61	0.78	0.90	0.76	0.59
4	0.71	0.86	0.71	0.77	0.75
5	0.64	0.39	0.80	0.53	0.62
6	0.94	0.89	0.73	1.00	0.87
7	1.12	1.13	1.05	0.92	0.89

and are virtually never flushed from the ground unless approached within 1.5 m. It was effectively impossible to see an individual on the ground because of vegetative cover.

The modified flush method on the other hand involves repeatedly flushing an individual a minimum of 20 times, and recording the flush points. In all my territories the individual began going back to the same flush points before I completed mapping. The "invisible barrier" that surrounded the territories seemed very distinct, especially where the territories abutted. When an individual was flushed into an adjacent territory it was chased out by the resident territory holder. The flush method results in 2 abutting territories much larger in size than would be shown by spot-mapping the same territories.

The territory sites did not seem to be "saturated" with individuals, which might have influenced territory size and shape. If the area had been saturated, spot-mapping might have resulted in more points along the territorial borders due to border disputes.

The flush method's usefulness is not restricted to small secretive bird species. One apparent disadvantage to spot-mapping is that a very large number of sightings of an individual (>20) may be necessary to establish its territorial borders. An individual is more likely to be seen anywhere in its territory except its borders, because the majority of time is spent centrally (Robbins 1971, Martindale 1982). Feeding and nesting activities are generally centered around the nest site, thus increasing the probability of sighting an individual away from its territorial borders (i.e., towards the territory center). Flush-mapping forces an individual to the edge of its border, and repeated flushing defines a distinct border which probably represents the "familiar area" of an established territory. I believe the flush method gave an accurate picture of territory sizes and distributions, while spot-mapping gave information on centers of conspicuous activity within the territory. This should be the case with any grassland species that does not readily leave its territory when flushed.

The flush method has the added advantage of being less time-consuming than spot-mapping, particularly when many sightings are required to delimit territorial borders. Flushing a Vesper Sparrow 20 times

generally took little more than 10 min, while the information needed by spot-mapping took much longer and can take hours of continuous observation time (Odum and Kuenzler 1955)—or at least a week of regularly walking a systematic path (Robbins 1970).

The flush method is ineffective for mapping territories for those species that leave the territory when flushed, e.g., Savannah Sparrows (*Passerculus sandwichensis*; Potter 1972). In this situation spot-mapping must be used. Likewise, a situation in which spot-mapping may be as effective as flush-mapping is when the species under observation is large enough that the vegetation does not obstruct its detection, e.g., Long-billed Curlews (*Numenius americanus*). In such cases the individual can be seen on the ground at some distance from the systematic path, which increases the possibility of seeing the individuals at the borders most distant from the path.

Variability.—When remapping territories the flush method showed much less variation in territory size within a given territory than between territories. Assuming that individual territory sizes remained constant during the remapping period, the flush method is a relatively precise method of measuring Vesper Sparrow territory size.

There is evidence that grassland bird species' territories increase in size during the breeding season (Risser et al. 1982:225). Results from individual territories in this study (Table 1) indicate that although fluctuations did occur in Vesper Sparrow territory size, there was no noticeable trend in direction of change during the short period of remapping. It may be that territories set up later in the season are larger than those established earlier due to decreased prey densities, but individual territories established earlier did not appear to increase with time.

SUMMARY

I compared the efficiencies and usefulness of the flush and spot-mapping methods of determining territory size of Vesper Sparrows. Territory borders were drawn using 4 different methods to make the comparison more robust. The flush method was faster and more accurate at delimiting territorial boundaries. The spot-mapping method may be more useful for mapping centers of activity.

The flush method resulted in consistent measures of territory size during remapping. This method should be more useful than spot-mapping in delimiting territories of grassland species that do not readily leave their territory upon pursuit.

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