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Use of Assessment Lines to Estimate Density of Small Mammals*

[With 6 Tables & 6 Figs.]

Removal trapping along three sets of lines was used to estimate density of small mammals in the lowland mesic-hardwood forest. Traps were checked on the octagon census lines for 28 days, on the primary assessment lines for a second 28 day period, and on the secondary assessment lines and the octagon census lines during a final 28 day period. Primary assessment lines were placed across the octagon census lines while the secondary assessment lines were placed across the primary assessment lines. Linear regression equations were fitted to accumulative captures over distance for the primary assessment lines and the secondary assessment lines to determine the area of effect around the octagon census lines and a selected portion of the primary assessment lines, respectively.

Linear regression equations were also used to estimate numbers of small mammals in the two areas of effect when the methods of Hayne (1949) and Janion, Ryszkowski & Wierzbowska (1968) could not be used to estimate number. Using the estimated areas of effect and numbers, density estimates in the area of effect of the octagon census lines were 2.7—2.9 *P. gossypinus*/ha, 3.7—3.9 *O. nuttalli*/ha, and 1.3—1.4 *B. brevicauda*/ha. Density estimates in the area of effect along the selected portion of the primary assessment lines were 7.4—9.8 *P. gossypinus*/ha, 5.4—7.1 *O. nuttalli*/ha, and 1.7—2.2 *B. brevicauda*/ha.

I. INTRODUCTION

Increased interest in bioenergetics, mineral cycling, and population dynamics through participation in the International Biological Program has resulted in the standardization of census techniques to provide reliable density estimates. Estimation of densities requires estimation of both the number of animals and the area from which animals were sampled. Use of present techniques seldom provides reliable density values for small mammals, although new methods of estimation of the

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number of animals in the area sampled have been presented (Tanaka & Kanamori, 1967; Janion, Ryszkowski & Wierzbowska, 1968). But calculation of the area affected by the sampling technique is still one of the major difficulties of density estimation.

Wheeler & Calhoun (1967), in designing a small mammal census program, International Census of Small Mammals (ICSM), discussed the use of assessment lines to determine the area affected by a grid of traps or an octagon-shaped trap line. Gentry, Smith, & Chelton (1971) tested the ICSM's octagon census method, Category 04 (Wheeler & Calhoun, 1968). Early results from the work of Gentry *et al.* (1971) were instrumental in designing and testing a large, modified version of the octagon census method.

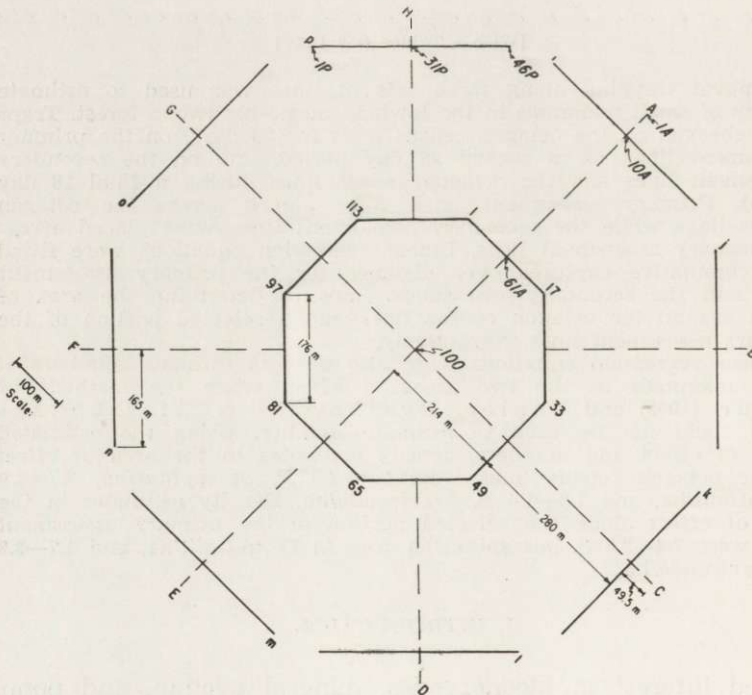


Fig. 1. Pattern of the trap lines.

Solid lines forming the octagon are the census lines. Numbers at the corners of the octagon represent the number of the trap station at the intersection of adjacent census lines. Primary assessment lines, lettered A-H and shown as dashed lines, were perpendicular to the middle of their respective census line. Stations 1A, 10A, 61A, and 100 illustrate the sequential numbering of stations along primary assessment lines. The 8 solid lines, *i-p*, represent the secondary assessment lines which are perpendicular to the primary assessment lines. Direction of sequential numbering along secondary assessment lines is given by stations 1P, 31P, and 46P.

The primary objective of this study was to test the use of assessment lines placed across census lines in estimating the density of small mammals in the area affected by these census lines. This paper presents the mathematical methods used in estimating the area of effect and numbers of small mammals from captures on census and assessment lines.

II. METHODS

Small mammal removal trapping was conducted using three sets of lines, the octagon census lines, and primary and secondary assessment lines (Fig. 1). Traps on each line were set for 28 trapping days. The study plot was located in a lowland mesic-hardwood forest (as described by Gentry, Golley & Smith, 1968). Traps were set on the octagon census lines from January 24 to February 21, 1969. The octagon consisted of 128 trap stations with an interstation interval of 11 m. Each census line had 16 trap stations.

Traps were checked on the primary assessment lines from February 22 to March 22, 1969. Four of the primary assessment lines had 61 stations and four had 100 stations, including a common center station. The interstation interval was 5.5 m on the eight lines.

The last phase of the study, conducted between March 23 and April 24, 1969, included setting traps on the secondary assessment lines and resetting traps on the census lines. Each secondary assessment line contained 46 stations. Adjacent stations were 5.5 m apart from 1—31 and 11 m apart from 31—46.

Two snap traps, 1 Victor and 1 Museum Special, were placed at each station. Traps were baited with peanut butter using squeeze bottles (Smith, Chew & Gentry, 1969) and were checked each morning. Species, location of capture, weight, sex, and reproductive conditions of each mammal were recorded.

III. RESULTS

Snap traps captured 533 small mammals on three sets of trap lines (Table 1). A total of 231 cotton mice *Peromyscus gossypinus* (Le Conte, 1853), 229 golden mice *Ochrotomys nuttalli* (Harlan, 1832) and 55 short-tailed shrews *Blarina brevicauda* (Say, 1823) were removed during 84 trapping days. These three species represented 96.6% of the total captures (533) and were the only species used in further calculations in this paper.

Traps removed 110 small mammals during the first trapping of the octagon census lines. Fifty-two golden mice, 38 cotton mice, 18 short-tailed shrews, and 2 eastern woodrats *Neotoma floridana* (Ord, 1818) were captured. The second trapping of the octagon census line yielded only 36 small mammals. These were 19 *O. nuttalli*, 12 *P. gossypinus*, and 5 *B. brevicauda*.

Two hundred fifty-six individuals, 7 species, were caught in traps on the primary assessment lines. Among these species were 131 *P. gossy-*

Table 1

Number and per cent (in parentheses) of small mammals captured on each of four sets of trap lines and all lines combined. Traps were set on the octagon census lines for 28 days immediately followed by a 28 day trapping period for the primary assessment lines. The study was concluded with a 28 day trapping period on the secondary assessment lines with a simultaneous retrapping of the octagon census lines.

Species	Octagon Census Lines (1st Phase)	Primary Assessment (2nd Phase)	Secondary Assessment (3rd Phase)	Octagon Census Lines (3rd Phase)	All Trapping (All Phases)
<i>P. gossypinus</i>	38(34.5)	131(51.2)	50(38.2)	12(33.3)	231(43.3)
<i>O. nuttalli</i>	52(47.3)	94(36.7)	64(48.9)	19(52.8)	229(43.0)
<i>B. brevicauda</i>	18(16.4)	21 (8.2)	11 (8.4)	5(13.9)	55(10.3)
<i>S. hispidus</i>	0	4 (1.6)	3 (2.3)	0	7 (1.3)
<i>S. longirostris</i>	0	4 (1.6)	0	0	4 (0.8)
<i>N. floridana</i>	2 (1.8)	1 (0.4)	0	0	3 (0.6)
<i>O. palustris</i>	0	1 (0.4)	0	0	1 (0.2)
<i>M. pinetorum</i>	0	0	1 (0.8)	0	1 (0.2)
<i>P. polionotus</i>	0	0	1 (0.8)	0	1 (0.2)
<i>G. volans</i>	0	0	1 (0.8)	0	1 (0.2)
Total	110(100)	256(100)	131(100)	36(100)	533(100)

Table 2

The time, in days, at which 1, 25, 50, 75, and 100% of the total number of each species and three species combined was removed by trapping on four sets of trap lines for 28 days.

Trap Lines	Per Cent Removed	<i>Peromyscus</i>	<i>Ochrotomys</i>	<i>Blarina</i>	Three Species
Octagon Census Lines (1st Phase)	1 25 50 75 100	1 3 10 23 27	1 16 19 23 25	11 17 20 23 28	1 11 18 23 28
Primary Assessment Lines (2nd Phase)	1 25 50 75 100	1 2 9 21 28	1 3 16 24 28	3 9 15 24 26	1 2 14 24 28
Secondary Assessment Lines (3rd Phase)	1 25 50 75 100	1 2 2 8 27	1 2 3 20 28	2 3 12 20 23	1 2 3 16 28
Octagon Census Lines (3rd Phase)	1 25 50 75 100	1 1 3 5 26	1 2 3 9 23	2 2 7 12 16	1 2 3 9 28

pinus, 94 *O. nuttalli*, and 21 *B. brevicauda*. The remaining species consisted of the cotton rat *Sigmodon hispidus* Say & Ord 1825, southeastern shrew *Sorex longirostris* Bachman, 1837, rice rat *Oryzomys palustris* (Harlan, 1837), and the eastern wood rat.

Traps on the secondary assessment lines yielded 131 small mammals. Sixty four golden mice, 50 cotton mice, and 11 short-tailed shrews were removed on these lines. Incidental captures included the pine mouse *Microtus pinetorum* (Le Conte, 1830), old-field mouse *Peromyscus polionotus* (Wagner, 1843), flying squirrel *Glaucomys volans* (Linnaeus, 1758), and the cotton rat.

1. Rate of Removal of Small Mammals

Accumulative per cent of *P. gossypinus*, *O. nuttalli*, *B. brevicauda*, and the three species combined captured on successive days using the total for 28 days as 100% was calculated for each of the 4 sets of trap lines (Table 2). The time in days when 1, 25, 50, 75, and 100% of the mammals were recorded was variable for the different species as well as for the same species on different trap lines (Table 2). Accumulative per cent removal varied more between species on the octagon census lines than on the primary assessment lines (Fig. 2; Table 2). Fifty per cent of *P. gossypinus* were removed sooner than or in the same time as *O. nuttalli*, although there were more *O. nuttalli* captured on 3 of the 4 sets of trap lines (Table 1). Fifty per cent of both *P. gossypinus* and *O. nuttalli* were removed faster than 50% of *B. brevicauda* on the four sets of trap lines except the *O. nuttalli* on the primary assessment lines. Curvilinear regressions, $Y = aX^b$, were calculated using Y as per cent removal and X as days. All r values were significant at $P < 0.01$ indicating that the relationship between per cent removed and time was curvilinear.

Captures per day did not decrease throughout the 28 day trapping period on each set of lines (Fig. 2). Daily captures were usually higher in the first 3—6 days than in the latter part of each phase. However, there were major inputs during days 16, 17, and 18 and 22, 23, and 24 on the octagon census lines and days 24, 25, and 26 on the primary assessment lines. The primary input of *Ochrotomys* and *Blarina* occurred on days 16, 17, and 18 on the octagon census lines with only 10—15% of the total of each species caught in the first 15 days. These changing daily captures indicated that the probability of capture was not constant during each phase of the study.

The first four days of captures on the primary assessment lines and secondary assessment lines were used in calculations of the width of

effect around the octagon census lines and the primary assessment lines, respectively. The per cent removal of the small mammals at the end of four days on primary assessment lines was 30–40% for *Peromyscus*, *Ochrotomys*, and the 3 species combined, but only 10% for the less numerous *Blarina*. Per cent removal of small mammals through the fourth day along the secondary assessment lines was greater than per cent removal on the primary assessment lines. Captures of *Peromyscus*, *Ochrotomys*, and the three species combined represented 60–65% of their total captures while 30–35% of the *Blarina* were removed.

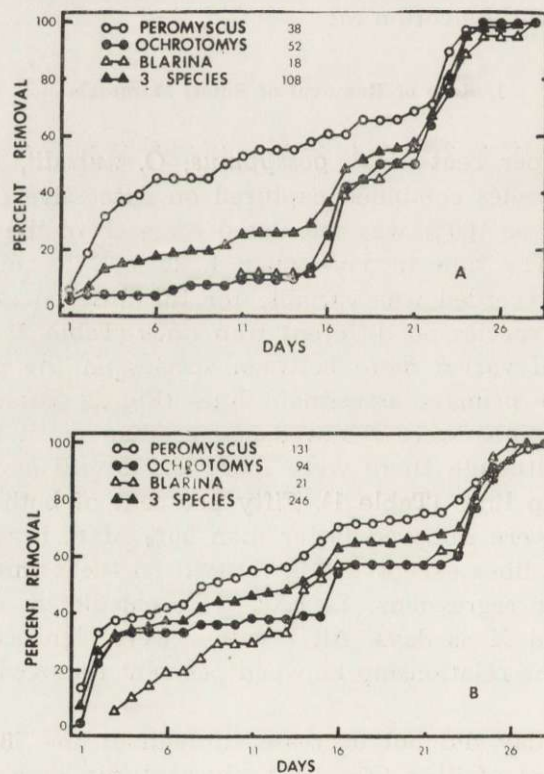


Fig. 2. Accumulative per cent removal of small mammals versus time (28 days) for two sets of trap lines.

A. Octagon census lines (1st phase). B. Primary assessment lines. Total number of small mammals of each species and 3 species combined captured in 28 days was 100%. Numbers following species in the legend were the number of animals caught in 28 days.

2. Removal of Small Mammals Along a Trap Line

Average captures per respective station were calculated for each set of trap lines. Average captures were then accumulated such that the

Table 3

Linear regression equations, $Y=a+bX$, were fitted to accumulative captures over distance. Values for a , b , and r were calculated for five time periods on each set of trap lines. All values of r were significant ($P < .01$).

Trap Line	Days	a	b	r
Octagon Census Lines (1st Phase)	1-4	-.155	.012	.97
	1-9	-.028	.015	.97
	1-14	.026	.019	.98
	1-21	.439	.043	.99
	1-28	.628	.076	1.00
Octagon Census Lines (3rd Phase)	1-4	.148	.015	.95
	1-9	.027	.016	.93
	1-14	.004	.019	.95
	1-21	.027	.021	.96
	1-28	.029	.023	.97
Primary Assessment Lines (2nd Phase)	1-4	.589	.023	.99
		4.779	.006	.93
		-7.773	.041	.99
	1-9	.746	.029	.99
		5.770	.008	.93
		-12.793	.053	.98
	1-14	.872	.036	.98
		6.512	.011	.95
		-13.101	.064	.98
	1-21	.756	.062	.99
		6.163	.025	.53
		1.425	.044	.85
	1-28	2.265	.082	.99
		7.162	.044	1.00
		-11.428	.095	.99
Secondary Assessment Lines (3rd Phase)	1-4	1.051	.028	.98
		2.167	.019	.99
		4.236	.008	.98
	1-9	-.799	.031	.99
		.977	.034	.98
		2.508	.021	.99
	1-14	-.350	.033	.99
		.919	.035	.99
		2.450	.023	.99
	1-21	-.872	.037	.99
		1.067	.040	.98
		2.527	.030	.99
	1-28	.282	.039	.99
		1.027	.043	.99
		-1.196	.071	.99
	4.684	.030	.99	
	1.626	.043	.99	

value at station 1 was the average captures per station 1, at station 2 the sum of average captures at stations 1 and 2, and at station 3 the sum of average captures at station 1, 2, and 3, etc. In addition, the accumulative captures per station were plotted over distance along the trap

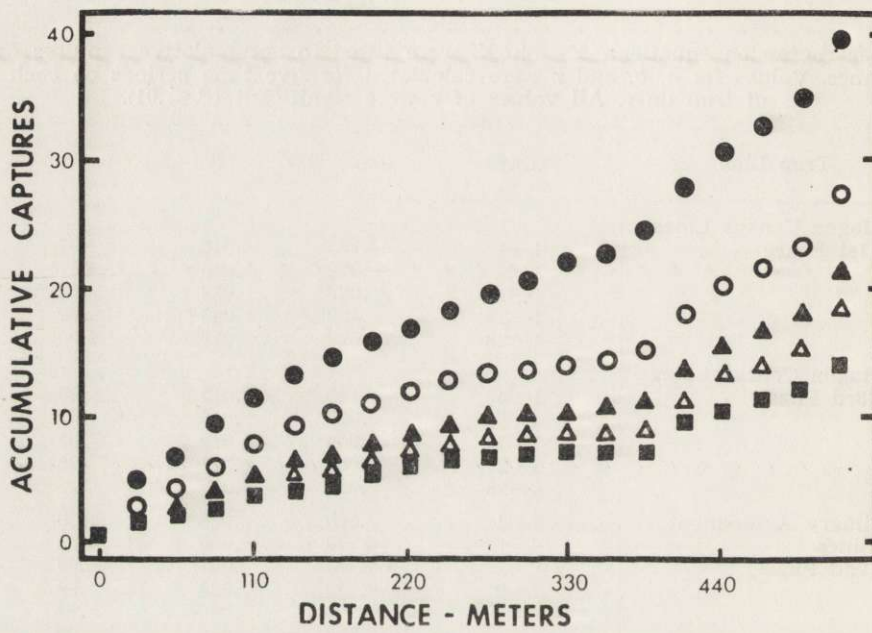
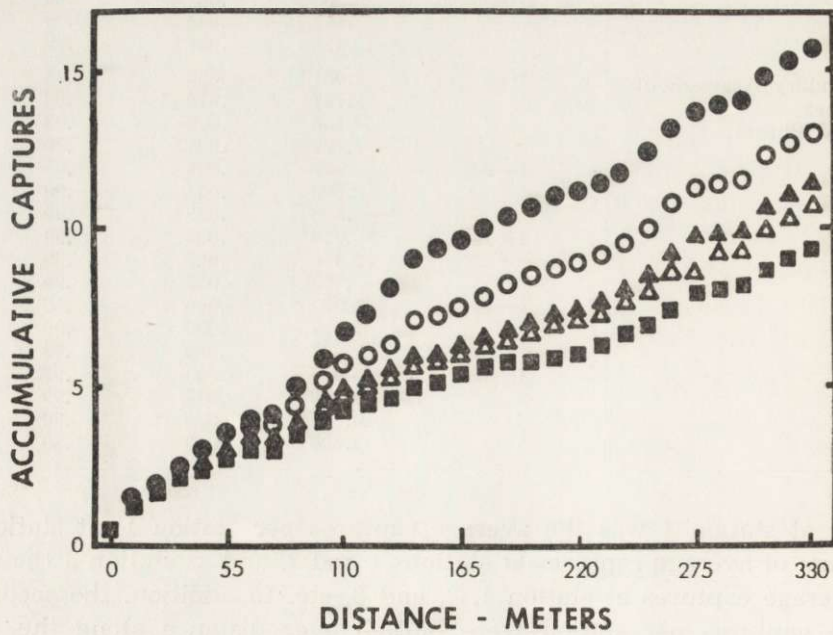


Fig. 3. Accumulative captures versus distance calculated from average captures at each respective station on the primary assessment lines. Solid squares represent accumulative captures for days 1-4, open triangles days 1-9, solid triangles days 1-14, open circles days 1-21, and solid circles days 1-28.



lines. Accumulative average captures versus distance for the eight lines of the octagon census lines, first phase and third phase, were calculated for 5 different time periods. Linear regression equations, $Y = a + bx$, were fitted to accumulative captures versus distance for each time period. Values for a , Y — intercept; b , slope; and r , correlation coefficient are given in Table 3. All r values are significant at the $P < .01$ level, indicating that relationship of accumulative capture to distance was linear. However, the correlation coefficients for all of the regression equations of accumulative capture over distance are biased upward because of the non-random nature of the X variable.

Removal of small mammals along the octagon census lines caused a reduction in captures on the primary assessment lines at the intersection of the census and assessment lines (Fig. 3). Accumulative captures versus distance were characterized by three linear regression equations for each of the 5 time periods (values for a , b , & r are given in Table 3). Stations were included in one of the 3 regression equations based on the plot of accumulative captures over distance (Fig. 3) and the fit of the data to the linear regression equations. Values of r indicated a significant fit of the linear regression equations at the $P < .01$.

Accumulative average captures versus distance on the secondary assessment lines were determined for five time periods (Fig. 4). Due to removal of small mammals by traps on the primary assessment lines there was a decreased number of captures of small mammals in the middle of the secondary assessment lines. Accumulative captures versus distance were characterized by three linear regression equations for 3 time periods, days 1—9, 1—14, and 1—21, and by four equations for the other 2 time periods (values for a , b , and r are given in Table 3). Associated r values indicated significant fit of the linear regression equations at the $P < .01$ level. Stations included in the regression equations were chosen as described above.

3. Estimation of Area of Effect

Removal of small mammals on the octagon census lines produced an area of effect totally or partially voided of small mammals on both sides of the lines. Captures over distance for days 1—4 on primary assessment lines delimited the area of effect and were used to calculate the width of the effect (Fig. 3). Accumulative average captures per

Fig. 4. Accumulative captures versus distance calculated from average captures at each respective station on the secondary assessment lines.

← For explanation of symbols see Fig. 3.

respective station on the eight outer and four inner portions of assessment lines over distance for days 1–4 were fitted to three linear regression equations (Table 3 and Fig. 5). Accumulative average captures over distance indicated the stations with reduced captures and therefore, which were in the area of effect (Fig. 3). Linear regression equation 1 represents captures on stations 1–44 with the correlation coefficient (r)=0.99, equation 2 stations 45–71 with r =0.83, and equation 3 stations 72–99 with r = 0.99. Correlation coefficients for regression

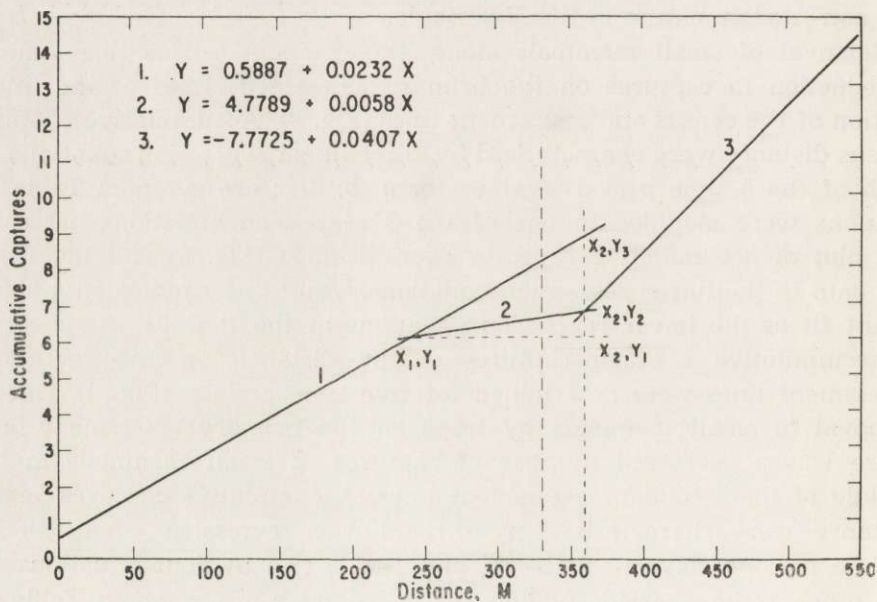


Fig. 5. Lines representing the 3 linear regression equations that characterize accumulative average capture (Y) over distance (X) on primary assessment lines for days 1–4. $X_1=241$ m. $X_2=360$ m. Primary assessment lines crossed census lines at 330 m (or 214.5 m from center of octagon). Width of the area of effect of octagon census lines was 119 m (X_2-X_1). Y_1 and Y_3 are the values of Y calculated from equation 1 when the value of X is X_1 and X_2 , respectively. Y_2 is the value of Y calculated from equation 2 when the value of X is X_2 . $Y_1=6.18$ captures. $Y_2=6.86$ captures. $Y_3=8.93$ captures.

equations fitted to accumulative capture over distance are biased upwards because of the non-random nature of the X variable. The rate of capture over distance in the area of effect, represented by the slope of line 2, was lower than those outside the area of effect, slopes of lines 1 and 3.

The generalized equations for the 3 regression lines (Fig. 5) were

$$Y = a_1 + b_1 X, \quad (1)$$

$$Y = a_2 + b_2 X, \quad (2)$$

and
$$Y = a_3 + b_3 X. \quad (3)$$

The margins of the area of effect were calculated by simultaneously solving equations 1 and 2 for X_1 , the outer boundary, and equations 2 and 3 for X_2 , the inner boundary of the area of effect by setting Y s equal, such that

$$X_1 = \frac{a_2 - a_1}{b_1 - b_2} \quad (4)$$

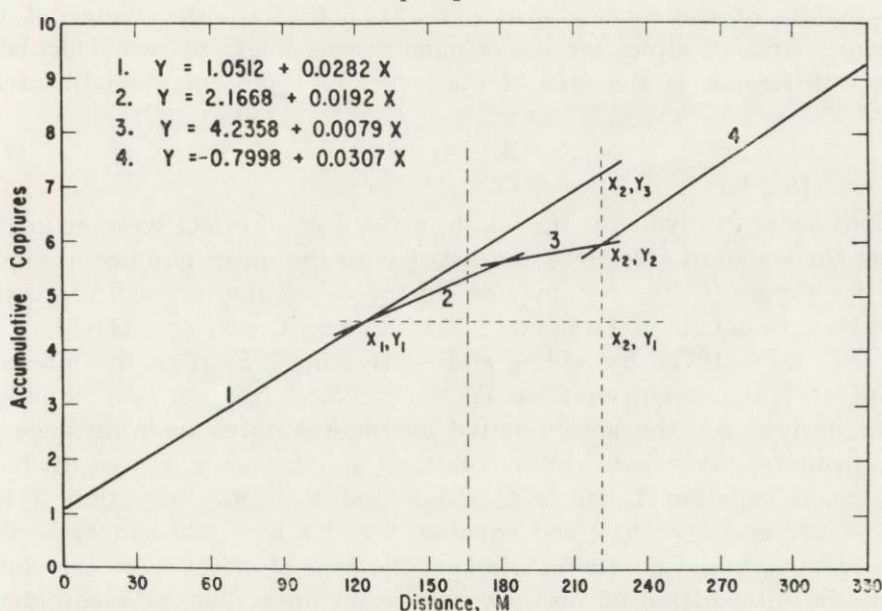


Fig. 6. Lines representing the 4 linear regression equations characterized accumulative average captures (Y) versus distance (X) on secondary assessment lines for days 1—4. X_1 was the common value of X for equations 1 and 2 and X_2 was the common value for equation 3 and 4. $X_1 = 124$ m. $X_2 = 221$ m. Primary assessment lines crossed the secondary assessment lines 165 m from the ends of the secondary assessment lines. Width of the area of effect was 97 m ($X_2 - X_1$). Y_1 and Y_3 were the values of Y calculated from equation 1 when $X = X_1$ and X_2 , respectively, Y_2 was the value of Y calculated from equation 2 when $X = X_2$. $Y_1 = 4.55$ captures. $Y_2 = 5.98$ captures. $Y_3 = 7.28$ captures.

and
$$X_2 = \frac{a_2 - a_3}{b_3 - b_2} \quad (5)$$

The width of the area of effect (W) was the distance between X_1 and X_2 or

$$W = |X_2 - X_1|. \quad (6)$$

For the octagon census lines $X_1 = 241$ m, $X_2 = 360$ m, and $W = 119$ m.

Primary assessment lines crossed the census lines at 330 m and therefore, the area of effect extended 89 m outside and 30 m inside the census lines. It was assumed that the outer edge of the effect was represented by a convex arc and the inner edge by a concave arc, so that the area of effect around the octagon was bounded by two concentric geometric figures approximating circles. The radius of the circle forming the outer boundary of the area of effect was $214.5 \text{ m} + 89.0 \text{ m} = 303.5 \text{ m}$ while the radius of the inner circle was $214.5 \text{ m} - 30.0 \text{ m} = 184.5 \text{ m}$ since the middle of the census lines were 214.5 m from the center of the octagon. Area of effect for the octagon census lines (A_0) was calculated as the difference in the area of the larger (A_1) and smaller (A_2) circles or

$$A_0 = A_1 - A_2 \quad (7)$$

A_0 was 18.2 ha.

Confidence intervals for the width of the area of effect were estimated using the standard error (S_c) associated with the mean number of captures per station (\bar{C}) for stations used in the calculation of each regression equation (Smith, Blessing, Chelton, Gentry, Golley & McGinnis, 1971). By adding and subtracting $2 S_c$ from the intercept (a) of each regression equation ($Y = a \pm 2 S_c + bX$) six new equations were derived for the accumulative average captures over distance on the primary assessment lines. Stations in the area represented by regression equation 1 had a $\bar{C} = .119$ and $S_c = .020$, equation 2 had a $\bar{C} = .032$ and $S_c = .014$, and equation 3 had a $\bar{C} = .220$ and $S_c = .046$. The maximum and minimum width of the area of effect were calculated from the intersection of the new regression lines. The 95% confidence interval for the width of the area of effect around the octagon census lines was 92–126 m which resulted in an area of effect of 17.1–19.4 ha.

The area of effect for stations 6–26 on the primary assessment lines was calculated from accumulative average captures per respective station over distance on the secondary assessment lines. This portion of the primary assessment lines was from 24.8 m to 140.3 m and 115.5 m in length (L) and had a constant rate of capture over distance for 28 days of trapping (Fig. 3). The procedure to determine W was the same as above except that four linear regression equations were fitted to accumulative captures over distance for days 1–4 (Table 3; Fig. 6). There were two different rates of capture in the area of effect so two equations were used thereby increasing the fit of the data to linear regression equations.

The generalized forms of the four equations were as in 1, 2, 3, and

$$Y = a_4 + b_4 X. \quad (8)$$

Linear regression equation 1 represented station 1—20, with $r = .98$, equation 2 stations 21—31 with $r = .99$, equation 3 stations 33—37 with $r = .98$, and equation 4 stations 38—46 with $r = .99$. X_1 was calculated using equation 4 given above with X_2 calculated using equation 3 and 7 such that

$$X_2 = \frac{a_3 - a_4}{b_4 - b_3} \quad (9)$$

Width of the area of effect (W) was calculated as described above. $X_1 = 124$ m and $X_2 = 221$ m with the intersection of primary and secondary assessment lines at 165 m (Fig. 6). Therefore, $W = 97$ m and extended 41 m on the side of the secondary assessment line with an interstation interval of 5.5 m and 56 m on the side with an interstation interval of 11 m. The area of effect of the primary assessment lines (A_1) was calculated from

$$A_1 = WL. \quad (10)$$

Using $W = 97$ m and $L = 115.5$ m, then $A_1 = 1.1$ ha and the total area of effect for this selected portion on the eight primary assessment lines was 8 A_1 or 8.9 ha.

Captures on the secondary assessment lines had in the area of line 1 a $\bar{C} = .188$ and $S_{\bar{c}} = .035$, line 2 a $\bar{C} = .114$ and $S_{\bar{c}} = .037$, line 3 a $\bar{C} = .075$ and $S_{\bar{c}} = .055$, and line 4 a $\bar{C} = .338$ and $S_{\bar{c}} = .069$. Using these four values of $S_{\bar{c}}$ the 95% confidence interval for the width of the area of effect was 70—124 m and the area of effect 6.5—11.4 ha.

4. Estimation of Density of Small Mammals

Number of small mammals living in the area of effect prior to trapping was estimated using the number of small mammals captured by the census lines divided by an estimated proportion of small mammals removed from the area of effect. The proportion of small mammals removed (R_p) from the area of effect by the octagon census lines was calculated from the values of Y_1 , Y_2 , and Y_3 (Fig. 5). Y_1 was the accumulative number of captures along the primary assessment line at X_1 from equation 1 or

$$Y = a_1 + b_1 X_1 \quad (11)$$

If all small mammals were removed from the area of effect, then Y_1 would equal the number of accumulative captures at X_2 . If no small mammals were removed from the area of effect, the number of accumulative at X_2 would be Y_3 calculated from equation 1 or

$$Y_3 = a_1 + b_1 X_2 \quad (12)$$

since rate of capture over distance would be the same outside and inside of the area of effect. If a portion of small mammals are removed, then the number of accumulative captures at X_2 will be Y_2 or

$$Y_2 = a_2 + b_2 X_2 \quad (13)$$

and $Y_1 < Y_2 < Y_3$.

The number of small mammals (N_1) that would have been captured by the primary assessment lines if no animals were removed by traps on census lines was $Y_3 - Y_1$. The number of small mammals (N_2) not captured along the primary assessment lines due to removal by the census lines was $Y_3 - Y_2$. The proportion of small mammals removed (R_p) was calculated using the formula

$$R_p = \frac{Y_3 - Y_2}{Y_3 - Y_1} = \frac{N_2}{N_1} \quad (14)$$

or for the octagon census lines $R_p = .75$.

The number of animals (N) living in the area of effect prior to removal of animals by census lines was estimated using the number of captures on the census lines (N_r) and the estimated proportion of removal (R_p); $N_1 = N_2/R_p$. Substituting N for N_1 and N_r for N_2 , the equation for estimating N was

$$N = \frac{N_r}{R_p} \quad (15)$$

Estimated numbers of mammals in the area of effect prior to trapping on the census lines using $R_p = .75$ were 51 *P. gossypinus*, 69 *O. nuttalli*, 24 *B. brevicauda*, and 144 total individuals of the three species. Density estimates using these estimates of N with an area of effect of 18.2 ha were 2.8 *P. gossypinus*/ha, 3.8 *O. nuttalli*/ha, 1.3 *B. brevicauda*/ha, and 7.9 individuals of the three species/ha.

New values of Y_1 , Y_2 , and Y_3 were calculated from the modified equations used in the calculation of the confidence intervals for the width of the area of effect around the octagon census lines. The range of R_p using these new values was .73—.77. The range of N was 49—52 for *P. gossypinus*, 67—71 for *O. nuttalli*, 23—25 for *B. brevicauda*, and 140—148 for the three species combined. Ranges for density were 2.7—2.9 *Peromyscus*/ha, 3.7—3.9 *Ochrotomys*/ha, 1.3—1.4 *Blarina*/ha, and 7.6—8.2 of the three species combined/ha.

Two values of R_p from the area of effect of stations 6—26 on primary assessment line were calculated using the slopes of equations 1 and 4 in

Fig. 6. For this area of effect

$$R_p = \frac{Y_3 - Y_2}{Y_3 - Y_1} \quad (16)$$

or

$$R_p = \frac{Y_1 - Y_4}{Y_2 - Y_4} \quad (17)$$

From the generalized equations, Y_1 was calculated using equation 11 and Y_3 using equation 12, Y_2 using X_2 , a_3 , and b_3 such that

$$Y_2 = a_3 + b_3 X_2, \quad (18)$$

and Y_4 using X_1 , a_4 , and b_4 such that

$$Y_4 = a_4 + b_4 X_1 \quad (19)$$

Values for Y_1 , Y_2 , and Y_3 are given in Fig. 6. R_p was .48 using equation 16 and .49 using equation 17. Since the slopes of the linear regression equations 1 and 4 (Fig. 6) were not significantly different ($P > .05$) and the values of R_p were essentially the same only the $R_p = .48$ was used to estimate numbers in the area of effect. Using equation 15 and $R_p = .48$, the estimated number of small mammals in the area of effect prior to trapping was 76 *P. gossypinus*, 55 *O. nuttalli*, 17 *B. brevicauda*, and 147 individuals of the 3 species. Density estimates were 8.5 *P. gossypinus*/ha, 6.1 *O. nuttalli*/ha, 1.9 *B. brevicauda*/ha, and 16.5 individuals of the 3 species/ha.

Using the new values for Y_1 , Y_2 , and Y_3 , the range of R_p was .42—.57. Using these values of R_p , the estimated range of N was 64—85 for *P. gossypinus*, 46—61 for *O. nuttalli*, 14—19 for *B. brevicauda*, and 124—165 for the three species combined. The ranges of density estimates were 7.4—9.8 *Peromyscus*/ha, 5.4—7.1 *Ochrotomys*/ha, 1.7—2.2 *Blarina*/ha and 14.5—19.1 of the three species combined/ha.

5. Effect of Interstation Interval on Removal

During the 28 day trapping period on the secondary assessment lines, there were 75 small mammals caught at stations 1—30 with interstation interval of 5.5 m. Only 48 small mammals were captured at stations 32—46 with interstation interval of 11.0 m. These captures included 29 *Peromyscus*, 39 *Ochrotomys*, and 7 *Blarina* at stations 1—30 and 19 *Peromyscus*, 25 *Ochrotomys* and 4 *Blarina* at stations 32—46. The mean number of small mammals captured per line at stations 1—30, 9.38 individuals, was significantly greater than small mammals captured per line at stations 32—46, 6.00 individuals ($P < .01$).

Table 4

The time, in days, at which 1, 25, 50, 75, and 100% of the total number of each species was removed at stations 1-30 and 32-46 on the secondary assessment lines during a 28 day trapping period.

Per Cent Removal	<i>Peromyscus</i>		<i>Ochrotomys</i>		<i>Blarina</i>		3 Species	
	1-30	32-46	1-30	32-46	1-30	32-46	1-30	32-46
1	1	1	1	2	2	2	1	1
25	2	2	2	2	3	2	2	2
50	3	2	3	3	12	3	3	3
75	16	8	24	3	20	12	21	9
100	27	22	28	28	23	20	28	28

Table 5

Number of males and females of three small mammal species captured on each of four sets of trap lines.

Species & Sex	Octagon Census Lines (1st Phase)	Primary Assessment Lines	Secondary Assessment Lines	Octagon Census Lines (3rd Phase)	All Trapping Lines
<i>Peromyscus gossypinus</i> Males	21	79	27	6	133
<i>Peromyscus gossypinus</i> Females	17	49	22	6	94
<i>Ochrotomys nuttalli</i> Males	26	55	32	9	122
<i>Ochrotomys nuttalli</i> Females	26	39	32	10	107
<i>Blarina brevicauda</i> Males	8	8	7	2	25
<i>Blarina brevicauda</i> Females	9	13	4	3	29

Table 6

Mean weights (g) of the small mammal species captured on each of four sets of trap lines (numbers in parentheses). Differences in weight (g) of males and females of each species on each set of trap lines was tested using *t*-test.

Species & Sex	Octagon Census Lines (1st Phase)	Primary Assessment Lines	Secondary Assessment Lines	Octagon Census Lines (3rd Phase)
<i>Peromyscus gossypinus</i> Males	23.4 (20)	24.2 (74)	23.9 (26)	24.3 (6)
<i>Peromyscus gossypinus</i> Females	22.8 (16)	23.5 (45)	23.9 (21)	22.2 (6)
<i>Ochrotomys nuttalli</i> Males	17.3 (25)	18.3 (47)*	18.3 (32)	15.9 (7)
<i>Ochrotomys nuttalli</i> Females	16.4 (25)	16.9 (37)	18.0 (31)	18.1 (10)
<i>Blarina brevicauda</i> Males	8.4 (8)*	9.7 (8)*	9.8 (7)*	9.6 (2)*
<i>Blarina brevicauda</i> Females	7.8 (9)	7.6 (13)	8.2 (4)	8.5 (3)

* values of *t* significant at the .05 level

Fifty per cent of each species of small mammal was removed at stations 1—30 and 32—46 by day 2 or 3 except for *Blarina* which took 12 days on stations 1—30 (Table 4). The time (20.0 days) required to remove 75% of a species at stations 1—30 was significantly greater than the time (7.7 days) at stations 32—46 ($P < .05$). But the time required to remove 25, 50, or 100% was not different between stations 1—30 and 32—46.

6. Sex Ratios

Sex ratios were calculated for *Peromyscus*, *Ochrotomys* and *Blarina* caught on each set of trap lines and the four sets of trap lines combined (Table 5). There were significantly more male than female *Peromyscus* captured on the primary assessment line and the four sets of trap lines combined ($P < .05$; $P < .05$, respectively). All other ratios in Table 5 were not different from an expected 50:50 ratio. Captures of *Peromyscus*, *Ochrotomys*, and *Blarina* did not demonstrate any trends of differential removal rates between males and females.

7. Weights of Small Mammals

Average weights of males and females were calculated for *Peromyscus*, *Ochrotomys*, and *Blarina* (Table 6). Male *Blarina* were significantly heavier than females captured on each of the four sets of trap lines. Both male and female *Blarina* caught on the octagon census lines during the third phase were heavier than males and females caught on the first trapping of the octagon census lines (for males $P < .01$; for females $P < .05$).

Weights of male and female *Peromyscus* and *Ochrotomys* captured on each set of trap lines were not different except for the golden mice on the primary assessment lines with males being heavier than females ($P < .01$). Males and females of *Peromyscus* and *Ochrotomys* from the first and second trapping of the octagon census lines did not differ in weight.

To determine if *Peromyscus* and *Ochrotomys* exhibited a differential removal with respect to weight, the weights of males and females of both species captured during days 1—7 were compared to the weights on days 8—28. Weights were not compared for the second trapping of the octagon census lines. There was no difference in weight between the two time periods except that *Peromyscus* males were heavier during days 1—7 than days 8—28 on the primary assessment lines ($P < .05$).

IV. DISCUSSION

Linear regression equations fitted to accumulative captures over distance have been used to estimate the width of the area of effect around octagon census lines by Gentry *et al.* (1971) and a grid by Smith *et al.* (1971). Smith *et al.* (1971) used the captures on assessment lines to estimate the area of effect around the grid and subsequently, the density of the small mammals. Gentry *et al.* (1971) reported an area of effect around the census lines but the effect was an increase in captures and density estimates were not made. In contrast to the results of Gentry *et al.* (1971), the area of effect around a line was delimited due to reduced captures and densities could be calculated in this study. Both studies used the same basic design, an octagon with assessment lines, but were conducted during different seasons of the year. In all three studies the estimation of densities would be improved by calculating the area of effect for each species from captures of only that species. However, the number of captures of each species was too low and the number of assessment lines would have to be increased by increasing the number of census lines or grids with their respective assessment lines.

The rate of removal was not constant during the 28 day trapping periods for both the octagon census lines and the portion of the primary assessment lines used for density estimation. The major inputs in Fig. 2 occurred with extreme changes in the weather conditions (ice storm and rains) resulting in a drastic change in the trappability of the small mammals. Daily fluctuations or changes in probability of capture prevent the use of the Hayne (1949) regression method since a constant probability of capture is required. Janion, *et al.* (1968) presented a method for the estimation of numbers of small mammals that mathematically corrected for fluctuating probabilities of capture. However, using their technique the estimates of numbers were high, 66 *Peromyscus* and 212 *Ochrotomys*, on the octagon census lines. These large estimates were probably the result of large variations in probability of capture over a long trapping period.

There are no other estimates of density for mammal populations in the lowland mesic-hardwood forest during the winter months to compare to the densities calculated in this paper. However, the combined density of *P. gossypinus*, *O. nuttalli*, and *B. brevicauda* in the area of the octagon census lines was lower, 7.6–8.2 small mammals/ha, than reported for small mammals by Smith *et al.* (1971), 14.9–15.4 individuals/ha, during August and September, 1968 in the same type of forest. Winter densities recorded at a time when the small mammals were not breeding, were expected to be lower than the densities for late summer. The

densities calculated for stations 6—26 on the primary assessment lines are higher than the estimates from the octagon census lines. This could be due to natural variation in density within the habitat or some other phenomenon related to movement patterns.

The basic requirement that needs to be met in our assessment line method is that the trapping period be long enough to create an area of effect for each major species. In most situations this would be much shorter than a 28 day trapping period. Also, if the number of census and assessment lines were increased, each species could then be considered separately and length of time of the trap period would become even less important.

Three criticisms of the assessment line method are differences in probability of capture along the assessment line due to removal by the census line, mortality over long trapping periods, and failure of the method to work at low densities (Smith *et al.*, 1971). Low densities would probably affect all techniques used for density. The other two criticisms have not been evaluated to determine if correction factors are needed. However, the fit of the data to the theoretical expectations of the model indicates the utility of the method even if it becomes necessary to add a correction factor for differential probability of capture or mortality.

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ZASTOSOWANIE LINII TAKSACYJNYCH DO SZACOWANIA ZAGĘSZCZENIA DROBNYCH SSAKÓW

Streszczenie

Celem badań było zbadanie zastosowania linii taksacyjnych umieszczonych w poprzek linii inwentaryzacyjnych do oszacowania zagęszczenia drobnych ssaków. Linie taksacyjne mierzą obszar wpływu usunięcia drobnych ssaków przez linię inwentaryzacyjną.

Odłowy drobnych ssaków prowadzono przy użyciu trzech zestawów linii, mianowicie linii ułożonych w ośmiobok oraz podstawowych i pomocniczych linii taksacyjnych (Ryc. 1). Powierzchnię badawczą umieszczono w nizinym, mezotroficznym lesie liściastym (Gentry *et al.*, 1968). Pułapki sprawdzano w ciągu 28 dni na liniach ośmioboku od 24 stycznia do 21 lutego 1969 r., na podstawowych liniach taksacyjnych od 22 lutego do 22 marca 1969 r., a na pomocniczych liniach taksacyjnych oraz po raz drugi na liniach ośmioboku od 23 marca do 24 kwietnia 1969 r. Na każdym stanowisku umieszczono po dwie pułapki z przynętą z oleju arachidowego. Na linię ośmioboku składało się osiem rzędów pułapek, każdy długości 165 m (16 punktów pułapek w odstępach 11 m) Ryc. 1. Zasadnicze linie taksacyjne przecinały środek linii ośmioboku. Cztery takie linie taksacyjne miały po 544 m długości (100 punktów) a 4 — po 330 m długości (61 stanowisk) (Ryc. 1). Osiem pomocniczych linii taksacyjnych przecinało podstawowe linie taksacyjne. Miały one po 330 m długości (Ryc. 1). Pułapki na pomocniczych liniach taksacyjnych znajdowały się w 6,5 m odstępach od stanowisk 1—31 i w 11,0 m odstępach od stanowisk 31—46.

W pierwszym odłowie usunięto z ośmioboku 38 osobników *Peromyscus gossypinus*, 52 osobniki *Ochrotomys nuttalli* i 18 osobników *Blarina brevicauda* (Tabela 1). Pułapki na podstawowych liniach taksacyjnych schwytały 131 osobników *B. brevicauda*. Na pomocniczych liniach taksacyjnych schwymano 50 osobników

P. gossypinus, 64 osobniki *O. nuttalli* i 11 osobników *B. brevicauda*. Drugi wyłów na liniach ośmioboku dał 12 osobników *Peromyscus*, 19 osobników *Ochrotomys* i 5 osobników *Blarina*.

Dzienne odłowy, a zatem i dzienne prawdopodobieństwo złowienia, wykazały duże wahania w każdej fazie badań. 50% osobników *P. gossypinus* usunięto szybciej niż 50% osobników *O. nuttalli* (Tabela 2), chociaż w 3 spośród 4 zestawów pułapek złowiono więcej osobników *O. nuttalli* (Tabela 1). Wartości wyłowu w określonym czasie w sposób wysoce istotny pasowały do równań regresji krzywoliniowej, $Y = aX^b$.

Wyłów dronich ssaków nie wykazywał żadnych zróżnicowanych trendów zależnie od płci lub ciężaru zwierząt. Na pomocniczych liniach taksacyjnych zanotowano różnicę w tempie wyłowu zależnie od rozstawu pułapek (11,0 i 5,5 m) (Tabela 4), jak również w całkowitej liczbie złowionych drobnych ssaków na dwóch połówkach tych linii.

Skumulowane przeciętne złowienia (Ryc. 3 i 4) na zasadniczych i pomocniczych liniach taksacyjnych wskazały obszar oddziaływania wyłowu wokół linii ośmioboku oraz zasadniczych linii taksacyjnych. Do oszacowania szerokości obszaru wpływu (Ryc. 5 i 6) a także proporcji wyłowionych ssaków użyto równań regresji liniowej. Na podstawie złowień ssaków wzdłuż linii taksacyjnych obliczono również przedziały ufności dla szerokości obszaru wpływu oraz dla proporcji drobnych ssaków usuniętych z obszaru wpływu.

95% przedział ufności dla szerokości obszaru wpływu wokół linii ośmioboku (pierwszy odlów) wynosił 92—126 m. Wachlarz oszacowań zagęszczenia dla linii inwentaryzacji ośmiobocznej wynosił 2,7—2,9 osobników *P. gossypinus*/ha, 3,7—3,9 osobników *O. nuttalli*/ha i 1,3—1,4 osobników *B. brevicauda*/ha.

95% przedział ufności dla szerokości obszaru wpływu wokół podstawowych linii taksacyjnych wynosił 70—126 m. Zasięg oszacowań zagęszczenia wokół podstawowych linii taksacyjnych wynosił 7,4—9,8 osobników *P. gossypinus*/ha, 5,5—7,1 osobników *O. nuttalli*/ha i 1,7—2,2 osobników *B. brevicauda*/ha.