

CALCULATION OF AREA OF ANIMAL ACTIVITY BY USE OF MEDIAN AXES AND CENTERS IN SCATTER DIAGRAMS*

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The following discussion is intended to review some preceding studies of observed or calculated home areas of animals and to compare the results with those based on use of median axes and median centers in scatter diagrams which represent places where individual animals were seen (MOHR and STUMPF, 1964, a and b).

Home range as used here is characterized by SETON (1909) who wrote, "No wild animal roams at random over the country; each has a home region even if it has not an actual home." The home region, or range, is an area in which an animal is active about its home or homes for a stated period. A home may consist of a form or thicket, burrow, nest or tree which is occupied at least twice during a 24-hour period. More frequent occupancy fixes its status better statistically.

The area usually is measured as though it were on a plane surface but many animals which occupy home ranges may use parts such as trees to a considerable height above the plane surface, especially in old and complex communities. Territories are considered to be part of the area of activity around home or homes.

PROCEDURE

Median axes and median centers (Fig. 1) are used as aids in evaluation of individual areas of activity, and for construction of composite maps. Our objective in making composite maps was to assemble data from enough individual maps, each based on relatively few observations, in such a way as to permit calculation of average shape of the areas of activity as well as to indicate or permit further statistical treatment when desired. Since calculation of the mean geometric centers (HAYNE, 1949) and axes (STUMPF and MOHR, 1962) require tedious calculation, median axes are used here. The composite maps were made by fitting long and short axes, and centers of calculated activity, together on a master map. Maps for animals for which many points have been observed in a short period may not require such treatment.

The long axis is so drawn as to: 1) pass through even numbers of points when the number of points in observed ranges is even in number, and through odd numbers of points when the number of points in the individual ranges is of odd number while, 2) dividing the remaining points into two equal groups so that, 3) the sum of their distances from the long axis is as small as possible. In ranges with odd numbers

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of widely scattered points, the long axis is made to pass through one point and equidistant between the two innermost remaining points (Fig. 1). The short axis is drawn so as to divide the group of points making up the home range into two equal groups in the other direction. The point at which the long and short axes intersect becomes the median center (Fig. 1).

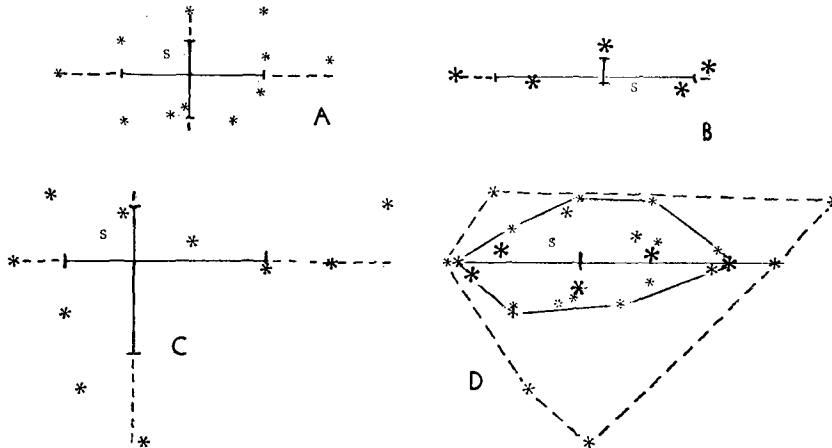


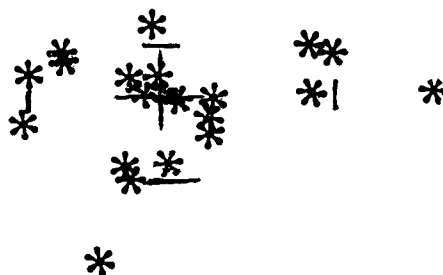
Fig. 1. Eleven-point (A), five-point (B) and 10-point (C) records of areas of activity of three animals (ticks) matched to make a single composite range (D). S represents the short segments of the major and minor axes. Centers (points at which the axes intersect) and like segments of the axes are matched in D. Portions of the axes which were matched are represented as solid lines. It was necessary to rotate Fig. B 180 degrees to make its short segment match the others. The inside polygon in D encloses 75 percent of the points.

Almost invariably, one of the two segments of each axis is longer than the other. It seemed fair to determine the relative length of each of the four segments from center by passing a line at right angles to each axis through the group of dots associated with its two segments in such a way as to divide the group into two equal groups and, naturally, to intersect the segment. This makes two submedian points on each axis, one to each side of the primary median point. The relative distance between these submedians and the primary median center determines the comparative lengths of the portions of segment to be matched with those in other ranges. Composite ranges, Fig. 1 D, were then made by matching the primary median centers and the short segments of each axis to short (and long to long) on a master map. Since some individual ranges are essentially mirror images of others, they require to be inverted when made into a total composite map.

To calculate the area within which activity was observed, convex polygons may be used to enclose all points (100%) in the composite range as is commonly done in the "minimum home range" procedure. However, since it usually is desirable to calculate the area enclosed by a smaller percentage of points, any other percentage may be selected. This selection is especially useful when special concentrations of

points or the core interest the investigator. In earlier papers (MOHR and STUMPF, 1964 b) we determined the area occupied by 67 and 90 percent of the points most distant from the axes. In the present paper we are concerned chiefly with the area enclosed by 75 percent of the points.

Fig. 2. Composite areas of observed activity of two wolverines (*Gulo gulo*) from KROTT, 1959. The center of the cross is the median center. Marks at ends and sides enclose 75 percent of the observed points.



The area to be calculated often may ideally be selected by drawing or fitting an elliptical figure over the composite diagram. It also may, more roughly but more conveniently, be chosen by drawing or fitting a rectangular figure over the map (Fig. 2) in such a way as to pass over the number of points not desired in a given calculation. We used the rectangle because of its convenience. Since, in this paper, we choose to study the area or dimensions of the major and minor axis occupied by 75 percent of the points we passed over 25 percent of the points, beginning at the outside. One fourth of these first were passed over at each flank of the home range, then one fourth at each end. When, for example, 5.5 points were to be passed over, 1.4 were passed



Fig. 3. Observed trails, A, and home ranges, C, converted into point systems. (A) represents the trail of a tick (SMITH et al), not necessarily a home area, with points marked on it. C represents outlines of areas of activity of turkeys (LEWIS, 1964) fitted by eye. An equal number of points was distributed around each outline so as to give each an equal weight. B and D show the points after deletion of the trail and the outlines. When greater detail is desired, the number of marks should be increased. The short lines at flanks and ends, in D, enclose 75 percent of the points.

over at each flank of the range, then 1.4 were passed over at each end (Fig. 2). This usually gives the same proportion of area enclosed as might be had by eliminating points first from the end, then from the side, but we prefer the first procedure.

After thus eliminating the 5.5 points from consideration for this particular calculation of area, we drew a convex polygon around the 75 percent of points remaining in the rectangle. We can then calculate the area within the convex polygon.

When the proportions of the axes of the ranges were of primary interest, we measured the width and length of the rectangle and report this as the proportion of the range including a selected percentage of points. The width and length of an ellipse, would be the same. Occasionally an oval fits a scatter diagram better than an ellipse. Appropriate measurements can easily be made to accommodate this form.

When maps of observed animal activity are shown as outlines or trails, in literature, we convert these to groups of points for easy counting (Fig. 3). Marks are made at given distances along the trail (Fig. 3A). A given number of marks is placed equidistant around each outline (Fig. 3C).

SELECTED OBSERVATIONS

MAMMALS: Locations of 23 Eurasian meadow mice, *Microtus agrestis* observed 709 times between April and September in England, by labelling with cobalt-60, and locating by use of a GEIGER-MULLER counter, indicate that the average maximum length of range (87 feet) was almost two times its average maximum width (GODFREY, 1954). Our calculations indicate 1×1.7 .

Proportions of the major and minor axes of areas of activity of California meadow mice, *Microtus californicus*, based on our median composite-range method of determining proportion were about three times as long as broad (MOHR and STUMPF, 1964b). Those based on our earlier method (STUMPF and MOHR, 1962) also were elongate; 75 percent of the points were within an area about 2.9 times as long as wide.

Home ranges of four male *Microtus ochrogaster* studied during short periods (a week to 3 weeks each) by means of radioactive labels and portable detectors during spring and early summer averaged remarkably narrow (HARVEY and BARBOUR, 1965, Fig. 1). That of one female observed about 1 month also was elongate but that of one male was moderately elongate. Average proportions of ranges of the males exceeded 1×3.0 .

Areas of activity of *Rattus jalorensis* observed by means of radio detectors, during a two-week period were approximately 50×200 m. in proportion; that is 1×4 . Since the author (GENTRY, 1965) used 100 percent of the observed points in the range when making his measurements it is probable that smaller percentages, say 75 percent, of the central points, made a narrow core. The area of activity of this species, observed by livetrapping and retrapping over a 6 to 7 month period varied from compact to very elongate (HARRISON, 1958). The difference in length of period used by these works makes comparison difficult.

Areas of activity of one male and one female *R. r. argentiventer* averaged 40×60 m. (1×1.5). GENTRY believed that these areas were compact because of the nature of use of the habitat. The ranges also were compact: 50×100 m. (1×1.7) in another habitat. This species tended to have only one major center of activity whereas *R. r. jalorensis* had several each in their areas of activity.

One adult male, two adult females and one juvenile male, *Reithrontomys humulis*, harvest mice, were observed by aid of a GEIGER counter from seven to ten days after being tagged with radioactive material (KAYE, 1961). Seventy-five percent of the points in the 7-day range of one female observed 38 times was 4.7 times as long as wide. A similar percentage of the 10-day range of another was 1.8 times as long as wide. The 9-day range of a male was broad: 1×1.1 and the 7-day range of a sub-adult male was 1×2.1 . The average, not weighted according to numbers of observations per range, was 1×2.8 . This was about the same proportion (1×2.7) calculated by STUMPF and MOHR (1962) for *R. megalotis*. The composite range was about 120 feet long, or about the same recorded by STUMPF and MOHR.

The calculated proportions of short to long axes of North American red squirrels, *Tamiasciurus hudsonicus*, based on the minimum home range method (LAYNE, 1954) in a park-like savanna habitat (the Cornell University campus) were as follows: males 1×3.0 during 1952 and 1×1.4 during 1953; females 1×3.0 during 1952 and 1×2.2 during 1953.

By linear-composite calculation the proportions of axes of adult ranges was as follows: during 1952—males 1×2.2 ; females 1×2.3 ; during 1953— 1×1.5 for both males and females. Although the shapes of observed ranges were alike for males and females, male ranges were longer: 826 feet for males and 512 for females during 1952, and 955 and 541 during 1953.

Composite ranges made from maps of points at which male red squirrels were seen only three times consecutively during approximately three postbreeding summer months were narrower: 1×4.5 in 1953, 1×5.0 in 1952. Possibly there is no significant statistical difference between these two figures. However the data indicate a marked tendency for the squirrels to use the entire lengths of their ranges.

Pocket gophers, *Geomys bursarius*, and *Thomomys bottae* are chiefly fossorial and their burrows are somewhat equivalent to runways of mice in herbaceous cover. The burrow systems are territory during most of the year, at least in the colder climates when the breeding period is restricted. The course of the burrows usually is marked conspicuously by mounds of earth pushed to the surface, and the weathering of the mounds, coupled with presence or absence of new ones, provides a fair indication of the degree and time of use of the various parts. Occasionally individuals forage on the ground surface, particularly when snow or dense vegetation shelter them.

Since considerable usable area around individual sets of burrows is in fact unused and, since the gophers probably can hear digging activity of neighbors at considerable distance through the soil, individual territories undoubtedly extend considerably beyond

the burrows (MOHR, 1947). Considerable usable but unused space is evident between individual groups of mounds.

When abundant, the gophers may add additional unused area by making considerable portions of their home ranges uninhabitable through destruction of staple, slow growing food plants and possibly by other activity (MOHR, 1947 : 239); they vacated stands of alfalfa after riddling the ground and destroying most of the plants. The composite range based on location of new mounds belonging to single individuals for 7-day periods had a proportion of 1 to 2.9. This seems also to be the case for *Thomomys bottae mewa* (HOWARD and CHILDS, 1959: Figs. 30A-30H). Composite ranges of males had axes of 1 to 2.7. The individual ranges were however studied over a 2-year period.

Howler monkeys, *Aoulatia palliata*, are arboreal and travel in troops composed of a few adult males, adult females with infants, and juveniles. Although troops tend to sleep or rest in given places during weeks or months and to maintain troop territories, they are not particularly attached to given nests or trees for long. Seventy-five percent of 121 observed points of two troops composed a compact area (1×1.1). The calculated center of territory of one of these bands observed 98 times by CARPENTER (1934) in comparatively poor habitat (thin jungle) was sharply skewed.

BIRDS: Home ranges of coveys of bobwhite quails, *Colinus virginianus*, have been portrayed as groups of points representing places where they were observed, or as areas enclosed by outline. Half of the points which are most closely grouped in the Missouri data of MURPHY and BASKETT (1952) lie in a spindle-shaped area about 2.2 times as long as broad. Those for the Texas data (LEHMAN, 1946) lie in an area about 2.7 times as long as broad. For 75 percent of the points the average proportion is about 1×2.3 hence is about the same as that (1×2.2 and 1×2.4) based on the earlier method (STUMPF and MOHR, 1962). Since bobwhite quail form pairs during the breeding season their range shapes may change during spring and early summer but we have been unable to find precise discussion and maps for the pair-bonded period.

The composite 1-month home range of ringed-neck pheasant, *Phasianus colchicus*, based on TABER's data (outlines of home ranges) for the breeding season of this polygamous species is 2.8 times as long as wide. The calculated area is narrower than that of unpaired bobwhite quail and of birds which live well above ground. Undoubtedly the range changes basic shape when the harems disperse in autums.

Eleven pairs of red-tailed hawks, *Buteo jamaicensis*, maintained territories (FITCH, SWENSON and TILLOTSON, 1946) of which fitted points made a linear-composite range in which 75 percent of the points were within an oval area 1.7 times as long as wide.

HISTORY OF HOME-RANGE STUDY

Maps of observed individual ranges commonly are scatter diagrams representing places at which animals such as monkeys were seen (CARPENTER, 1934); or represent trails along which animals progressed, as for wood ants, *Formica rufa* (ELTON, 1932);

smoothed outlines as for many birds, or large mammals which are observed directly, (NICE, 1937); or polygons as for small animals which are live-trapped, marked, released and reobserved by live-trapping (DALKE and SIMÉ, 1938). In the latter case traps usually are set in parallel lines, the lines at right angles to one another resulting in a grid, or Latin square, pattern.

Results of the live-trapping procedure gave rise to doubts as the very beginning. CHITTY (1937) found that individual mice tended to be caught in a line, or in two parallel lines of traps, when the traps were set in a grid pattern, particularly when the traps were far apart. It seemed that the placement of traps in lines might have caused the animals to follow the line of traps, hence to alter the shape of range from one governed by natural distribution of objectives in the habitat. So far as such tendency may exist, any animals which do follow trap lines must go either in the direction of competition from neighboring mice, or in the direction of no competition, presumably into areas which were unsuitable before placement of the traps because of absence of such desiderata as food and shelter. The effect of trapping on observed range therefore would be different for: 1) species which are territorial as compared with more tolerant species, and 2) habitats which are lightly populated as compared with those heavily populated.

Investigators also were doubtful as to how far animals might extent their travels beyond the lines of traps in which they were caught. The investigators therefore added an area equivalent to half the distance between lines of traps, (or the area equivalent to that of the grid occupied by a trap in which an animal was caught) to both the observed ends and sides of the ranges as illustrated by COCKRUM (1962). This frequently exceeded addition of area equal to a home-range width to the width of the observed ranges, while adding only the equivalent of a small percentage of the length to the observed length (MOHR, 1947 : Fig. 2A). When, for example, observed home ranges of Polynesian rats, *Rattus exulans mansorius*, were compared by such methods (JACKSON and STRECKER, 1962 : 118), the results of two methods are too different for useful comparative study of ranges.

Furthermore, since traps which are too far apart cull out some species, or physiologic or psychologic individuals (HAYNE, 1950, and TANAKA, 1962), addition of estimated range to an imperfectly observed and calculated range seems undesirable.

After discussing the effects of such factors in calculation of the size of home range, HAYNE (1949) bypassed the problem and initiated the concept of calculated center of home range, and computed distances of observed travel from that center. Fortunately this initiated wider statistical interpretation and testing (DICE and CLARKE, 1953; HARRISON, 1958; CALHOUN, 1964), although statistics could have been, and can be, applied easily to the convex polygons used in the minimum method of calculating area (LAYNE, 1954). LAYNE used 100 percent of the points in each range but other percentages may be more useful. As noted above we chose 75 percent of the points composing the core, but we have used 67 and 90 percent (MOHR and STUMPF, 1964b).

Misinterpretation of several everyday words by later workers complicated the concepts. Inclusion of the phrase "calculation of size of home range" in HAYNE's title led some workers to believe that HAYNE was prescribing a method of calculating area rather than simply discussing the problems involved. DICE and CLARKE (1953 : 2), for example, referred to HAYNE's "concept of home range", and JORGENSEN and TANNER (1962) and MOHR (1961a, b) took "standard range" and "standard diameter" of HARRISON (1958) to mean "standard home range" and "standard diameter of the home range". Calculations based on this concept are good enough so long as the average area used by one animal or species are very nearly the same shape as those of others with which they were being compared. This happened to be so in my study of pairs of similar animals (MOHR, 1961). Actually few home ranges are circular, hence use of the terms "radius" and "diameter" is incorrect.

Most observers either continue to use polygons, or smoothed outlines to delineate observed areas of activity, probably because they are: 1) aware that shapes of home areas of species and individuals vary because of some fundamental biological factor or factors which may be revealed by comparative studies, and, 2) because they are interested in amount of area used by individual animals.

GODFREY and CROWCROFT (1960, Fig. 18) used a moderately subjective method (mixed concave and convex angles) of outlining the home ranges of the European mole, *Talpa europaea*, and MICHAEL and BAROUR (1965) have tried a moderately objective method of using concave-convex angles in study of home ranges of *Microtus ochrogaster*. The writers have turned to use of the median major and minor axes (MOHR and STUMPF, 1964 a and b). Some comparative results are described.

COMPARISON OF RESULTS

Unless otherwise noted, statements of proportions of home ranges will concern 75 percent of the points composing the core of the composite ranges. The nearest approximation of circularity which we found is represented by a proportion of 1×1.1 for minor and major axes in the composite range of two troops of howler monkeys reported by CARPENTER (1934). One of the observed ranges was almost circular and the other was elongate with skewed center. This was followed by proportions of 1 to 1.4 of the minor to major axes of composite ranges made from outline maps for song sparrows, *Melospiza melodia*, as adapted from NICE (1937) by MOHR and STUMPF (1964b) and for birds of similar habit and habitat. Composite home ranges of the red-tailed hawk were some what narrower (1×1.7). These composite ranges are, nevertheless, relatively compact.

Average proportions of the ranges of bobwhite quail (1×2.2 and 1×2.7) and ring necked pheasants (1×2.8) are more elongate. This could be the result of matching points as in Fig. 4B in the case of the quail and matching area (Fig. 4A) in the case of the pheasants. It also might be the result of a longer period of observation (several

fall and winter months for the quail versus one-month periods the pheasants), of the different seasons, and of physiologic and social status of the birds. (The quail were observed between breeding seasons and the pheasants during the breeding season). Nevertheless, the observed ranges of both are notably elongate for these birds which spend most of their time on the ground.

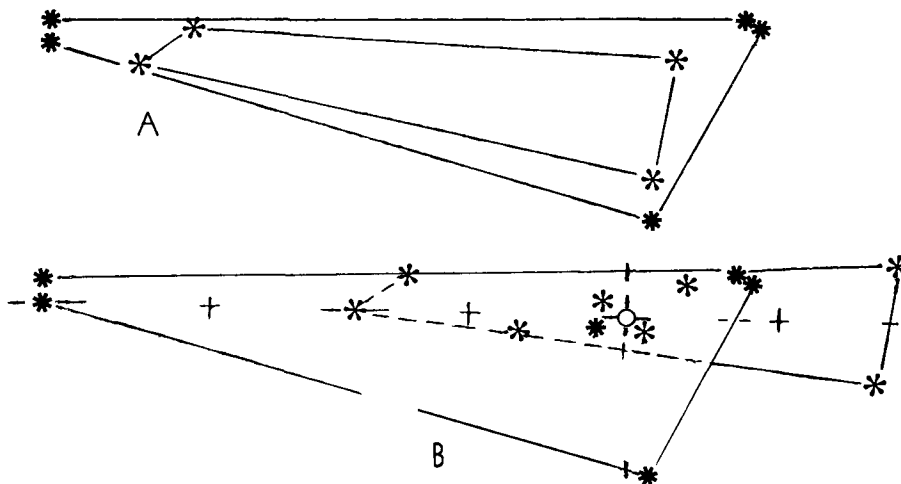


Fig. 4. The approximate effect of averaging areas within convex polygons as used in the minimum home-range method of calculating area of activity (A) and, B, the approximate effect of using *all* points (outer and inner) to construct a linear composite home-range map. This indicates why the latter method results in a compact core and rather wide scatter of isolated points than does the minimum home range method.

The composite-range procedure used in this paper for quails yields a more compact core for ranges than did the related but less exact procedure based on axes passed through the average (mean) center by STUMPF and MOHR (1962, Fig. 3) but the scattering of points on the flanks of the ranges is greater in the procedure used here.

The proportions of the ranges of eastern harvest mice (1×2.8) observed by KAYE are similar to proportions of home-ranges (1×2.7) of western harvest mice observed by MOHR and STUMPF (1962) based on the geometric mean center of HAYNE (1949) with the axes passing through that center.

Proportions based on the median center and axes in a scatter diagram are the same; that is, for the limited data, composite ranges were similar for both methods.

Except for the reported proportions of ranges of the *European meadow mice* (1×1.7) based on the minimum home-range method (GODFREY, 1954) and for *Rattus argentiventer* (GENTRY 1965) which may have exaggerated the width, the observed areas of activity about homes by the ground-inhabiting mammals are decidedly narrow.

RELATION OF AREA ENCLOSED IN OBSERVED COMPOSITE RANGES

The core containing 75 percent of observations of North American red squirrels

lay in areas which were about the size of those calculated by the minimum-range method using 100 percent of the observed points per range. For adult male squirrels the area calculated by the minimum home-range method was 6.03 ± 1.51 acres (LAYNE, 1954), as compared with 6.6 acres based on the linear-composite range. That for adult females was 4.72 ± 1.48 as compared with 4.5 acres.

In some years the linear-composite method gave the larger acreage (5.2 as compared to 4.4 for males in 1952) and in others, the minimum range method gave the larger (6.3 acres as compared with 5.6 during 1953 for females). Any calculation based on the assumption that the range was circular would have yielded a product 78 percent too large for males and 47 percent too large for females.

INDIVIDUAL VARIATION IN RANGE PROPORTION

Home ranges are frequently referred to as being ameoboid in shape, indicating more or less temporary marginal extensions upward or downward as well as on a single plane. They have no hard fast borders. Any method of averaging furnishes only a more or less convenient procedure. The individual areas of activity frequently are curved or sinuate. To what extent sinuosity is detected depends on the method of calculation used, and sufficient data.

Curvature is revealed frequently in linear-composite figures. When we made separate composite ranges for adult male and female meadow mice, the resulting ranges were slightly hook-shaped or pear-shaped. Possibly this was the result of the positions of patrolling and foraging areas as related to positions of nests or shelter as was the case for beach mice, *Peromyscus polionotus leucocephalus*, reported by BLAIR, (1951); and by GENTRY (1965) for *Rattus argentiventer* and *jalorensis*, and for harvest mice by KAYE (1961).

The proportions of maximum and minimum axes of ranges of California meadow mice and North American red squirrels apparently do not vary greatly with the number of observations per individual (MOHR and STUMPF, 1964a: Table 2) although the observed size does. The mice and squirrels tend to use the ends of their ranges as much as the sides. This suggests that these animals perform important functions a range length away from the calculated centers about as frequently as they do half a range width from center. The functions and social relations of individuals undoubtedly are different at side and end.

Proportions of ranges also may vary with the amount of uninhabitable area incorporated into an individual's home range. Red squirrel ranges, particularly those of males, extended completely around open lawn about 100 feet square because they avoided areas beyond the leafy crowns of trees. During 1953, such engulfing of uninhabitable area by males was in part responsible for the observed broadening as compared with that in 1952. The ability to cross such blank areas undoubtedly helps them to pass over certain kinds of unusable area, thus also affect the size of range.

BUFFER ZONE

Few observations of home areas in the field reveal the characteristics and sizes of buffer zones between individual home areas as described for *Mus musculus* in captivity (CROWCROFT, 1955), or partially for pocket gophers *Thomomys bottae* (HOWARD and CHILDS 1959), and *Geomys bursarius* (MOHR, 1947). The gopher burrows constitute a very small percentage of the area which gophers require. The unused areas, which frequently can be observed and measured as interspaces between individual clusters of mounds, undoubtedly are territory when gophers are sufficiently crowded hence require careful study to distinguish from uninhabitable area (which, however, also has buffer value at times).

SUMMARY

Results of use of several concepts of individual range: circular (CALHOUN 1964) simple linear composite (STUMPF and MOHR, 1962); median linear-composite (MOHR and STUMPF, 1964 a and b); and minimum home range and DALKE (1938) are compared for calculating areas of activity from scatter diagrams (maps) indicating points at which individual animals were seen. These are compared with results of calculation of area in outlines of home range as commonly used for birds, but with the outlines converted to scatter diagrams.

Calculations of home area based on a concept of home-range shape as being circular and having a "diameter" seldom yield accurate products. The percentage of error varies with the observed shape of range.

The minimum-range method naturally yields products which are smaller than those based on the circular-range concept. Although the area enclosed in a convex polygon connecting 100 percent of the outer points as commonly is used in such calculation, smaller percentages may be more useful. When preparing for use of smaller percentages, the composite home range frequently is helpful, particularly when there are few points observed in individual ranges. The composite range furnishes a pictorial average.

The median linear-composite method yields a more compact central area, or core, than do the circular and minimum home-range methods, but it also yields a progressively wider scattering of isolated points toward the outer part of the range. The result is a compact core of points, which is recommended as useful.

In one case (squirrel home ranges which are examined here) the area which enclosed 75 percent of the points in the core of the composite range was about the same as that enclosing 100 percent of the points as commonly used in the minimum home-range method.

The shapes of the areas within which activity is observed generally change with number of observations and the time required to make observations. The areas or

places at which observed activity occurs need not be called home ranges. The time factor requires more careful standardization and incorporation into statistics of home area. Frequency-distribution studies based on the distances of points from each, the major and minor, axis, permit statistical analyses of deviations of activity from these bases (Fig. 5).

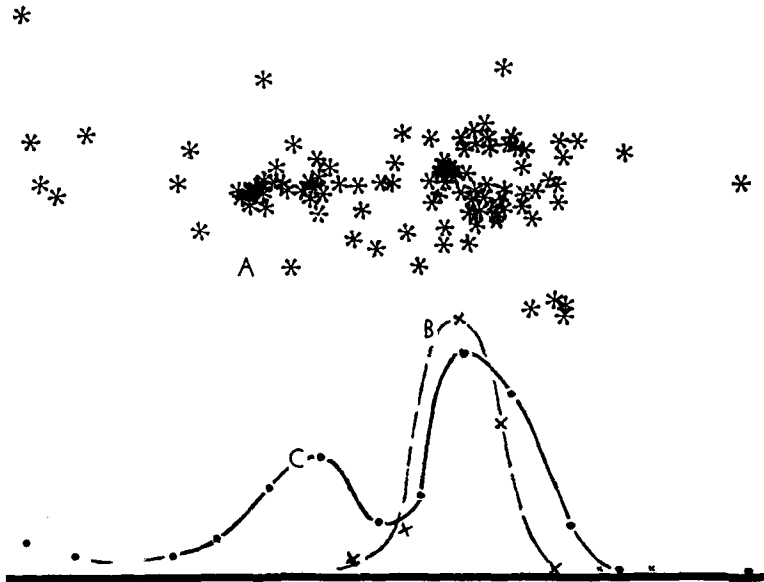


Fig. 5. (A) is a composite scatter diagram of observed places of activity of adult North American red squirrels near their homes. (B) represents a smoothed frequency distribution of distances of the points from the major axis. (C) represents the frequency distribution of distances of points from the minor axes.

Since proportions of the axes of pair-banded arboreal-aerial uni-territorial animals most closely approach the widely postulated theoretical circular range, we may make a tentative deduction. A proportion of 1 by 1.4 for minor to major axes is common among these species and the difference (0.4) may be the result of the arrangement of desiderata and obstacles in the home range, or of the shape of the habitat. Since polygamous terrestrial animals in which females and males have different territories generally maintain elongate ranges, say 1×2.7 , the difference (1.3) between the 1×1.4 ranges and the 1×2.7 ranges may be an index to the difference in sociology of the two groups. That numerical difference is, at least, a common one, though greater differences also exist. The function, value and comparative size of blanks and buffer areas, within or between home ranges, require assignment within this framework.

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動物出現点散布図より中央軸中心による行動面積の算出

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動物のホームレンジは一般に円形でなく、むしろ長方形に近い。この本態を表現する合理的算出方法を提示し、主に鳥類・哺乳類のデータを用いて算出結果を考察する。

各個体の散布点について、長短両軸（メジアン的位置）を決定し、これらによってそれぞれ2等分された4点群の各々を2等分する垂線をひいて軸交点よりの腕の長さをきめ、1つの個体の長軸長腕は他の個体の長軸長腕に（短軸についても同様）重なるように、すべての個体の複合散布図を作る。そして両軸に最も近い75%の点をもってホームレンジ中核面積（凸多角形）平均を算出することができる。