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Review of Methods for Estimating the Parameters of the Home Range of Small Forest Rodents from the Aspect of Sample Size

[With 1 Table & 3 Figs.]

Using data obtained from simulating the capture of rodents from an experimental area, examination was made of the relation between the average size of the home range of a rodent population and the value of parameters defining the boundaries of this range, and sample size (number of captures of a rodent). This relation has been examined for the estimators proposed by Calhoun & Casby (1958), Mazurkiewicz (1971), Tanaka (1972) and Wierzbowska (1972). Four types of model were taken into consideration, differing in respect of shape of individual range and intensivity of penetration of this range. It was found that the minimum number of captures of rodents for estimating a range of given size depends on the character of the estimated parameter and on the estimation method. The centre of gravity of the capture sites of the rodent is subject to the smallest fluctuations depending on sample size, but it differes markedly from the centre of activity. Analogical conclusions must be reached in relation to the angle of inclination of the longer axis of the home range to a chosen direction on the experimental area. The degree of elongation of the home range estimated on the basis of a sample containing less than 10 captures of a rodent, and also of a sample taking into account the »distant sally« point, indicate that the circular model home range is elliptic in shape. Estimates of the area of the home range also depend on sample size, and are in addition connected with the type of distribution of the number of captures of a rodent on the trap site and with the spatial distribution of these captures within the home range. The most general methods, capable of application in different ecological situations, are the methods given by Tanaka (1972) and Wierzbowska (1972).

1. INTRODUCTION

An important question in population studies on small forest rodents is estimation of density and definition of the spatial structure of the given population. Estimation of these values is closely connected with the home range (its size and the parameters defining its boundaries).

The home range is a concept with a fairly distinct intuitional significance, but a concept difficult to define. Burt (1943) undertook to define it by accepting that the »home range has been defined as that area traversed by an individual in its normal activities of food gathering, mating and caring for its young. Occasional sallies outside the area were specifically excluded«. The ambiguity of this definition may cause different interpretations of such concepts as distant sallies or systematic visiting of given places in the home range.

The lack of a definition of the home range has not, however, hindered the search for its size and determination of the area traversed by an individual. When making estimates the researcher assumes for the time being that the concept of the home range has been defined. He next chooses the estimation method which permits of estimating the parameters of the home range. In turn he defines once again the concept as that which is measured by the given estimation method. The choice of estimator is equivalent to accepting the given model, which lays down in its assumptions the structure of the area of the home range and the way in which it is traversed. Values of estimators are obtained from a sample of given size.

Sample size, when estimating the parameters of the home range, is the number of captures of a rodent for which these parameters are assessed. Captures supply information as to the places visited by the rodent and at the moments in time in which these captures took place. When assessing the values of the average parameters of the home range for a given population of rodents, sample size is the number in the group of rodents representing the study population, from which each individual was caught a given number of times. Thus with an established size of the group of rodents representing the study population, sample size is the number of captures of an individual, and will be understood in this sense in this paper.

The majority of the methods hitherto used for estimating the parameters of the home range are based on data collected from an experimental area of optional shape (usually a rectangle), covered by a grid of live traps. Captures follow at given moments of time. Results obtained on the basis of a sample may be burdened with errors of three kinds. In the first place the model represented by the estimation method chosen by the researcher may not be adequate for the actual situation. In the second place the error in the result may be due to the inappropriate size of the sample. In the third place an inadequate sample size increase the error of an answer. The degree to which the model is adequate cannot alwasy be checked. It may be taken as a general rule that the model will be adequate when the estimation method possessed the quality of »generality«, and can thus be applied in different ecological situations. The interests of the ecologist and the requirements of statistics are intertwined in the choice of suitable sample size. The ecologist is interested in a small sample (small number of captures) representing a short period of time. In ecological situations in which there are variations in the home range (in its shape, situation and size) in time, and when the trappability of a rodent is low, it becomes necessary to estimate the parameters of the home range on the basis of a small sample.

A sample sufficient from the aspect of statistical requirements may be too large from the standpoint of the ecologist. In order to ensure that the sample is fully representative it is necescary in the first place to plot out an experimental area of suitable size, in which caught rorent can be observed, while simultaneously ensuring that there is full representation of the ecological type.

From the point of view of the above difficulties and requirements, the ecologist is faced by the dilemma of choosing the appropriate estimation method. The choice of such a method depends in general on the way in which the concept of home range is understood, on what the researcher imagines the study area to be and way in which the rodent traverses it. Both the researcher's experience and his ecological intuition play an important part here, although the significant element here is a knowledge of the dependence of the values of parameters, estimated by the given method, on sample size. In addition to a knowledge of this problem it is also important to be able to evaluate the given method from the point of view of its »generality«.

The question of the effect of sample size on the estimate obtained has been elaborated by Stickel (1954) for a certain group of estimation methods make use of information relating only to the places in which the rodent was caught, without taking the number of captures on these sites into consideration. These are methods of the non-statistical type. Stickel (1954) based her analysis on the results of simulating the process of catching the rodent. A large group of statistical methods and the method of the non-statistical type proposed by Tanaka (1972) are connected with this same method of trapping, and have not so far been elaborated in detail from the aspect of the dependence of their estimators on sample size. The authors of certain of these methods give the minimum number of captures essential to estimation of the area of the range. For instance Blair (1942), Calhoun & Casby (1949), Metzger (1973) and others propose making at least 10 captures in order to estimate the area of the home range. Mazurkiewicz (1972) states that 5 only captures are sufficient to estimate home range area and the parameters defining the limits, shape and position of the home range. T a n a k a (1972) suggests 6 captures for estimating home range area and the degree of its elongation. W i e r z b o w s k a (1972) states that it is possible to estimate the average size of the home range for a given population on the basis of two captures of a rodent, although the number of rodents representing this population must be sufficiently large.

Minimum size of sample is usually estimated for a given species of rodent, and thus is connected with the definite size of the home range. A discussion on the minimum size of sample for assessing the home range parameters should thus take this connection into account. Attention must also be drawn to the fact that minimum sample size is obtained by certain researchers on the basis of analysis of empirical data, and not on data originating from simulation of the trapping process. This is risky, particularly when the assumption of the estimation method cannot be verified for empirical data, on the basis of which minimum sample size is estimated.

In addition to S t i c k e l (1954) the effect of sample size on estimation of home range parameters on the basis of conclusions reached from simulation was examined by M e t z g a r (1973). He studied the effect of a sample consisting of 10 captures of a rodent on the estimated degree of elongation of the home range, taking into consideration the model proposed by C a l h o u n & C a s b y (1958). Apart from the above elaborations, the problem of the effect of sample size on estimation of home range parameters obtained by statistical methods has not so far been dealt with in detail.

The purpose of the present study is to try to fill this gap. Examination has been made of the effect of sample size on the values of the estimators obtained. Attention has also paid to the question of the »generality« of estimation methods and the assumptions of these methods have been interpreted from the aspect of definition of home range. Analysis has been made of methods used by C a l h o u n & C a s b y (1958), M a z u r k i e w i c z (1971), T a n a k a (1972), W i e r z b o w s k a (1972), while the methods used by D i c e & C l a r k (1953) and B u r g & J o r g e n s e n (1973) have been dealt with separately (W i e r z b o w s k a, in press).

2. TERMS CONNECTED WITH THE AREA STRUCTURE OF THE HOME RANGE

For the sake of clarity and conciseness of decription of the spatial structure of the home range accepted by the given estimation methods, the following terms will be used in this study:

(a) Complement of a set X — set, the element of which do not belong to series X;

(b) Connected domain — a region such that each two points within it can be connected continual curve laying entirely within this region. Connected domain may be:

(b_1) simple connected domain — its complement is a connected domain. The simple connected domain has no »holes« — places which the rodent does not visit. A simple connected domain may be:

($b_{1,1}$) convex — a region such in which each sector connecting any two points lies entirely within region,

($b_{1,2}$) concave domain — if it is not convex;

(b_2) multiply connected domain — its complement is not a connected region. These are regions of any shape with »holes«;

(c) unconnected domain — it is region which is not connected domain. It can be divided into separate regions.

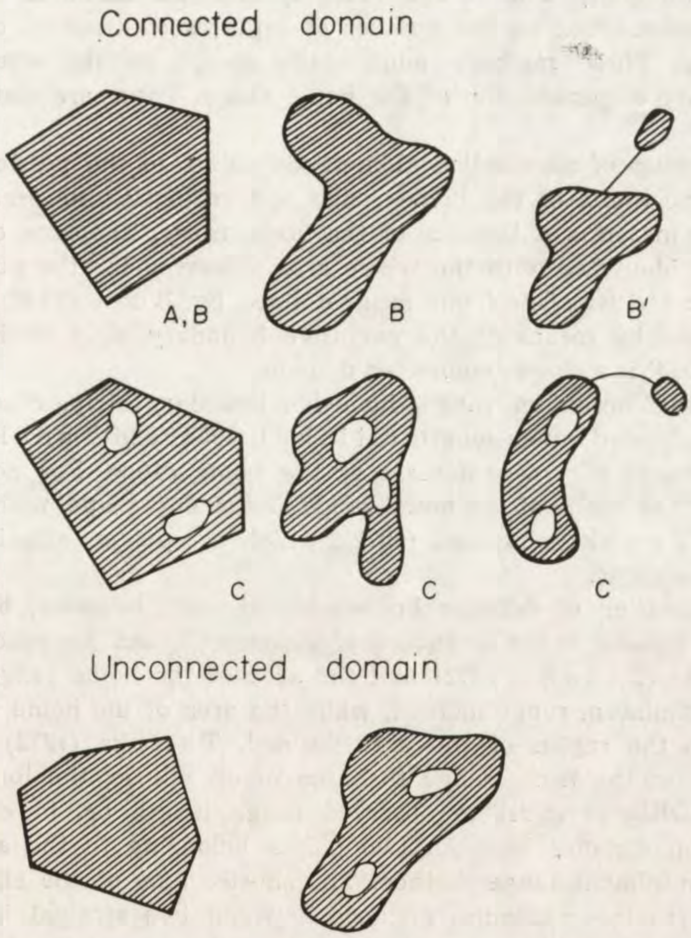

Fig. 1. Types of different structure of the home range area.
A — convex field, B — simple connected domain, C — multiply connected domain.

Illustrations in diagram form of the field structures presented above are to be found in Fig. 1.

3. REVIEW OF METHODS FOR ESTIMATING PARAMETERS DESCRIBING THE INDIVIDUAL HOME RANGE OF SMALL FOREST RODENTS

Methods estimating the values defining a home range (its size, limits, intensivity with which different parts of the home range are traversed) can be roughly divided into two categories. The first of these includes methods which give estimates describing the home range on the basis of information on the places in which the rodent was caught, irrespective of the number of times captures were made in this place (non-statistical methods). The second category includes methods which make use of information on the number of captures of a rodent on the trapping site. These methods additionally accept certain assumptions on intensivity of penetration of the home range. These are statistical methods.

The group of non-statistical methods points to the possibility of defining the limits of the home range and estimating its area, or giving a linear measure of the size of the home range. The area of the home range is identified with the whole area traversed for the purpose given by Burt (1943). The home range defined by Burt (1940), Haugen (1942) and by means of the exclusive boundary strip methods (Stickel, 1954) is a simple connected domain.

Methods: minimum range, inclusive boundary strip, observed range length, adjusted range length (Stickel, 1954) and Tanakas method (1972) accept a convex domain as the home range. For non-statistical methods the limits of the home range are of any shape, with the exception of Tanakas method (1972), which accepts an elliptic shape for the home range.

The question of defining boundaries has not, however, been presented by Tanaka in an unequivocal manner. It can be concluded from the paper (Tanaka, 1972) that the area of the home range is defined by the minimum range method, while the area of the home range is not equal to the region of the area defined. Tanaka (1972) takes as a measure of the home range the area of an ellipse, the longer axis of which (*ORL*) is equal to observed range length or, in other words, maximum distance between two points belonging to the area defined by the minimum range method. The shorter axis of the ellipse (*ORW*) is equal to the maximum distance between two straight lines passing through points with a trap, belonging to the area defined by the minimum range method and perpendicular to the axis *ORL*. This is the so-called observed range width. If, however, it is accepted that the position of *ORL* indicates the true position of the longer axis of the elliptic home range, and axis *ORW* is situated appropriately to *ORL*, then it is also possible to define the boundaries of the home range. The boundaries of the area defined in this way will differ from the boundaries defined by the minimum range method, and this difference will be the greater, the more the true shape of the home range differs from the elliptic shape (cf. Fig. 2). Considerable divergences also arise when the number of captures of a rodent is too small and the estimate of the home range boundaries are based on them. A conclusion of the same type can be reached in relation to the size of the area defined by means of the methods described above. T a n a k a (1972) presents the question of estimating this field in a completely straightforward way, as he does the measure of elongation of home range, which is equal to the value

$$\sqrt{1 - \frac{1}{W^2}} \qquad \text{where } W = \frac{|ORL|}{|ORW|}$$

Methods of the statistical type make use of information relating both to the capture sites and frequency of captures in these places. The home range is a convex area circular in shape (C a l h o u n & C a s b y, 1958; D i c e & C l a r k, 1953; H a r r i s o n, 1958; M e t z g a r, 1973) elliptic; (S t i c k e l, 1954; M o h r, 1965; M a z u r k i e w i c z, 1969; J e n u r i c h & T u r n e r, 1969), or a convex polygon (B l a i r, 1942).

According to W i e r z b o w s k a (1972) the home range may be not only convex domain but an any region, and therefore simple connected domain, multiply connected and unconnected.

In the case of the group of statistical methods the home range is traversed with an intensivity represented by the given distribution of random points within the home range.

The area of the home range is identified with the whole area traversed for the purpose given by Burt (W i e r z b o w s k a, 1972) or with part of this area (remaining methods of the statistical type). Supporters of the two-dimension normal distribution accept this part of Burt's area (B u r t, 1943) as the home range, counting concentrically from the centre of the rodent's activity in which the rodent appears in a given per cent of captures (*e.g.*, 95% for the following methods: C a l h o u n & C a s b y's, 1958; M a z u r k i e w i c z's, 1971).

All the methods presented above particularize definition of the home range given by B u r t (1943). They give an exact definition of the structure of the home range area and the intensivity with which its different part are traversed. They treat the boundaries of the home range as established (non-statistical methods, W i e r z b o w s k a's method, 1972); or accept them arbitrarily (supporters of the two-dimension normal distribution for random points in the home range). The first approach to home range boundaries will be termed Tanaka's approach, the second

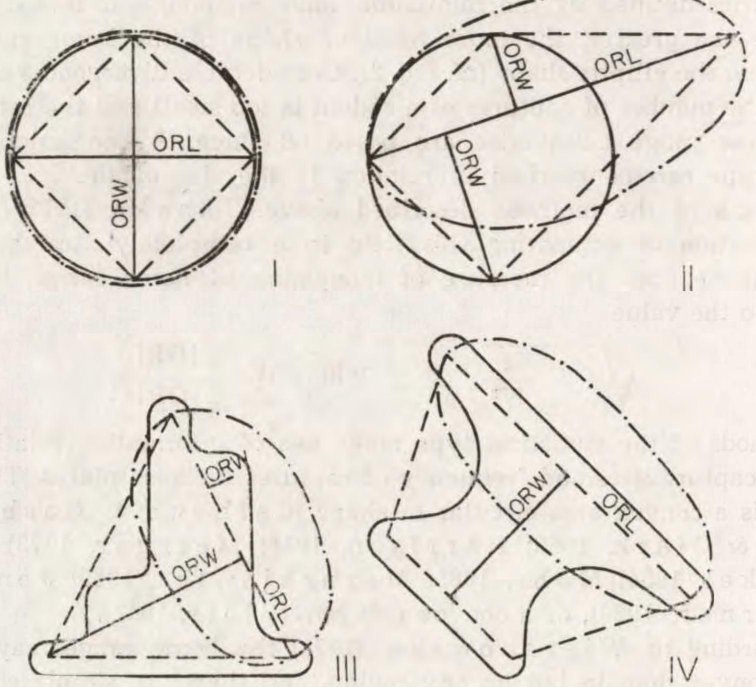

Fig. 2. Interpretation of the way in which home range boundaries are determined by Tanaka's method.

I, II, III, IV — numbers of models,
ORL, *ORW* — length, breadth of home range,
———— — true boundaries of home range,
— — — — — boundaries of home range determined by the minimum range method,
—.—.—. — boundaries of the home range determined by means of *ORL* and *ORW*,
. — trap site.

Calhoun and Casby's approach, which we shall use in the further part of this paper.

4. MODELS OF THE PHENOMENON OF PENETRATION BY RODENTS OF THEIR HOME RANGE

Consideration was given to four models, differing from each other in respect of assumptions of the shape of the home range and intensivity of penetration of the various parts of the range. The assumptions of each of the estimation methods considered in this study are adequate for the assumptions of one of the four models. This makes it possible to assess these methods from the aspect of their dependence on sample size. The other models permit of estimating to what degree each of the estimation methods can be applied in different ecological situations. A particularly important matter here is evolution of estimation methods from the aspect of their »sensivity« to inclusion in the sample of information on the place

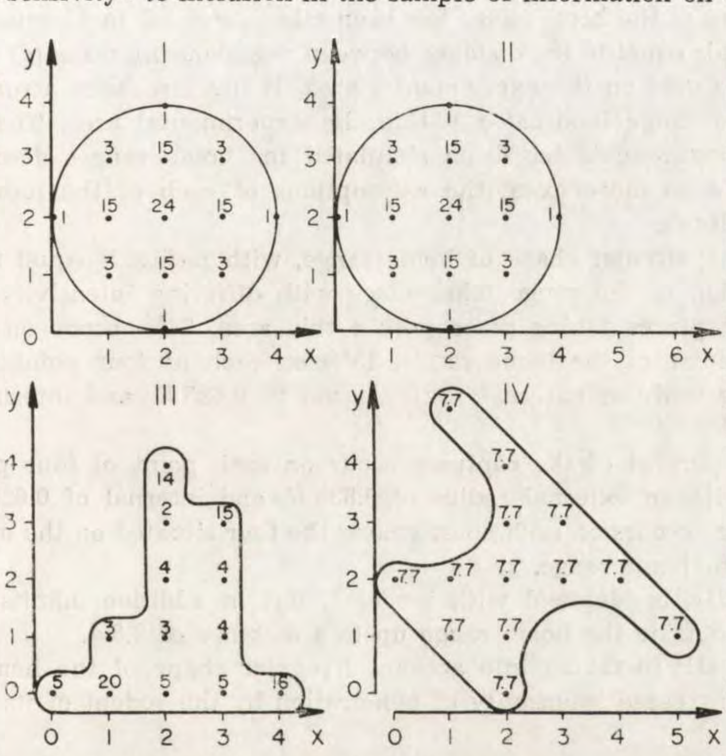

Fig. 3. Illustration of intensivity of traversing home ranges.

I, II, III, IV — numbers of models,

• — trap site,

1, 2, 3, 4,...... — percentages of time spent by the rodent in the neighbourhood of the trap site,

x, y — axes of coordinates of trapping point.

on which the rodent was caught outside its home range (so-called »places of distant random sallies«) (B u r t 1943). In examining parameters of the home range area it is frequently difficult to qualify the places in which a rodent was caught as »distant sallies«. This difficulty is particularly evident when the number of captures of a rodent, on the basis of which the parameters of the home range are estimated, is too small.

In the models considered in this paper both the circular and irregular shape of the home range have been taken into account. The elliptic shape has been omitted, as the circle is a particular form of the ellipse (when the long axis is equal to the short axis). Both uniform and varying intensivity of penetration into places within the home range have been allowed for. Varying penetration included the case of preferences for places stituated on the extreme limits of the home range and the case of preference for places in the centre of the range.

The size of the home range has been taken as equal to 13 square units. This unit is equal to the distance between neighbouring traps (d) arranged to form a grid on the experimental area. It has also been assumed that the home range is situated within the experimental area. The process of trapping rodents has been simulated for home ranges described as above. To be more exact the assumptions of each of the four models are as follows:

Model I: circular shape of home range, with radius R equal to $2.04\ d$. Penetration of the range takes place with differing intensivity. Among all the captures taking place within this area, 24% occur on the site in the centre of the home range, 15% on each of four points situated in a ring with an external radius equal to $0.625\ R$, and internal equal to $0.250\ R$.

Three percent of the captures occur on each point of four points on a ring with an external radius of $0.835\ R$, and internal of $0.625\ R$. One percentage occurs on each point among the four situated on the outermost ring of the home range.

Model II: is identical with model I, but in addition admits a point situated outside the home range up to a distance of $2.8\ d$.

Model III: in taking into account irregular shape of the home range accepts increased intensivity of penetration by the rodent of its extreme limits.

Model IV: also assumes irregular shape of the home range, and in addition accepts uniform intensivity of penetration within its boundaries (cf. Fig. 3).

Twenty captures for each of 30 rodents were simulated for the models described above. The group of these rodents represented the study population. On the basis of results of 6, 10 and 20 »captures« of a rodent the following parameters of the home range were estimated by means of the estimation methods analysed in this paper:

(1) area of home range (S)
(2) centre of rodent's activity ($\bar{x}$, $\bar{y}$).
(3) angle of inclination of longer axis of the home range to chosen direction of experimental area (φ),

(4) index of elongation of home range (W),

(5) index defining the percentage of captures of rodents in this part of the estimated home range which is situated within the model area (t).

Parameter t has been introduced in this study. The other parameters have been considered by the authors of the estimation methods analysed here. Parameter t provides the possibility of defining to what degree the area considered (on the basis of the sample) as the home range, from the aspect of the percentages of captures taking place in it, coincides in the sense of this percentage with that part of Burt's area (B u r t, 1943) which is considered as the home range by the given estimation metod.

In examining the effect of sample size on estimation of the above parameters it was assumed that these parameters remained unchanged during the period covering 20 captures of the rodent.

5. RESULT OF SIMULATION

Results of estimating home range parameters on the basis of a sample of appropriate size have been presented in Table 1.

5.1. Calhoun and Casby's Method

The size of the home range alters very little with increase in the number of captures for Model I, which is adequate from the assumption aspect for the assumptions of the estimation method. In the sense of the percentage of captures taking place (value of index t) the estimated area is the area of the home range in accordance with Calhoun and Casby's concept. A »distant random sally« (model II) and preference for sites on the limits of the home range (model III) considerably increase the estimated size of the home range. Uniform distribution, and a shape differing from circular (model IV) also give an over-estimated size of the home range. The area considered as the home range estimated for these models covers both the whole area from Burt's area ($t = 100\%$) and the area never visited by the rodent.

The smallest fluctuations depending on sample size (number of captures) are found for the centre of gravity of the capture sites of the rodent, but this coincides with the centre of gravity only for model I. For the remaining models the centre of gravity is not situated in the place of the rodent's greatest activity. In the case of preference for places on the boundaries on the home range (model III) the centre of gravity is situated in the place of the rodent's lowest activity.

5.2. Mazurkiewicz's Method

Mazurkiewicz's method gives an estimate of the home range area for model I approximately equal to the area considered as the home range according to Calhoun and Casby's concept. For the remaining models the home range area is considerably overestimated, even for 6 captures of the rodent, the degree of overestimation increasing with the number of captures. As in the case of Calhoun and Casby's method, a »distant random sally« outside the home range (model II), preference for places on the limits of the home range (model III) and uniformity of the distribution of intensivity of penetration (model IV) significantly affect this overestimation. In general, however, the degree of overestimation is lower for Mazurkiewicz's method than for that of Calhoun and Casby. The area considered as the home range, as estimated by Mazurkiewicz's method (1971), does not coincide with the area considered as the home range in the assumptions of this method (value t).

Mazurkiewicz accepts Calhoun and Casby's concept and considers the area including 95% of the captures of the rodent as the home range. It can be seen from Table 1 that the estimated value t differs considerably from 95%, even when the estimated area of the home range is markedly overestimated. A »distant rondom sally« outside the area of the home range (model II) and number of captures smaller than 10 points to an elliptic shape, even when the true shape is circular. An identical result in the range of the effect of sample size on the estimate of the degree of elongation of the home range was obtained by Metzgar (1973), who found that for the model assuming two-dimension distribution as normal for random points in the home range, the estimated shape of the home range is connected with sample size (number of captures). He took into account a sample including 10 captures, and obtained an elongated shape of the circular home range for this value. For Mazurkiewicz's method (1971), the angle of inclination of the longer axis of the home range to axis x (Fig. 3) is subject to slight fluctuations depending on the number of captures, but differs considerably from the real angle. A »distant sally« outside the home range (model II) »inclines« the longer axis of the home range in the direction of this sally.

5.3. Tanaka's Method

In the range of sample sizes analysed the assessed values of the area are understimated, the estimation error decreasing with increase in the number of captures. The lowest results are obtained with model I, assuming the greatest activity of the rodent in the middle of the home range. For this model even 20 captures of the rodent gives a considerable error in the estimated area of the home range. Inclusion in calculations of the point of »distant sally« gives an overestimated area of the home range, but with simultaneous reduction of the estimation as the result of preference for central points in the home range, the result of estimation of the area is slightly underestimated (model II). Comparison of the estimated area values for the home range for model I and III shows that for the model assuming increased activity of the rodent on the boundaries of the home range (model III) a smaller sample size is necessary than for the model assuming increased activity of the rodent in the middle of the home range (model I).

The above conclusions coincide with the results of simulation obtained by Stickel (1954), who showed that the value of the maximum distance between capture sites of the rodent which is taken into account in Tanaka's equation (1972) in calculating the area of the home range, depends on the number of captures of the rodent, on the basis of which this distance is calculated. Stickel (*l.c.*) found that with the elongated shape of the home range the »revelation« of *ORL* takes place more slowly than with the circular shape. For the model assuming increased activity of the rodent on the boundaries of the home range the »revelation« of *ORL* takes place more rapidly than for the model assuming increased activity of the rodent in the middle of the home range. If the rodent »revealed« all the trapping sites situated in the home range (on the basis of a suitable large number of captures) estimate of area obtained by Tanaka's method (1972) would differ very little from the estimate obtained by the exclusive boundary strip method, but to a greater degree that the estimate obtained by the minimum range method. The sizes of these areas for Tanaka's, the exclusive boundary strip and minimum range methods would be respectively:

model I:	12.6,	13.0,	8.0	model II:	18.9,	16.0,	12.0
model III:	15.8,	13.0,	9.0	model IV:	13.2,	14.0,	12.0

The above conclusion is contrary to the conclusion reached by Tanaka (1972), who states that his method gives estimates closer to the minimum range method than the exclusive boundary strip method. The results obtained by Tanaka's and the exclusive boundary strip methods become, however, even more divergent when sample size (number of captures) is smaller, Tanaka's method giving results closer to the real size of the home range. An analogical conclusion is to be drawn from the study Stickel (1956): the real *ORL* is more rapidly revealed by rodents than the area calculated by the exclusive boundary strip method.

As in the case of Mazurkiewicz's method (1971) taking into account the point of »distant random sally« in estimating the degree of elongation of home range points to an elliptic shape of the home range, even when the true home range is circular (model II). As mentioned earlier, it is not clear from Tanaka's study (1972) in what way the map of the home range has been drawn up, and consequently the values of parameter t were not defined for different sample sizes.

5.4. Wierzbowska's Method

Wierzbowska's method (1972) makes it possible to estimate the average size of the home range of the study population, but does not permit of ascertaining the home range boundaries. As in the case of the preceding methods, the estimated size of the home range depends on the number of captures, this being underestimated from the standpoint of Tanaka's concept.

The lowest estimates are obtained using model I, for which 96% of the captures of the rodent take place on 9 sites in the home range, out of a possible 13. If the fact is taken into account that points on which the rodent remained longest are most rapidly »revealed«, then Wierzbowska's method estimates on the basis of 6 captures of the rodent the field of this area in which 88% of the captures of the rodent (model I and model III), 85% of captures (model IV) and 97% (model II) take place. The size of these areas varies from 6.6 square units (model I) to 11.7 (model IV). Increasing the sample size to 10 captures of the rodent increases the value of the estimated home range size to the values contained within limits of 6.9 square units (model I) to 11.7 (model IV). This is the size of the area in which, on an average, 90% to 96% of the captures of the rodent take place. Increasing sample size to 20 captures does not significantly alter results. Estimates of area may, however, be made on the basis of a smaller sample (smaller number of captures) with simultaneous increase in the group of rodents representing the study population. The effect of the mutual relation of numbers in the group of rodents representing the population and number of captures of the rodent belonging to this group on the error in assessing home range size has been described in an earlier paper (Wierzbowska, 1972). Wierzbowska's method makes it possible to estimate the average size of the home range, even on the basis of two captures of the rodent, with a suitably numerous group of rodents representing the population.

6. DEGREE TO WHICH A SAMPLE IS REPRESENTATIVE IN ESTIMATING THE EXTENT OF THE HOME RANGE

Apart from sample size and degree to which the true model is adequate for the assumptions of the abstract model, the size of the experimental area also affects the estimated values of the parameters defining the home range (its area and situation). In accordance with the assumptions of methods estimating home range parameters, the home range is completely contained within the experimental area. This assumption in not always accurate, and it becomes especially unreliable when the size of the experimental area is too small with the given size of the home range. In this situation there is a large percentage of rodents, among all those which are caught within the experimental area, whose home ranges partly overlap this area. In the last case the rodent is caught on an area smaller than its home range and the estimated parameters of the home range burdened with considerable error. The percentage of rodents whose home ranges overlap partly on to the experimental area have been defined by Tanaka (1972).

The dependence of the average size of home range overlapping the experimental area on home range size and on the size of the experimental area has been given in the following studies: Morisita & Murakami, 1968; Tanaka, 1972; Janion & Wierzbowska, 1972. Thus when the experimental area is too small, *e.g.*, is a square width side=7 units of length, while the size of the home range is equal to 13 square units, then in accordance with the equations given by Tanaka (*l.c.*) and Morisita & Murakami (*l.c.*) the estimated home range area is subject to 2.5 times underestimation, but in Janion & Wierzbowska's opinion (1972) there will be 2.2 times underestimation.

The assumption of appropriate size of the experimental area is thus important in estimating home range parameters (particularly its size). This is not, however, always possible particularly when rodents have large home ranges. In general in making estimates those captures of rodents caught near the boundaries of the experimental area should not be taken into consideration.

7. DISCUSSION

Methods estimating the home range of small forest rodents give in their assumption the definition forming a more detailed version of Burt's definition (1943). They define the spatial structure of the area of the home range and the way in which it is traversed. Measurements of home range parameters assessed by means of these methods depend on sample size. For the methods analysed in this paper the type of this relation is not uniform for the home range sizes estimated (Table 1). For instance, the centre of gravity of the capture sites of the rodent which is the estimator of the centre of activity is subject to slight fluctuations, depending on sample size (on the number of captures of the rodent), but in general does not coincide with the centre of activity

(Calhoun's and Mazurkiewicz's method). It is situated in the place of the rodent's greatest activity only for model I. When the rodent prefers places situated on the boundaries of the home range (model III) the centre of gravity is situated in the place of the rodent's lowest activity. When the point of »distant random sally« is included in the sample this shifts the point of gravity in relation to the centre of activity. Irregular shape of the home range and uniform distribution of activity within this area also indicates incorrect placing of rodents's maximum activity (model IV). The estimated value of angle of inclination (φ) of the longer axis of the home range in relation to the chosen direction of the experimental area does not coincide with the true angle of inclination, although the estimate changes slightly with increase in the number of captures. The value of the angle assessed is significantly connected with the position of the point of »distant random sally« (Mazurkiewicz's method). Sample size plays an important part when estimating the degree of elongation of the home range (Mazurkiewicz's and Tanaka's method). An estimate of this parameter obtained on the basis of a sample smaller than 10 captures of the rodent, and on a sample taking into account the point of »distant random sally« points to the elliptic shape of the home range, even when the real home range is circular in shape (Table 1, model I and II). The effect of sample size on the value of the degree of elongation of the home range was also found by Metzgar (1973). He found from the results of simulation for a circular home range that 10 captures of a rodent point to considerable elongation of the home range.

Part from the home range parameters discussed above, a value estimated by all the methods analysed in this paper is the size of the home range. The estimates obtained may be related to the area of 13 units (this is the area of the home range according to Tanaka's concept), or to a smaller area (in accordance with Calhoun's concept). From the point of view of Tanaka's concept, Calhoun and Casby's and Mazurkiewicz's methods considerably overestimate the home range area even for 6 captures of a rodent, this overestimation increasing with increase in the number of captures of the rodent (Table 1). An exception is formed by model I. The acceptance by Mazurkiewicz of the assumption of an elliptic shape for the home range corrects her results in relation to the estimate obtained by means of Calhoun and Casby's method but even so the estimates obtained area far too high. When Calhoun & Casby's concept (1958) of the boundaries of the home range are accepted, overestimation of the area by means of the above methods is even greater than with Tanaka's concept. Tanaka's and Wierzbowska's methods give too low estimates of home range area, the error of underestimation decreasing with increase in the number of captures. When Calhoun and Casby's concept is accepted the error in estimation is smaller than with Tanaka's concept. Maximum understimation of the home range area occurs in model I for Tanaka's methods (Table 1).

The estimates obtained for home range area for the estimation methods analysed are connected with the type of distribution of the number of captures of a rodent on a trapping point and with the spatial distribution of these captures within the home range.

With the same distribution of number of captures on a site different results are obtained when there is preference for places on the limits of the home range and different when there is preference for central places. With increased intensivity of the rodent's activity on the boundaries of the home range Calhoun and Casby's method (1958) and Mazurkiewicz's method (1971) give too high an estimate of area in relation to the true area size and far too high in relation to the estimate obtained when there is preference for central places in the home range. Wierzbowska's method (1972) is not significantly connected with the spatial distribution of the rodent's activity within its home range, but depends primarily on the type of distribution of the number of captures made of the rodent on the trap site.

When »distant random sallies« are taken into account in estimating the home range area this is of importance to Calhoun & Casby's method (1958) and for Mazurkiewicz's method (1971), as it considerably overestimates it (Table 1). Inclusion of this point when assessing area by Wierzbowska's method (1972) and Tanaka's method (1972) does not significantly alter the result of the estimate in relation to the result when the place of »random sally« is omitted.

On the basis of the results given in Table 1 it can be said that the most general methods capable of application in a large number of ecological situations for estimating the home range area are Tanaka's method (1972) and Wierzbowska's method (1972).

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PRZEGLĄD METOD OCENY PARAMETRÓW AREAŁU OSOBNICZEGO DROBNYCH GRYZONI LEŚNYCH Z PUNKTU WIDZENIA WIELKOŚCI PRÓBY

Streszczenie

Dla metod statystycznych Calhoun'a i Casby (1958) Mazurkiewicz (1971), Wierzbowskiej (1972) oraz dla metody typu niestatystycznego (Tanaka, 1972) zbadano wpływ wielkości próby (liczby złowień gryzonia na wartość

ocenionych parametrów z symulacji procesu łowienia się gryzonia wewnątrz areału osobniczego. Przyjęto, że areał ten znajduje się na powierzchni eksperymentalnej pokrytej żywołownymi pułapkami znajdującymi się w węzłach siatki o kwadratowych oczkach. Wielkość obszaru areału wynosi 13 jednostek (jednostka równa jest kwadratowi odległości między sąsiednimi pułapkami powierzchni eksperymentalnej).

Rozważono cztery modele zróżnicowane z punktu widzenia kształtu areału osobniczego oraz sposobu penetracji jego wnętrza (Fig. 3). Rozważano kształt kołowy (model I i II) oraz nieregularny (model III i IV. Rozważano sytuację preferowania przez gryzonia miejsc znajdujących się na krańcach areału osobniczego (model III), oraz preferowania miejsc środkowych (model I i II). Uwzględniono także jednakową intensywność penetracji areału osobniczego (model IV). Poza ustalonym obszarem areału osobniczego umieszczono punkt odwiedzany przez gryzonia przypadkowo, w ramach „dalekiej, przypadkowej wędrówki" (model II).

Dla przyjętych modeli symulowano 20 złowień dla każdego z trzydziestu gryzoni reprezentujących badaną populację. Na podstawie 6-ciu, 10-ciu oraz 20-tu „złowień" gryzonia oceniono dla grupy 30-tu gryzoni średnie wartości następujących wielkości charakteryzujących areał:

(1) środek aktywności gryzonia,
(2) kąt nachylenia dłuższej osi areału do wybranego kierunku powierzchni eksperymentalnej,
(3) wskaźnik wydłużenia areału,
(4) procent złowień zrealizowanych przez gryzonia w części wspólnej areału prawdziwego i ocenionego,
(5) pole areału osobniczego.

Z przeprowadzonych wyliczeń (Tab. 1) wynika, że najmniejszym wahaniom w zależności od liczby złowień gryzonia podlega środek ciężkości punktów złowień gryzonia, oraz kąt nachylenia areału. Wielkości te odbiegają jednak od prawdziwych wartości. Włączenie do wyliczeń punktu „dalekiej„ przypadkowej wędrówki" (model II) zmienia znacznie kąt nachylenia areału, oraz zwiększa wzajemną odległość środka aktywności i środka ciężkości punktów złowień. Punkt ciężkości miejsc złowień znajduje się w miejscu najmniejszej aktywności gryzonia w przypadku modelu preferującego zwiększoną aktywność gryzonia na krańcach areału (model III). Zbyt mała liczba złowień gryzonia (mniejsza od 10), a także włączenie do obliczeń punktu „dalekiej wędrówki" wskazuje na eliptyczny kształt areału nawet wówczas, gdy prawdziwy areał ma kształt kołowy (model I i II). Analiza procesu złowień zrealizowanych przez gryzonia w części wspólnej prawdziwego areału i ocenionego wykazała (Tab. I, parametr t), że oceniony procent odbiega znacznie od przyjętego w założeniach metody estymacyjnej.

Metoda Calhoun'a i Casby (1958) oraz metoda Mazurkiewicz dają zawyżone oceny pola areału już na podstawie 6-ciu złowień gryzonia, przy czym zawyżenie to wzrasta wraz z wielkością próby (liczbą złowień). Metoda Mazurkiewicz poprawia wyniki w stosunku do oceny metodą Calhoun'a i Casby, niemniej oceny te są znacznie zawyżone. Szczególnie duży błąd powstaje dla modelu preferującego zwiększoną aktywność gryzonia na krańcach jego areału (model III) oraz uwzględnienie w obliczeniach punktu „dalekiej wędrówki" (model II). Jednakowa intensywność penetracji(model IV) powoduje także znaczną przecenę pola areału. Dla powyższych metod, błąd oceny pola areału jest większy przy przyjęciu koncepcji Tanaki, dla wszystkich modeli z wyjątkiem pierwszego.

Metoda Tanaki oraz metoda Wierzbowskiej dają zaniżone oceny pola areału osobniczego. Jednak ze wzrostem liczby złowień błąd oceny maleje. Znaczne zaniżenie pola areału występuje dla modelu I-szego, przy użyciu metody Tanaki. Dla obu metod większy błąd oceny występuje przy przyjęciu koncepcji Tanaki. Bezwzględna wielkość błędu oceny pola areału jest dla metody Tanaki i Wierzbowskiej mniejsza niż dla metody Mazurkiewicz oraz Calhoun'a i Casby.

Ogólnie można przyjąć, w oparciu o wyniki Tabeli 1, że dla analizowanej wielkości areału, spośród metod estymacyjnych analizowanych w tej pracy, metoda Wierzbowskiej oraz metoda Tanaki są najbardziej ogólne przy ocenie pola areału, a więc mogą być stosowane w różnych sytuacjach ekologicznych. Ponadto są one łatwe w użyciu ze względu na prosty aparat rachunkowy. Poza analizą błędu oceny parametrów areału związanych z wielkością próby, poruszono w niniejszej pracy sprawę błędu wynikającego z wyboru niewłaściwej wielkości powierzchni eksperymentalnej do oceny pola areału gryzoni, żyjących na tej powierzchni.