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ESTIMATING POPULATION PARAMETERS OF THE RICEFIELD RAT (*RATTUS RATTUS MINDANENSIS* MEARNS)

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SUBMITTED TO THE GRADUATE FACULTY OF THE COLLEGE OF AGRICULTURE UNIVERSITY OF THE PHILIPPINES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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BIOGRAPHIC DATA

The author was born in Laoag City on September 4, 1949. He is the youngest son of Felix Benigno and Marcelina Abalos. In 1954 the family migrated to Pagadian City where he took his primary education at the Pagadian Central Elementary School. Later, they settled in Davao City where he finished his intermediate (with honors) and secondary (with honors) courses at the Davao Central Elementary School in 1961 and University of Mindanao (High School) in 1965, respectively.

He was admitted to the University of the Philippines, College of Agriculture as an entrance scholar. At various times during his undergraduate study, he was a university scholar, college scholar, and an UPCA undergraduate fellow. He finished his Bachelor of Science in Agriculture (cum laude) degree in 1969. In the same year, he was awarded a research assistantship by the Rodent Research Center (NEC-US/AID) Scholarship Program to pursue his M. S. degree in this university.

EDWIN A. BENIGNO

DEDICATION

This work is lovingly dedicated to my parents and my brothers for their endless encouragement and inspiration throughout my studies.

ACKNOWLEDGEMENT

The author appreciates the constructive criticisms made by the members of his guidance committee: Prof. P. J. Alfonso (adviser), Dr. V. G. Momongan, Dr. F. F. Sanchez, Dr. M. B. de Ramos, and Mr. S. M. Alviar. The author is also indebted to Dr. I. P. David for his unselfish suggestions in the planning of this work.

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ABSTRACT

Benigno, Edwin Abalos, University of the Philippines, November, 1972, Estimating Population Parameters of the Ricefield Rat (*Rattus rattus mindanensis* Mearns). Major Professor: Pablo S. Alfonso.

Livetrapping was conducted twice a month for two crop seasons in a selected rice growing area in Siniloan, Laguna. Data for the estimation of population parameters were obtained independently for each season by means of the capture, release and recapture method.

Monthly population density per hectare and subsequent damage to rice was greater during the wet season. In both seasons, density increased toward maturity of the crop. Density was negatively correlated with the proportion of males in the monthly samples while no significant correlation was found between density and the proportion of juveniles in the sample.

Juveniles were more mobile and exhibited larger home ranges than adults; adult males and females were equally mobile. Harvesting and land preparation without incorporating control did not exert immediate and significant displacement effect on the population.

Trap location, animal behavior, and the prevailing weather conditions affected trappability resulting in variable trap index even within the same trapping period. The problem of few recaptures of marked animals in this study could indicate that the capture, release and recapture method alone may not be practical for assessing population parameters.

INTRODUCTION

The study of animal populations has recently received considerable attention. Many attempts have been made to describe the structure of a given population quantitatively. Consequently, more refined statistical methods have to be evolved to obtain accurate estimates of the different parameters characteristic of the population.

Population parameters in turn provide one of the bases for sound pest management and maximum utilization of animals of importance to man. Allen (1949) further stressed the need for such parameters. He blamed the lack of fast and accurate estimation procedures for the slow progress in efficient wildlife management. The statement holds especially true for vertebrate pest management in the Philippines. With the intention to contribute in the effort to remedy the situation, this study was conducted at the Department of Entomology and Applied Zoology, and in the rice fields of Sintloan, Laguna from September, 1971 to June, 1972.

The main objectives of this study are:

1. To apply under typical ricefield conditions of rat infestation, available techniques for estimating population parameters such as population density, survival rates, and home range;

2. To formulate some procedures suited to the study of local rodent populations.

REVIEW OF LITERATURE

No population is ever static. It may attain equilibrium but at any given time it is the result of the interaction of three generalized forces recognized by Davis (1953a):

> "Reproduction tends to increase the population, mortality tends to decrease it, and movements tend to increase it or decrease it depending upon the net result of immigration and emigration."

Lotka (1925) expressed the relationship among these forces conveniently in the equation:

$$\frac{dN}{dt} = k(B - D) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where:

N = number of individuals in the population

B = birth and/or immigration

D = death and/or emigration

t = unit of time

k = a constant

The population size (N) is therefore a convenient index of the state of a population at any given time. There is at present a number of techniques for estimating this important parameter.

Andrewartha (1961), Emlen, Stokes, and Davis (1949) classified the different estimation techniques as measurements of absolute density (direct measurement) and of relative density (indirect measurement), density being defined as the number of animals in a given area. Kucheruk (1964) discussed them as indirect, direct, and

absolute census. Gutierrez (1967) further grouped them into total count, incomplete count, indirect count, and marking methods.

Complete enumeration utilizes the whole population and thus give absolute counts. This includes methods such as: exhaustive trapping with return of marked animals to the field, visual counting on measured areas, and systematic killing with an enumeration of the animals as they are removed. In this type of census, each member of the population has to be counted without confusion, duplication, or omission. The problem is magnified whenever a large population is under study and there are only a few enumerators. This approach therefore, although direct and desirable, usually is expensive and time consuming.

Incomplete enumeration is resorted to when only a part of the whole population can be seen or enumerated at any one time. This has the advantage over the total count when one is dealing with mobile populations ranging over extensive areas. Included in this grouping are: the quadrat method, strip censuses, roadside counts, flushing counts, and other sampling techniques.

Indirect counts on the other hand, are based on signs or indices of abundance such as trails, droppings, nests, and amount of food consumed rather than actual numbers. These indices are useful in the study of timid or nocturnal animals but it may be difficult to compare the signs from one period to another unless natural variations are considered.

Trap-mark-recapture method. This method is variously called as mark, release and recapture method; multiple-recapture census; capture-recapture; and the like. Andrewartha (1961) considered it as a measure

of absolute density while Emlen et al. (1949) grouped it under indirect measurement yielding relative data. Some models under this group likewise provide estimates of survival and dilution rates which are in effect similar to birth and death rates.

This technique is fast becoming popular among biologists. Lecren (1965) believed that Dahl was the first to use it in estimating population density in 1917. He stated that Peterson, one of its main founders, used it only in estimating mortality rates in 1889. The Lincoln index, still used by mammalogists, was first used to calculate waterfowl abundance in 1930. Since then several refinements and added features have been made on this technique.

Jackson (1939, 1940, 1944, 1948) developed his deterministic model to estimate tse-tse fly populations when every individual in the population was assumed to be subjected to the same survival rate. Fisher and Ford (1947) used this method in studying the spread of a gene in a moth colony. Bailey (1951, 1952) refined Jackson's methods and improved the interpretation of recapture data. Darroch (1958, 1959) gave estimates for a closed population and for a population where there is immigration or death. He also provided a two-sample census when tagging and sampling are stratified (1961). Cormack (1964, 1966) developed estimates for a nonrandom sample of fulmar petrels and a test for equal catchability of marked and unmarked animals. Seber (1962, 1965) considered the case when marked individuals cannot be recaptured more than once as in hunting and fishing. He also provided a test for equi-catchability in a closed population.

Jolly (1963, 1965) developed his deterministic and stochastic models with maximum likelihood equations, estimates of numbers, survival and dilution rates with corresponding variances and covariances. Manly and Parr (1968) and later Manly (1969) also developed estimating equations using recapture data but these were reducible to Jolly's. Cormack (1971) cited alternative estimates when the standard assumptions of the Jolly-Seber models do not occur. Janion et al. (1968) likewise suggested estimates of numbers of rodents with variable probability of capture. Eberhardt (1969) suggested a modified method for estimating density based on the assumption that recaptures follow the geometric grequency distribution.

The efficiency of the technique is largely dependent on how well the animals are marked before they are released into the population. Techniques of efficient marking of the animals and their uses in ecological studies are given by Woodbury (1956), Taber (1956), and Pendleton (1956).

The basic principle of the trap-mark-recapture method is rather simple. The population is first sampled. Each animal caught is assigned a unique number or marking code before it is released into the population. Later, another sample is taken and the ratio between the number of marked and unmarked animals provides the estimates of the population density given by the equation:

$$P = \frac{NM}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Where:

P = population density

N = number of individuals captured including those recaptured

R = tagged individuals recaptured

M = number of tagged individuals released into the population

The procedure is generally repeated over a period of time. Every unmarked individual is given a unique marked on its first capture. Recaptures are then recorded under appropriate dates without further markings.

The precision of the estimates, however, are dependent on certain assumptions which usually include:

1. The marked animals distribute themselves uniformly with unmarked individuals, and

2. The marked ones are caught at the same rate as the unmarked ones.

Andrewartha (1961) cited two technical difficulties encountered in this method, namely:

> 1. When traps are used, especially in an area that is not limited by sharp ecological boundaries, difficulties arise with respect to the placing of traps relative to the boundaries of the area.
>
> 2. It is difficult to attribute a precise variance to the estimates that are given by this method because the calculations are tedious and difficult.

Benigno (1969)[1] prepared a program (FORTRAN II) of the more general and widely applicable stochastic model of Jolly (1965) to facilitate the calculations of the estimates and their variances.

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[1] E.E. Benigno, "Capture, release and recapture technique: programming and application". (Unpublished undergraduate thesis, University of the Philippines, 1969)

Quadrat method. In this method small areas are chosen at random from the area which contains the whole population. Complete counts of the animals in the smaller areas are then taken to estimate the total number in the larger area. It is implied that the smaller areas are of known sizes relative to the whole area. One difficulty with this method is that some animals have the tendency to escape the observer. The reliability of the estimates by this method therefore depends on how representative the quadrats are to the whole area and on how much of the actual numbers in the quadrats are observed. This method is likewise greatly affected by aggregation. Gutierrez (1967) cited the quadrat method as used in the study of fishes, birds, and mammals. Bole (1939) and Pelikan et al. (1969) also worked on this method.

Trapline index. This index, also known as trap-night index or simply trapping success is a simple measure of relative abundance. With this method, a number of traps are usually set for three consecutive nights and the trapping success is then taken as the ratio of the total catch to the total effective trap-nights. Formozov and Isakov (1967) expressed the index in terms of 100 trap-nights. Southern (1965) discussed the use of this method in tracking broad changes of distribution in time and space of small rodent populations. Although the procedure is simpler than the other techniques, its reliability has been questioned by various workers. Stickel (1948) concluded that the trapline is not fully reliable due to differences in individual ranges and habitat factors. Tanaka (1960) found evidences against the method but stated that the density estimated by

this method may be reliable if the probability of capture remains constant. Kucheruk (1964) recommended the standardization of the techniques of spacing traplines in order to obtain comparable results. Hansson (1967) noted that the relation between the index and population density differed with species.

Removal technique. This is similar to the two methods mentioned earlier. Leslie and Davis (1939) and Davis (1964) described complete removal to yield absolute density. Chapman (1955) chose selective removal to effect change in population composition while Cahalane (1941) used trap-removal census. Grodzinski *et al.* (1966) suggested the use of regression estimates with this method. Zippin (1956) described and evaluated the use of this method in estimating animal populations.

This technique assumes a stationary population during the trapping program. Like the other techniques, it also assumes a uniform and constant probability of capture from one trapping to another for a given period. Population size is then estimated by regression method as:

$$E(y_i) = (N - x_i)\, p \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Where:

p = the probability of capture during a single period of trapping

N = the original population size

x_i = the number of animals caught prior to the ith period

The absolute value of the slope of the line estimates the probability of capture and the y-intercept estimates the population size.

Determination of the precision of the estimates as well as the appropriate sample size are given by Zippin (1956).

Change-in-ratio estimate. Kelker (1940, 1943) used sex ratio equations for determining wildlife populations. Chapman and Robson (1960) analyzed the catch curve with respect to age distributions. They stated that the catch curve from a stationary population based on the assumption that age distribution is geometric. They gave the annual survival rate as $\bar{X}(1 + \bar{X} - \frac{1}{n})$, $\bar{X}$ being the mean age of sample size n. Hanson (1963) calculated productivity, survival, and abundance of some vertebrates based on sex and age ratios.

Rupp (1966) stated that the estimates based on changes in relative abundance (change-in-ratio) of two classes of individuals in the population can be presented in one basic estimating equation, namely:

$$N_1 = \frac{M - p_2(M + F)}{p_2 - p_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Where:

N_1 = the total number of animals in the population at time $1(T_1)$

p_1 = the decimal fraction of population N_1 which consists of one kind (males, for example)

p_2 = new decimal fraction (of males) among N_2 individuals at T_2

M = number of males added or removed between T_1 and T_2

F = number of females added or removed between T_1 and T_2

In a more recent work, Paulik and Robson (1969) suggested a general unified approach for estimating abundance, productivity and exploitation rates from observed changes in population composition, whether natural or artificially constructed. They provided plans for experiments and surveys, and also charts for determining sample size required to estimate the population size within a given percent error. Likewise, they showed that the multiple-mark-recapture analysis is a form of a change-in-ratio estimate.

The change-in-ratio estimate may be used when a population can be classified into two categories and a change occurs in the relative abundance in the two types of animals.

Population structural model. Population density and other parameters may also be obtained from the population structure. Blair (1951), Leslie, Venables and Venables (1952), Anderson (1961), and Davenport (1964) studied the structure of some rodents under certain conditions. Tanaka (1954) observed considerable yearly change in population size and structure but did not give the character and cause of the population shift. Smirnov (1967) and Henny, Overton, and Wight (1970) gave estimates of parameters based on the analysis of structural models.

Forecasting method. Every population has its innate capacity for increase in numbers. Andrewartha and Birch (1954) suggested that this capacity be denoted by r_m and defined by:

$$r_m = \mathrm{Log}_e \frac{R_o}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Where:

r_m = innate capacity for increase in numbers, calculated from experimental data and relating to a population with a stable age distribution.

R_o = number of times a population will multiply per generation (net reproductive rate)

T = generation time

Realizing the importance of this new population statistic, Laughlin (1965) proposed a simple approximation of equation (5):

$$r_c = \text{Log}_e \frac{R_o}{T_c} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Where:

T_c = cohort generation time which is also equal to the mean age of mothers in cohort at birth of a female offspring

The antilog$_e$ r_c gives the number of times a population multiplies itself per unit time.

Advanced techniques for forecasting the numbers of some rodent populations have been proposed by Schindler (1959), Egorov (1961), Shkilev (1963), and Maksimov (1962).

Home range measurement. Burt (1940, 1943) found that the concepts of territoriality and home range were applicable to mammal populations. He defined home range as that area traversed by the individual in its normal activities of food gathering, mating, and

caring for the young. Jorgenson (1968) stated that home range may also measure probable interaction of small mammals. Stickel (1964) provided a means of utilizing the home range information to estimate density.

The estimation of this useful parameter has been studied from synthetic recaptures or simulated trapping of artificial populations by Davis (1953b) and Stickel (1954). Davis (1953b) found that recaptures were not normally distributed but the frequency distribution of distances between captures was approximately normal and showed that there were few chances of recaptures at short distances. He recommended that the number of recaptures at particular distances be divided by the number of chances of recaptures at those distances. Stickel (1954) stated that range size increased with successive captures until a level was reached which approximated the true range. He further revealed that fewer captures were required when traps were far apart then when they were close together. Metzgar and Hill (1971) compared the amount of observed overlap of a given set of home ranges against the expected overlap if those ranges were randomly distributed within the habitat. They also devised a computer program to determine the expected overlap of a set of home ranges.

Home range may be analyzed from recapture data (Davis, 1953b), tracks on smoked karyograph paper (Justice, 1961), and by means of telemetry (Tester and Siniff, 1965). The first approach is the same as the capture-release-recapture method. The only difference is that the distances between recaptures of marked animals are also measured.

Traps are usually arranged in rectangular grid. Davis (1953b) stated the disadvantages of the grid system as:

1. The animal's home range does not necessarily coincide with the distribution of the traps, the home range may extend beyond the grid or the traps in which the animal was caught, and that the home range can not be calculated for animals caught in traps that are in straight line.

2. Great labor in laying out the grid itself, the necessity of setting some traps in obviously unfavorable locations, and the need to recapture a single individual many times (about 15-20 times) to obtain adequate data.

3. Little idea of the intensity of use of the various parts of the home range is gained.

Estimation techniques using recapture data include: recording movement data in terms of frequency of maximum distance between recaptures (Evans and Holdenreid, 1943); distances of recaptures (Davis, Emlen, and Stokes, 1948); minimum method (Dalke, 1942; Mohr, 1947); and boundary strip method by Blair (1940).

The second approach makes use of smoked karyograph paper instead of traps in detecting home ranges of individually toe-marked rats. The smoked paper placed in unbaited cartons are also arranged in rectangular grid. Justice (1961) stated that with this method as many as ten records can be obtained from an individual in a single night; the biases of trap inhibition, learning and trap fatigue inherent in the mark-and-recapture method can be avoided; and

information suitable for investigation of the theoretical probability density functions of animal activity can be found.

Difficulties encountered in the study of home range as stated by Davis (1953b) are:

1. Animals do not travel in straight lines between captures.

2. Animals may learn to go into traps for food, and hence give too many short distances.

3. Traps may not be suitably spaced to indicate maximum movements.

4. Transients are included.

5. The data give only an index of home range.

Stickel (1954) compared some methods and found the so-called exclusive boundary strip method as the most accurate. In this method, rectangles are constructed, the external points of capture are considered centers of the rectangles, the sides of which equal the distances between traps and the corners are so connected so as to enclose the less area.

MATERIALS AND METHODS

By means of numbered stakes, the study areas were set up in selected rice fields in Siniloan, Laguna. Work in these areas focused on the study of rat movement, size and shape of home range, density, and survival rates based on the capture-release-recapture method. Prevailing farm practices and weather conditions were recorded.

Wet season. The study area (Figure 1) consisted of six rectangular paddies totalling about 5,400 sq. m.. It was bounded on the northern side by *Scirpus grossus* grasses; on the east by a marshy area and shorter grasses mostly *Cyperus imbricatus* and *C. compactus*; on the south and west by rice fields. The eastern half of the field was usually left uncultivated during the season as it was often deeply flooded. The other half was also submerged almost throughout the year.

In this study area, 50 locally made live traps (17 x 28 x 13 cm. were cages) were set 10 meters apart along the dikes. The live traps were baited with coconut in the afternoon and inspected early the next morning. Live trapping was done every other week, each trapping period lasting three nights. This portion of the study lasted six months to include the entire wet season crop and the land preparation and transplanting of the next crop.

Dry season. During the dry season more fields, including the previously marshy areas, were cultivated and planted to rice of the C-4 variety. A bigger (approximately 16,900 sq. m.) and more uniform area (Figure 2) adjacent to the wet season plot was selected for the rest of the study.

A total of 196 collapsible live traps were set 10 meters apart near numbered stakes arranged in a permanent grid inside the paddies. Traps were baited with sweet potato late in the afternoon and inspected early the next morning. Trapping was also done every other

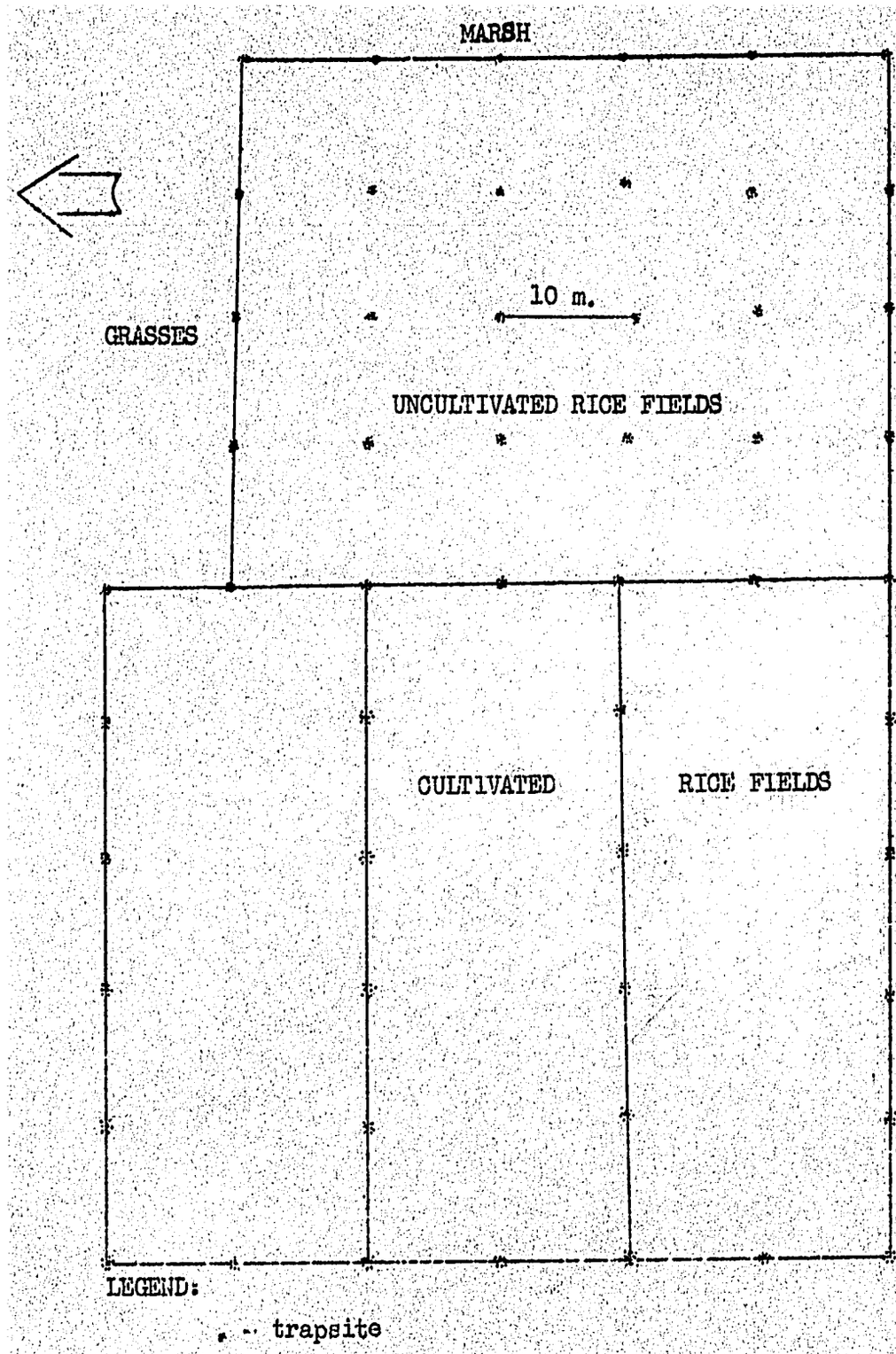

Figure 1. Wet season study area, with traps set along paddy dikes.

week to cover the following stages of the dry season rice crop: 4 weeks after transplanting (WAT), 8 WAT, 12 WAT, and 1 week after harvest. Each trapping period lasted three nights.

In both seasons, every rat was marked on its first capture by earpunching or by numbered aluminum ear tags. After determining the sex, weight, reproductive condition, and visible parasitism, the numbered rat in good condition was released at the site of capture. Sites of first capture and subsequent recaptures were noted.

During the last trapping period, snap traps were set at 15-meter interval for three consecutive nights around the grid in an attempt to recover marked rats that may have emigrated or shifted home range up to 75 meters from the sides of the grid.

Radio-tracking. Radio-tracking was done a week before harvest of the dry season crop to supplement the recapture data. Only seven rats caught at least 10 meters from the sides of the grid were fitted with miniature transistorized radio transmitters. The rats were monitored at least once every six hours from time of release until no further contacts could be made. The dike along line 6 of the grid served as the reading dike (Figure 2). Most of the points were taken simultaneously by two radio receivers stationed near points 6-1 and 6-4. The trap sites in the grid also served as reference points for the approximate locations of the rats.

Home ranges and movements. The distance traveled by a marked or radio-monitored rat was measured by taking the shortest distance

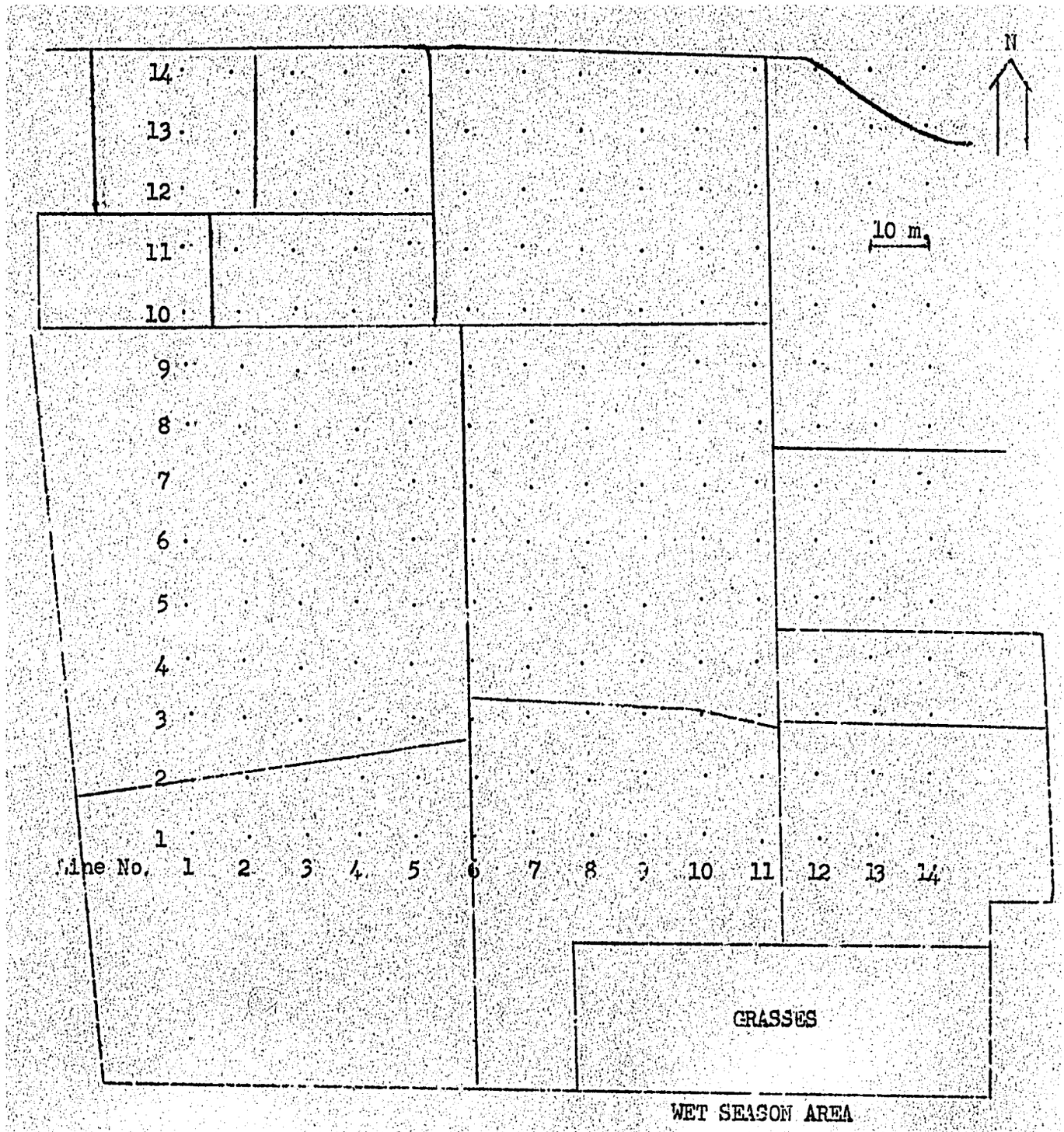

Figure 2. Dry season study grid.

between two successive contact points (stations). The distance from release point was taken in a similar manner.

Shape and size of home range was determined by the inclusive boundary strip method (Blair, 1940). Boundary strips equal in width to half the distance between traps (five meters) were laid off around the minimum area wherein the rat was located. The home range was then divided into smaller rectangles and triangles of known dimensions, the sum of the smaller areas being equal to the area of the home range.

Population densities. Population densities were estimated by models, based on capture-release-recapture method, whose requirements were met by the data. For the wet season data, only the Petersen model as used by Bailey (1952) was applied. For the dry season data, Hayne's (1949) graphical model as well as Jolly's (1965) stochastic model were also used. To be able to apply Jolly's (1965) stochastic model, the March and April data were combined, and the recapture in June was excluded as it was made outside the study grid. Marked animals captured and recaptured within the same month and animals that escaped untagged were excluded from the computations. Population densities per hectare were based on the number of rats in the effective census areas as defined by MacLulich (1951).

RESULTS AND DISCUSSION

Home ranges and movements. Figures 3a and 3b show the apparent home ranges of individually marked rats based upon recapture data.

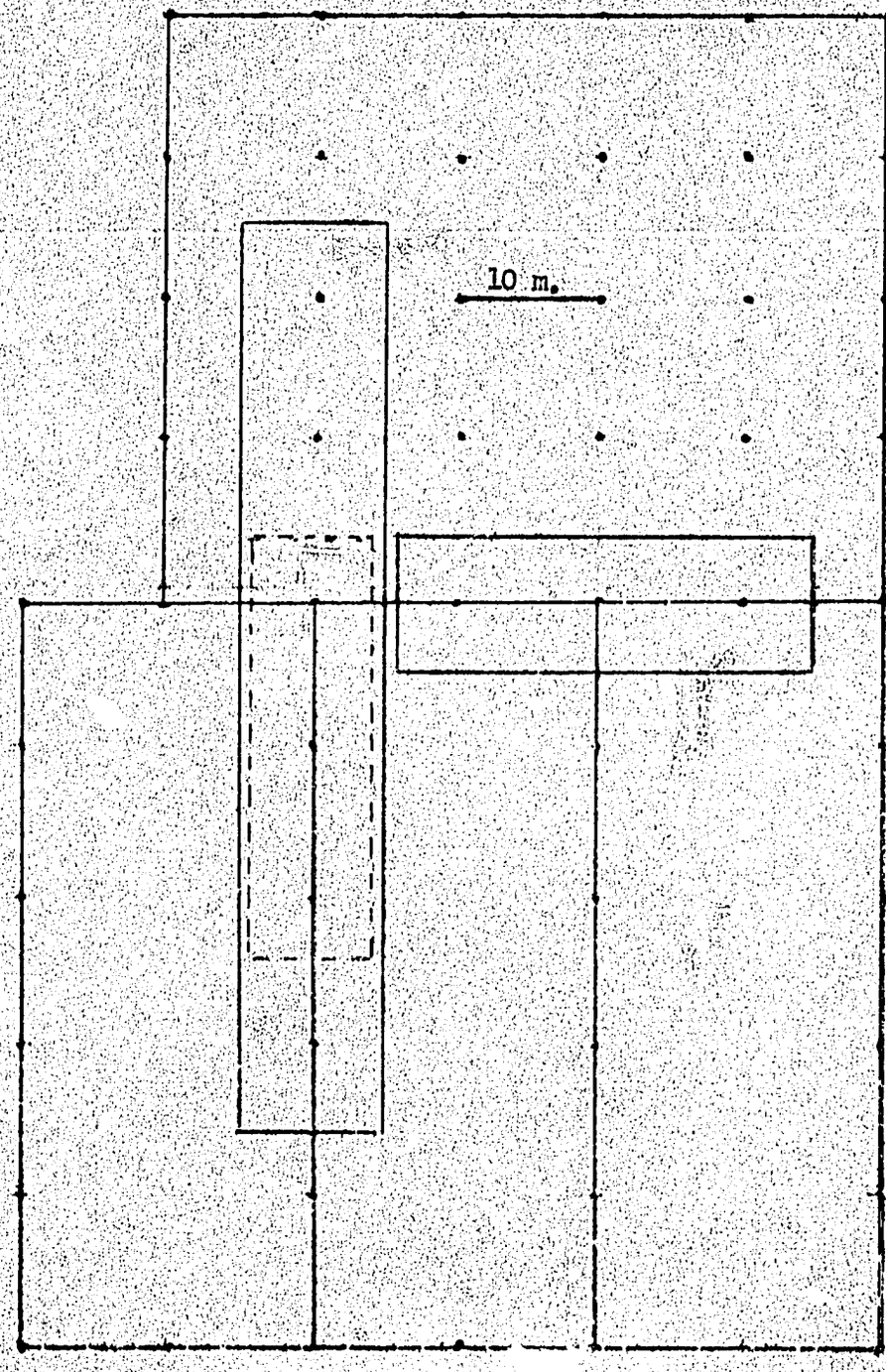

Figure 3a. Apparent home ranges of individually marked rats based upon wet season recapture data.

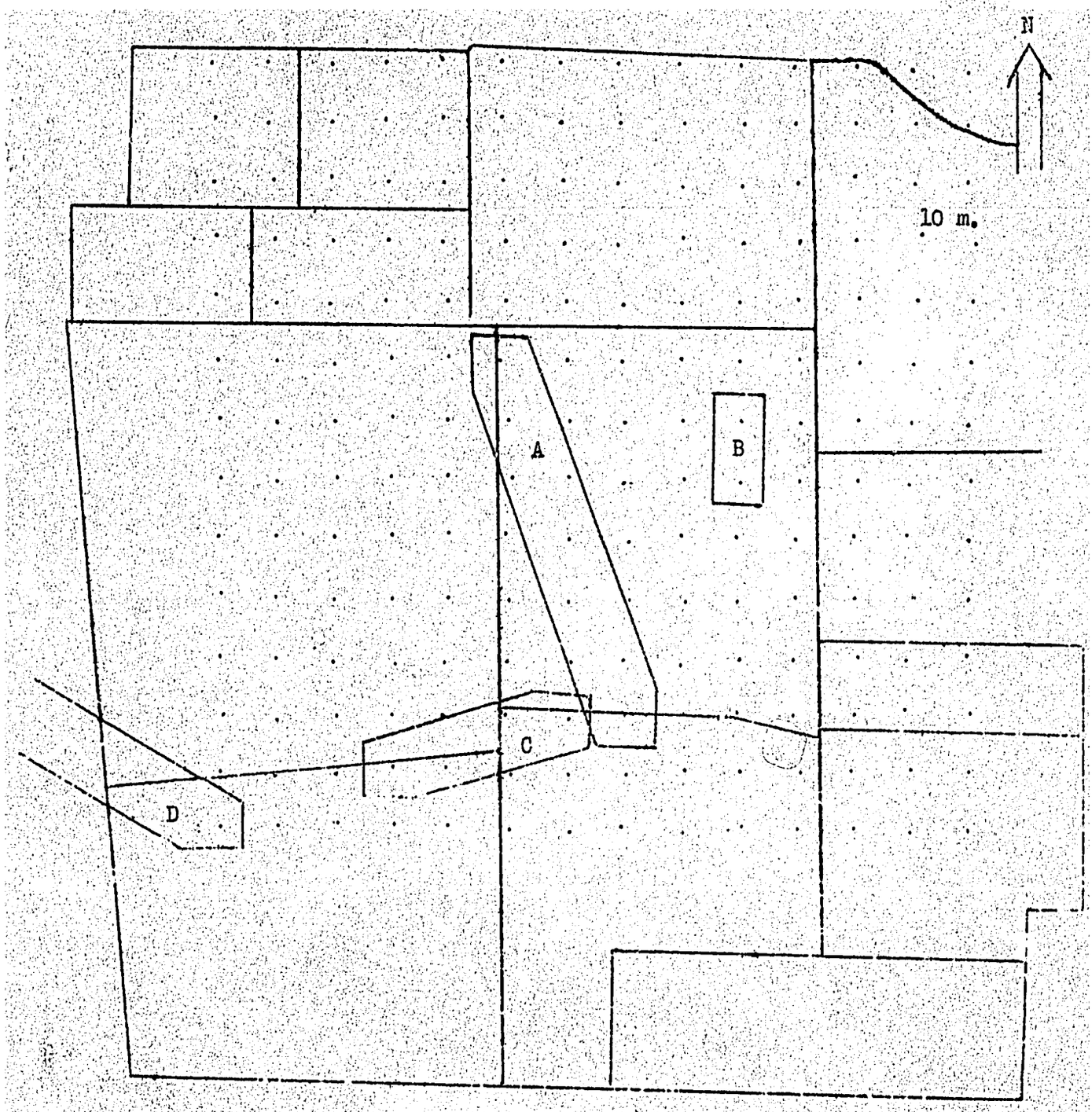

Figure 3b. Apparent home ranges of individually marked rats based upon dry season recapture data.

All rats were recaptured only once over a period of four months during the wet season, and one month in the dry season. Individual home ranges based on the two stations, measured from 300 to 600 sq. m. (wet season data) and from 200 to 800 sq. m. (dry season data). Overlapping of home ranges was evident. Transients were also included as indicated by one home range extending beyond the study grid.

Sizes and shapes of individual home ranges of six radio-monitored rats are shown in Figure 4a. The home ranges of the radio-monitored rats, likewise, were not mutually exclusive. Most of the detected home ranges extended well beyond the study area.

The approximate sizes of the home ranges based on two to eight stations were from 400 to 4080 sq. m., twice up to five times larger than the sizes based on two stations (recapture data). Based on the second up to the last day radio-tracking data (three to four stations), maximum home range measured approximately 2400 sq. m.. These data could indicate that the observed range size is proportional to the number of contacts or captures of the same individual as reported by Stickel (1954). Range size increases with more recaptures until a level approximating the true range is reached. Davis (1953b) suggested the need to recapture a single individual about 15-20 times to obtain adequate data.

Areas A and D were occupied by juvenile female rats, C and F by adult males, while areas B and E were occupied by adult female rats (Figure 4a). The juveniles appeared to have larger home ranges (1925-4080 sq. m.) than the adults (400-2160 sq. m.). The adult males

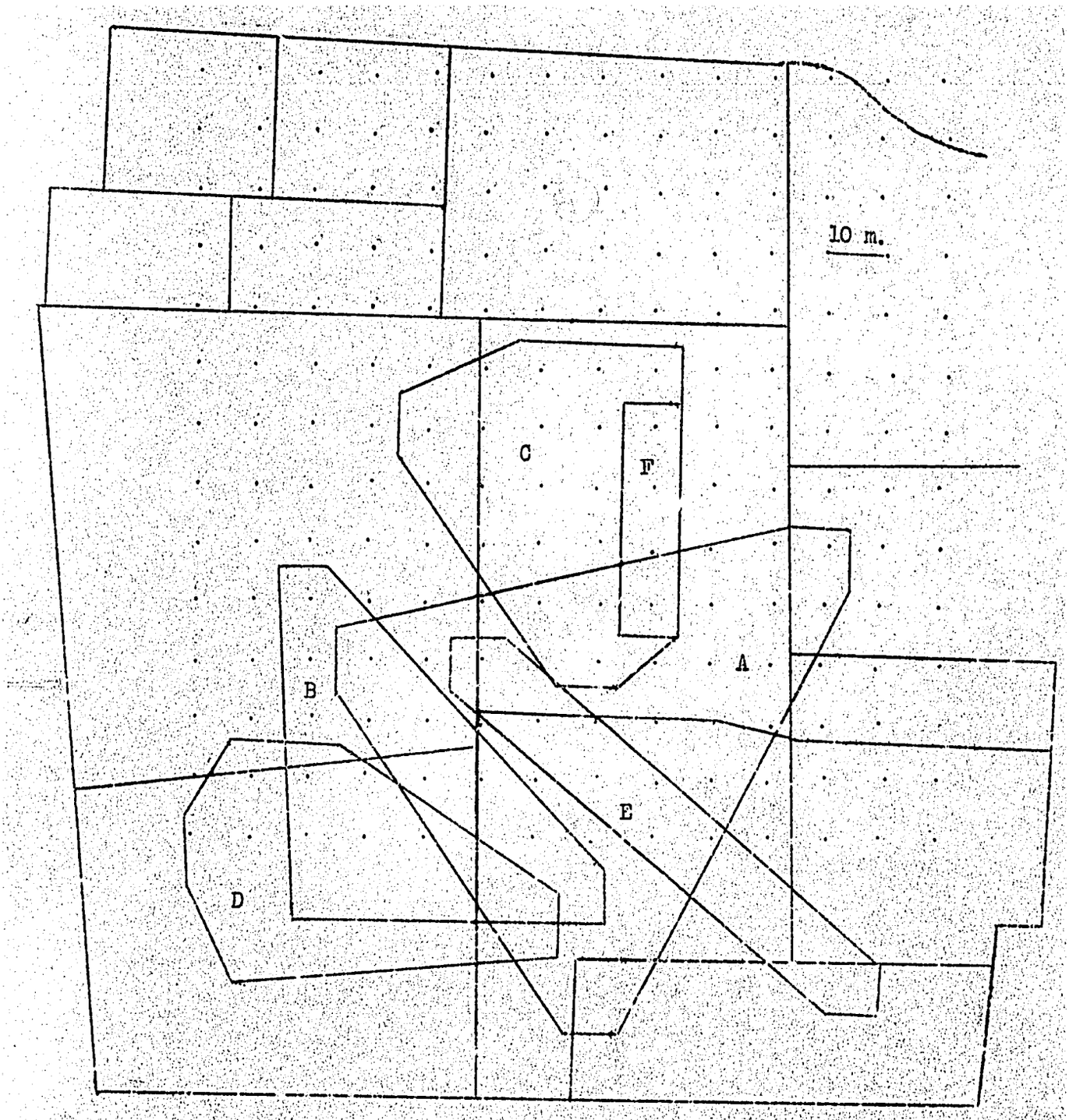

Figure 4a. Inclusive boundary strip home ranges of six radio-monitored rats.

and females had home ranges of similar sizes (up to 2160 and 2100 sq. m., respectively). The relative sizes of the observed home ranges with respect to age and sex agree with the findings of Stickel (1954) and Getz (1961) on woodmice and other species. Subadults may cover more area since they are not as established as do adults in their home ranges. T he adult female inside area E may possibly be a transient to the area and the available data cannot describe its apparent home range.

Movement patterns of radio-monitored rats are shown in Figure 4b. Rats established in their respective home ranges may be erratic but they seem to revolve about an imaginary point which Hayne (1949) called center of activity.

Distances traveled between two successive stations, distances from site of release, and the time involved to cover such distances, are shown in Table 1a for recaptured rats and Table 1b for radio-monitored rats.

Table 1a. Movement of marked rats detected by recapture method.

Sex	Age	Distance traveled (m)	Time elapsed
Male	Adult	20	4 months
Male	Adult	50	4 months
Male	Adult	10	1 day
Male	Adult	50	1 month
Male	Juvenile	10	2 days
Female	Adult	63	2 weeks
Female	Adult	32	1 day

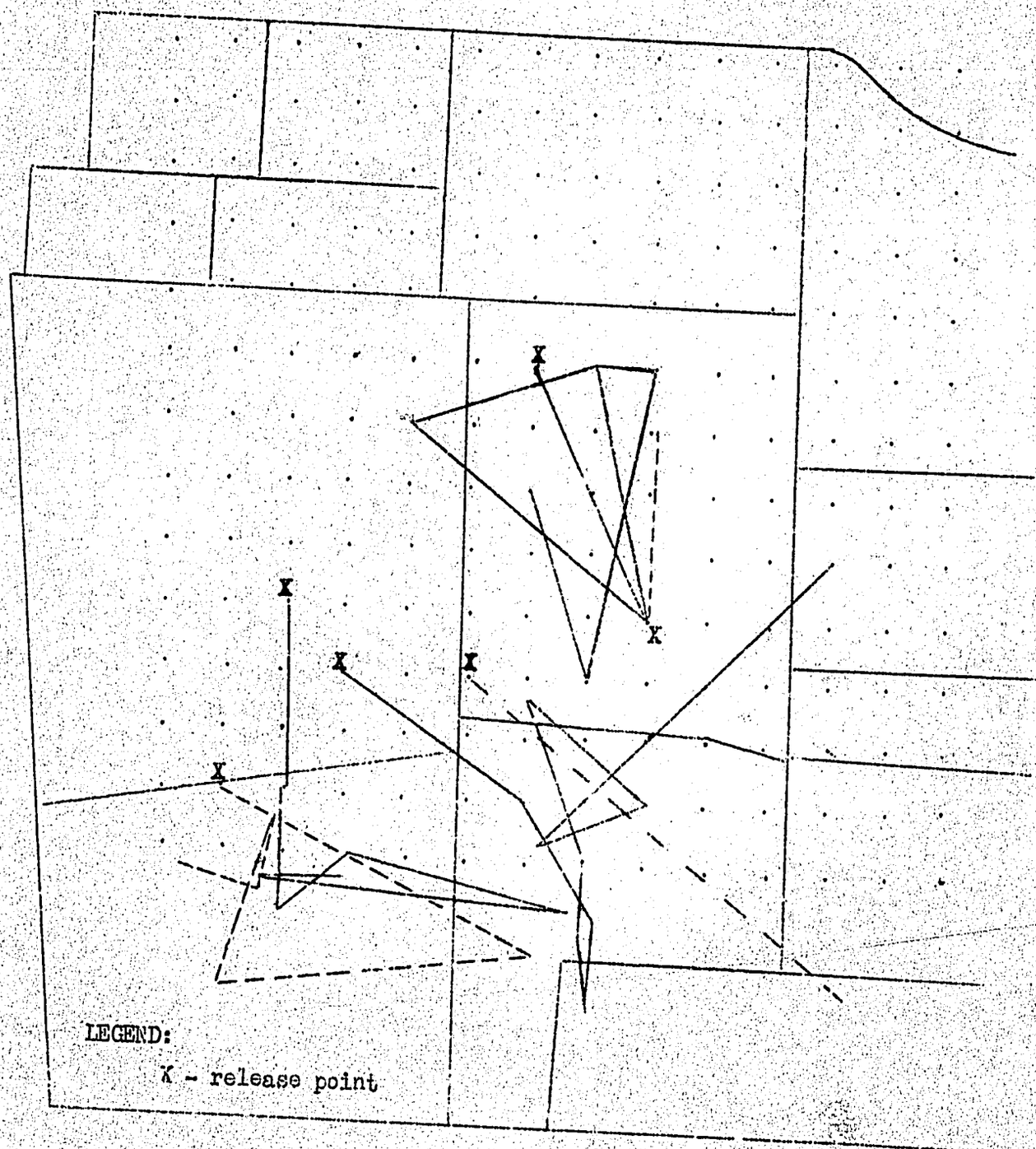

Figure 4b. Movement patterns of radio-monitored rats.

Table 1b. Movement of radio-monitored rats.

Sex	Age	Distance traveled (m)	Distance from release site (m)	Time elapsed
Male	Adult	30	30	6 hours
Male	Adult	45	45	3 hours
		40	10	3 hours
		50	22	6 hours
		50	45	6 hours
		40	10	6 hours
		10	20	2 days
		52	52	6 hours
		32	20	6 hours
Female	Juvenile	55	55	3 hours
		50	30	3 hours
		35	10	6 hours
		15	20	12 hours
		15	15	6 hours
Female	Juvenile	35	35	3 hours
		25	60	3 hours
		15	70	6 hours
		25	50	6 hours
		28	30	2 days
		25	55	6 hours
		70	83	1 day
Female	Adult	80	80	3 hours
Female	Adult	30	30	3 hours
		20	50	3 hours
		15	40	6 hours
		40	70	12 hours
		50	45	6 hours

Disregarding the time element, the average departure of marked rats from their site of release was 26.67 and 38.75 meters during the wet and dry seasons, respectively. Radio-monitored rats had an average of 40.18-meter departure from site of release. From the point of release, juveniles ranged 10-83 meters, adult males ranged 10-52 meters, and adult females ranged 30-80 meters.

Flash floods brought about by heavy rains, weeding, harvesting, and land preparation did not displace the rats to great extent, similar to the findings of LaVoie, et al. (1971). Maximum departure from point of release, as disclosed by the recapture data, under these conditions was only 63 meters. Likewise, some rats remained within 50 meters from point of release for as long as four months. Rats may live long in their established home ranges and may not be immediately displaced by usual farm activities without incorporating control.

Population densities. Tables 2a and 2b show the recapture data along with the monthly trap indices over the entire study period. Listed in Tables 3a and 3b are the population densities and variances as estimated by different models.

Table 2a. Wet season recapture data.

Month	Trap Index (%)	Recapture Same period	Recapture Others	Crop Stage/ Farm activity
September	32.6	0	0	Transplanting
October	29.4	0	0	Booting
November	22.2	0	0	Maturity
December	40.3	0	0	Area cleared
January	32.0	1	2	Land preparatio
February	12.1	0	0	Transplanting

Table 2b. Dry season recapture data.

Month	Trap Index (%)	Recapture Same period	Recapture Others	Crop Stage/ Farm activity
March	1.5	1	0	Pre-booting/ Booting
April	4.1	0	0	Weeding/Maturity
May	4.7	1	1	Harvesting
June	5.0	0	1	Post harvest

Table 3a. Monthly wet season densities as estimated by the Petersen method.

Month	Density[a]	Variance
October	132	7260
November	330	50820
December	1824	66100
January	1020	24400
February	693	213444

[a]Based on the cumulative total number of marked animals since September.

Table 3b. Monthly dry season densities as determined by different models based on the capture-release-recapture technique.

Month	Model				
	Hayne	Jolly		Peterson	
	N	N	s.e.	N	s.e.
March	25	a	a	15	6.71
April	a	a	a	a	a
May	160[c]	55[b]	7.35	120[c]	4.90[c]
	340[d]			819[d]	118.32[d]

[a]Insufficient data, model not applicable.

[b]Recapture within the same month are excluded.

[c]Based on the number of tagged animals starting from the trapping to which the recapture animal belonged.

[d]Based on the total number of animals tagged since March.

It can be seen that the frequency of recaptures, relative to the total number of tagged individuals, affects the precision of the estimates (Table 3b). The Petersen and Hayne estimates are less precise (s.e. = 118.32) when based on the cumulative total number of animals tagged since the first trapping period, than when based on the total number tagged from the trapping period to which the recaptured animal belonged (s.e. = 4.90). As more tagged animals are released during the first period and few are recaptured during the next period, the Petersen and Hayne models tend to overestimate the population size or if they ever come close to the true value, the confidence intervals are widely spread. On the other hand, the Jolly model tends to underestimate the population size (N = 55; s.e. = 7.35), as compared to Petersen's (N = 120; s.e. = 4.90) and to Hayne's (N = 160), when based on very few recaptures, few samples, and low trap indices (Table 2b). Dilution rates incorporated in the Jolly model also cannot be determined due to insufficient recapture data.

The effective census areas (MacLulich, 1951) were 9,995 sq. m. and 28,548 sq. m. for the wet and dry seasons, respectively. Based on these, changes in population densities per hectare were estimated using the Petersen method and presented in Figure 5. Population sizes were higher in the wet season than in the dry season. In both seasons, density increased toward the maturity of the crop. From November to early December (wet season) the rice fields with the maturing crop were abandoned by the farmers. During this time the rice plants in the study area and its vicinity were almost totally damaged by rats.

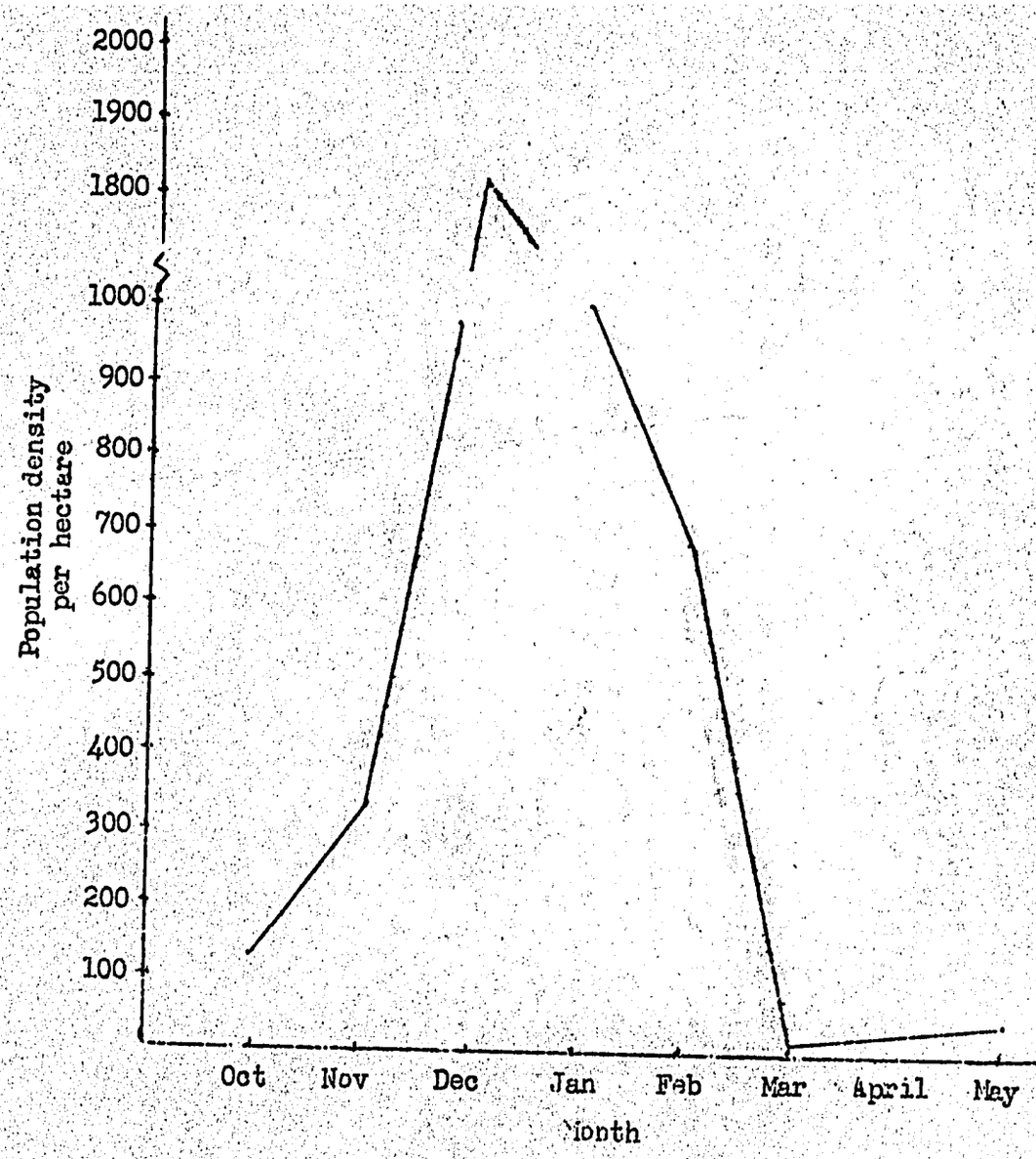

Figure 5. Monthly population density per hectare.

Weeds likewise filled the remaining spaces inside the paddies and on the dikes. The resulting increase in cover and food supply may have favored a net increase in population size. This could also explain the population build up in November which became evident in the later part of December.

It was noted that the proportion of males in the monthly samples was negatively correlated with population level ($r_s = -.87$). No significant correlation was found between population density and the proportion of juveniles in the samples.

Trappability. Table 4 shows a very low dry season probability of survival of marked animals within the study grid ($\phi = .022$). This could mean that for every 100 marked rats, roughly only two remained inside the grid for the next month's trapping period, the rest either died or moved outside the study area.

Table 4. Dry season population parameters estimated by Jolly's stochastic model.

Month	N	V(N)	ϕ	V(ϕ)
March-April	-----	-----	.022	.0414
May	55	54	-----	-----

The parameter (ϕ) could also explain mathematically the few recaptures, under the following conditions:

a. Equal probability of capture of marked and unmarked animals;

b. Low trappability (1.5-5.0 percent during the dry season);

c. Relatively uniform survival rates throughout the study period chances of survival of marked and unmarked animals being equal; and

d. The population is highly mobile.

Under the first two conditions mentioned, the chance of recapturing the marked animal is greatly reduced. During the dry season study, only 2-5 rats were caught on the average for every 100 available traps (Table 2b). Since only 2 out of every 100 marked rats stay for the next month's trapping period (Table 4), chances are the 2-5 rats caught per 100 available traps are all unmarked. The third condition is one assumption of most capture-release-recapture methods, while the last condition is suggested by the movement and home range data.

The rate of recapture, likewise, was inversely proportional to the available food supply and the amount of plant cover as can be infered from Tables 2a and 2b. All recaptures were made from harvest up to the pre-botting stage of the next crop, when these factors were low. From booting toward maturity, and while the fields remained irrigated, there was plenty of food supply in the form of snails, insects, and even weeds which may have competed with the baits in the traps. This could account for the low trapping successes (29.4

and 22.2 percent during the wet season; 1.5 and 4.1 percent during the dry season) and subsequently few or no recaptures during these periods.

These findings are in agreement with those reported by Swink et al. (1969) in Central Luzon and Sanchez et al. (1971) in Siniloan, Laguna. Swink et al. (1969) recaptured over half (64 percent) of their tagged animals during the height of the dry season when food and cover were at a minimum. Sanchez et al. (1971) had a low trap index (7.92 percent) at booting stage and gradually increased toward land preparation for the next crop.

The recapture problem may also be traced to differences in individual behavior of marked animals. As can be seen from Tables 2a and 2b, three rats were captured, marked, and recaptured in just one trapping period while four rats were marked in one period and recaptured only in later trappings. This implies that some rats may tend to be traphappy or trapshy more than others. It may take only one day to recapture a traphappy rat and as long as or even longer than four months to recover a trapshy rat (Table 1a).

Trappability is likewise influenced by the response of rats to the location of the traps as shown in Figure 6. Although the center of the grid was close to the imaginary center of activity, most of the catches were made on the southwesthern portion of the grid. Some traps, especially on the deeply submerged eastern portion of the grid did not have any catch throughout the study. This indicates that rats seem to prefer traps set in higher grounds to traps set above deep irrigation water.

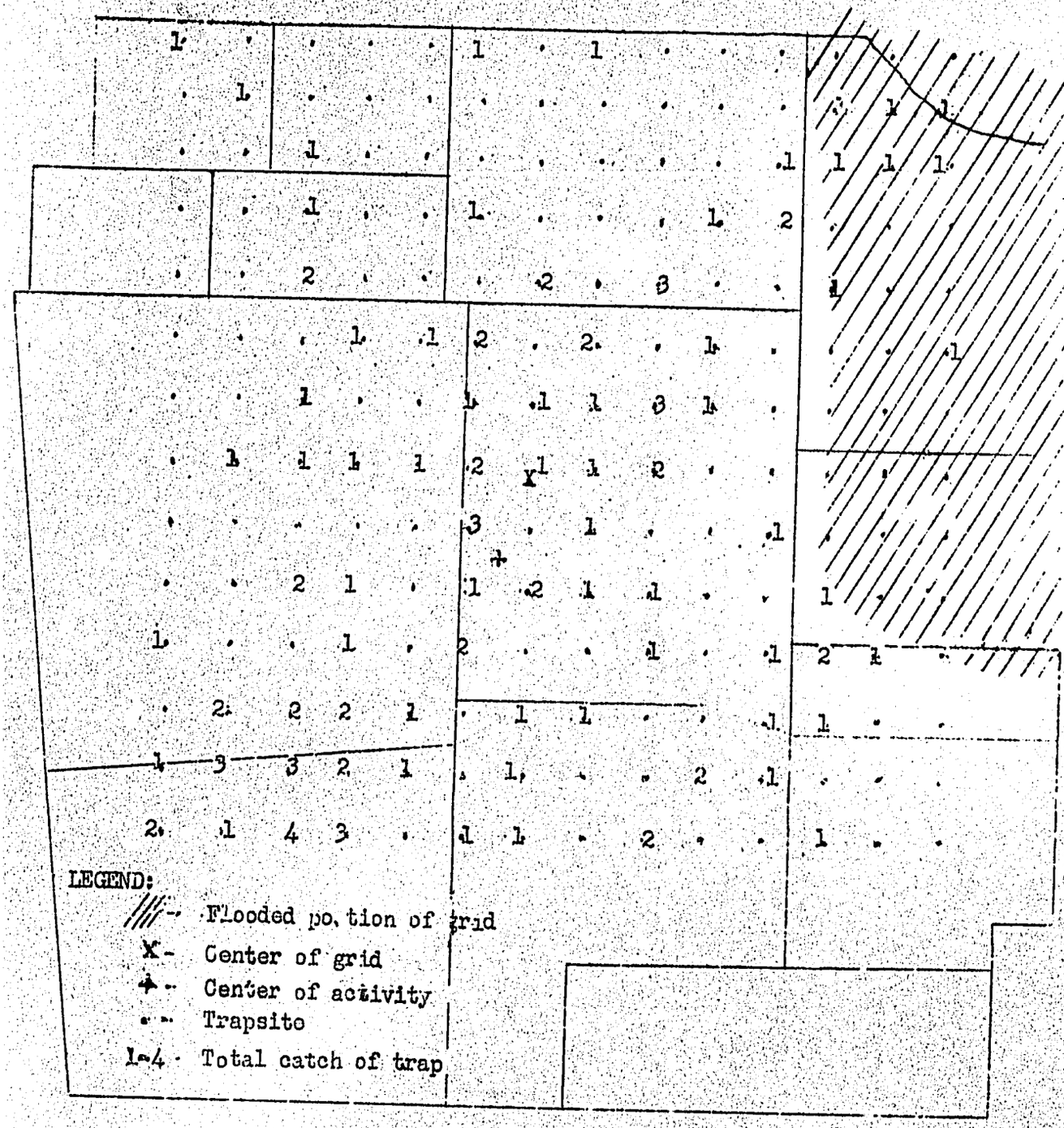

Figure 6. Distribution of catch among traps set in grid.

Setting more traps in grid inside the paddies did not improve recapture data, although the frequency of recapture was better distributed. Trap success was generally higher when traps were set along the dikes during wet season than when traps were set inside the paddies during the dry season. Likewise, in the dry season grid, trap success was higher among traps set within 2.5 meters from the nearest dike (5.02 percent) than among traps set more than 2.5 meters from the nearest dike (3.12 percent).

Trap success was quite variable even within the same trapping period. Generally, more rats were caught during overcast and rainy nights than on clear and moonlit nights.

Capture-release-recapture technique: a case study. This study was conducted not only to estimate population parameters but also to set some guidelines for future works along this line. In general, the information obtained in the present work is much less than expected and the conclusions based on the limited observations remain to be verified. It is hoped that a simple and objective case study of the merits and demerits of this work would be of help to other researchers.

The difficulties encountered in this study approximated those reported by Davis (1953). One problem was the selection of a fairly homogenuous area which approximately coincides with the home ranges of the animals and such that no traps would be set in obviously unfavorable locations. This problem was not successfully overcome. In the first part of the study, the traps were set adjacent to rough

areas. These bordering areas must have contributed some extraneous factors whose individual effects could not be distinguished. In the latter part, not all paddies included in the grid were planted at the same time. Likewise, the fields were not equally flooded due to poor drainage particularly on the eastern portion of the field.

Related to this problem was the great time and effort spent in laying out the grid, setting the traps, and data collection especially in the deeply flooded portions of the field. It took 14 man-hours to stake the 14 x 14 grid inside the paddies, another 4 man-hours to set the 196 live traps, and 3 man-hours to collect the data. More man-hours and care were required during the reproductive stages of the crop. Also, proper arrangement have to be made with the landowners and tenants especially towards maturity of the crop.

It is suggested that a uniform study plot be chosen at least 100 meters from rough areas. Blair (1941) recommended a study plot 10 to 20 times the expected home range of the species. In this case, the average home range of 2564 sq. m. hints the need for a uniform study area at least 160 m x 160 m or its equivalent so as to include the otherwise transients to a 130 m x 130m grid as used in this study. A larger plot will also provide more reliable data per trapping.

Traps should be laid in grid pattern at the same spacing (10 m between traps) if the problem mentioned earlier are not encountered. The grid evenly distributes the traps, simplifies the calculations of home ranges, and facilitates direct comparison with similarly conducted studies. Whenever this is not feasible, the traps may be

set 10 m apart along the dikes of uniformly sized and shaped paddies similar to the wet season study plot. This system of laying traps simulates a combination of different trap spacings recommended by Kikkawa (1964), MacLulich (1951) and other investigators of home ranges of different species.

Traps should be checked time and again for damage to prevent animals from escaping. Also, numbered eartags are better to use than ear punching since the holes may in time become indistinguishable from irregular cuts or damages along the margin of the ears. Care should likewise be exercised in handling the animals to prevent shock and possible death. For bait, it may be more convenient to use sweet potato than fresh coconut.

Thus far, this study has yielded some information worth further inquiry.

The capture-release-recapture technique may not be a practical method for assessing rodent population density unless the problem of few recaptures is solved. On the other hand a change-in-ratio estimate might give a reliable index to population size based on the observed negative correlation between the proportion of males in the sample and population size. A study aimed at estimating population density should be planned such that two or more counter-checking methods are employed simultaneously. For example: the removal method may immediately follow the last data collection for the capture-release-recapture method or the two methods may alternate at some interval time; the change-in-ratio estimate may be used with the capture-release-

recapture method by not returning to the population rats caught in certain trapping periods so as to effect some change in population composition. Many possible combination of methods may be tried but in any case, availability of resources should be considered.

Traps set in grid inside the paddies were no better than traps set along the dikes in detecting movements and home ranges of marked rats. Improved telemetry and tagging techniques should give reliable data in this regard. In the present study, radio-monitored rats presented some problems such as: difficulty in pinpointing the location of individuals especially at night, weak signals, and mixed radio receptions. The tiniest, lightest, most powerful, and most durable transistorized radio transmitter has yet to be developed. It is also vital that the rats fitted with telemetry devices be given enough time to recover from the handling and the attachment of the of the transmitter before movement data be collected. Before adjustment, movement could possibly be attributed to stress or displacement behavior.

Trappability, upon which the estimates of the different parameters are based, is the result of the interaction of several factors stated by Kikkawa (1964) as the environment and the characteristics of the individual as well as the population itself. Unfortunately, it is not easy to detect the separate effects of each factor and conclude that the result is simply the sum of each effect.

As Kikkawa (1964) himself concluded:

> "The standardization of a single method, permitting the minimum expenditure of time and labor for maximum yield of information on all aspects of a population is probably impossible. Design of experiments and observations must be made in accordance with the specific purpose of the study."

In this connection, a limited study may provide more meaningful results than a broad one.

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APPENDIX

ADDITIONAL FORMULAS

Petersen method (Bailey, 1952).

$$N = M(C + 1)/(R + 1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$s^2 = N^2(C - R)/(C + 1)(R + 2) \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Where:

N = population size

M = number tagged in the first period

C = total number caught in second period

R = number of tagged caught in second period

s^2 = variance of N

Hayne (1949).

$$N = \frac{x}{y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Where:

N = population size

x = number of animals previously marked

y = proportion of marked animals in the catch

Stochastic model (Jolly, 1965).

$$N_i = M_i n_i / m_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\phi_i = M_{i+1}/(M_i - m_i + s_i) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Where:

N_i = population size at time i.

M_i = total number of marked animals in population at time i.

m_i = number of marked animals in ith sample

n_i = number captured in the ith sample

s_i = number released from the ith sample after marking

ϕ_i = probability that an animal alive at the moment of release of the ith sample will survive till the time of the (i+1)th sample (emigration and death being synonymous for this purpose). The period of captivity is assumed very short compared with the interval between sampling.

Effective census area (MacLulich, 1951).

$$A = (P + R)(Q + R) - 0.22\ R^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Where:

A = effective census area

P = length of quadrat

Q = width of quadrat

R = mean diameter of home range or range of movement during trapping period.

The thesis attached hereto, entitled "Estimating Population Parameters of the Ricefield Rat (Rattus rattus mindanensis Mearns) prepared and submitted by Edwin A. Benigno in partial fulfillment of the requirements for the degree of Master of Science (Applied Zoology) is hereby accepted.

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