ESTIMATION OF DESERT RODENT POPULATIONS BY INTENSIVE REMOVAL

by

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ABSTRACT

Six tests of the Standard Minimum Method for small mammal population estimation were conducted on two sites in southern Arizona to determine this method's adequacy for sampling nocturnal desert rodent populations. The 256 station grids covered an area of 5.76 ha. and took a total of 1,626 small mammals in 19,968 trap nights. Although four families and sixteen species of nocturnal small mammals were represented, 91.0% of all animals captured were in the family Heteromyidae. Hayne's method of linear regression was used to calculate population estimates, and from these, densities were calculated for total animals and for major species which displayed uniform capture probabilities. Densities for total animals ranged from 11.4 to 107.3 animals per hectare. Increased capture success in the outer trap belts was noted in all but one sample, however, tests for immigration showed only minor movement onto the grid in two out of six samples. Heavy rainfall had a significantly negative effect on capture success twice during the testing. Minor species often displayed a non-uniform probability of capture, but for total animals and major species a five day trapping period preceded by two days of prebaiting gave a uniformly decreasing regression line and reliable population estimates.

CHAPTER 1

INTRODUCTION

History

Numerous investigators have proposed and tested census methods for sampling small mammal populations (Dice, 1938, 1941; Stickel, 1946a; Calhoun, 1964; Grodziński, Pucek, and Ryszkowski, 1966; and others).

Basically, methods have involved either catch-mark-release live trapping or kill trapping. A few have utilized combinations of the two. The results of all methods are affected by numerous variables including, among others, weather, species present, movement of animals, intra and inter-specific interactions, population density and prebaiting.

A uniform census method, accurate for sampling populations under a wide variety of conditions, would lessen the variation encountered in comparing data from different geographic regions and time periods. The Standard Minimum Method was proposed and tested by a group of Polish ecologists for use in the International Biological Program (IBP) (Andrzejewski et al., 1966; Grodziński et al., 1966). A total of eight tests of this method were conducted in Polish hardwood forest associations. These studies were carried out in the Bialowieża National Park in a Querco-Carpinetum mediocuropeum association in autumn 1964, and in spring and autumn 1965 by J. Olszewski and Z. Pucek of the Mammals Research Institute, Polish Academy of Sciences, Bialowieża. A. Drożdż, A. Górecki, and W. Grodziński of the Department of Animal Genetics and Organic Evolution, Jagiellonian University in Cracow, checked the method in spring and autumn 1965, in a beech wood habitat of the Fagetum carpaticum association in the Jamki Gorge, Ojców National Park. K. Adamczyk, H. Chelkowska, M. Janion, and L. Ryszkowski of the Institute of Ecology, Polish Academy of Sciences, Warsaw, conducted their studies in the following associations; Pino-Quercetum, Vaccinio myrtilli-Pinetum subassociation, molinietosum, Tilio Carpinetum, Carici elongatae-Alnetum. Another series of captures was conducted in an association of Glyceriaetum maximae, Caricetum elatae, Carici (Canescentis)-Agrostetum, Stellarie-Deschampsietum.

A further test was conducted by Gentry, Golley, and Smith (1968) on the United States Atomic Energy Commission's Savannah River Plant in South Carolina. The test site included the following plant associations: upland hardwoods (Quercus spp. and Carya spp.); lowland hardwood-swamp forest, (Liquidambar styraciflua; Nyssa sylvatica, Liriodendron tulipifera); and lowland oaks, (Quercus spp.).

If this census method is to be used as a standard technique for IBP studies, it should first be tested and evaluated under a wide variety of conditions. Previous tests were conducted primarily with cricetid rodents (Grodziński et al., 1966) except for the South Carolina study by Gentry et al. (1968), which mainly involved shrews. No one has tested the method or made recommendations for its use in the arid southwestern United States with its predominantly heteromyid rodent communities.

Statement of Questions

This study was undertaken to answer the following questions. Is the proposed IBP Standard Minimum Method an adequate small mammal censusing system for the arid, semi-arid lands of southern Arizona? What accuracy can be expected under conditions such as those tested? What are some of the major factors in this area which are capable of influencing the estimates? What recommendations should be made regarding lengths of prebaiting and trapping periods, type of bait, type of trap, and other variables of the testing procedure?

CHAPTER 2

MATERIALS AND METHODS

Study Areas

Studies were conducted on two dissimilar sites in southern Arizona. One (hereafter referred to as Santa Rita) was on the Santa Rita Experimental Range in the Coronado National Forest south of Tucson, Arizona. Tests were conducted on this site during trapping periods of November 11 through November 16, 1972; and September 7 through September 12, 1973.

The grid was half on a "chained" area (woody vegetation was pulled down by a chain dragged between two bulldozers) of pasture 5N in the S.E. ¼ of the N.W. ¼, Section 12, Township 18 South, Range 14 East. The vegetative type is a Lower Sonoran Desertscrub Desert-grassland ecotone at an elevation of 3200 feet. Common perennial vegetation included *Prosopis juliflora* (Swartz) DC., *Cercidium floridum* Benth., *Acacia Greggi* Gray, *Celtis pallida* Torr., *Opuntia Engelmannii* Salm-Dyck, *Opuntia versicolor* Engelm., *Opuntia fulgida* Engelm., *Encelia frutescens* Gray, *Zinnia pumila* Gray, *Happlopappus tenuisectus* (Greene) Blake, *Gutierrezia Sarothrae* (Pursh) Britt. and Rusby, *Bouteloua Rothrockii* Vasey, *Trichacne californica* (Benth.) Chase., and *Aristida barbata* Fourn. When the area was chained in June 1970, most of the larger perennials (i.e., *Celtis*, *Prosopis*, *Cercidium*, *Acacia*, and *Opuntia* spp.) were torn down to ground level except in the deeper arroyos. The topography on the unchained side of the grid was flat except for a small arroyo near the chained-unchained border. On the chained half of the grid there were several small arroyos up to 2 meters deep and 10 meters wide, running from southeast to northwest. Soil composition was generally sandy with few pebbles and almost no large rocks. The temperatures on the experimental range average a few degrees cooler than in Tucson and the average rainfall is slightly higher than in Tucson.

The second site (hereafter referred to as Red Hill) was on the southeast side of Red Hill, northwest of Tucson, 4.7 miles east, 1.8 miles north of Silverbell Peak, in Section 34 Township 11 South, Range 9 East, at an elevation of 2200 feet.

Studies at this site were conducted from September 9 through September 15, 1972; September 7 through September 12, 1973; September 1 through September 11, 1974; and October 4 through October 6, 1974. Red Hill is in a Lower Sonoran Desertscrub with perennial plant associations including *Franseria deltoidea* Torr., *Larrea divaricata* (DC.) Coville, *Cercidium microphyllum* (Torr.) Rose and Johnston, *Opuntia fulgida* Engelm., *Opuntia* spp., *Carnegiea gigantea* (Engelm.) Britt. and Rose, *Calliandra eriophylla* Benth., *Acacia constricta* Benth., *Jatropha cardiophylla* (Torr.) Muell. Arg., *Mammillaria* spp., *Fouquieria splendens* Engelm., *Encelia farinosa* Gray, and *Bouteloua* spp.

Station A-16 was placed on the southeast side of Red Hill, approximately 60 feet higher than the lowest stations on the east side of the grid. A major arroyo, lined with *Acacia*, *Celtis* and other shrubs, ran from southwest to northeast along row P. Other smaller ravines ran in the same direction throughout the grid. Bedrock was shallow on the slope of the hill, usually less than 1 meter below the surface. The soil was generally sandy, containing small pebbles and cobbles in the flats on the east side of the grid. Larger rocks were scattered and much more common higher on the slope of Red Hill.

Rainfall records from the U.S. Weather Bureau Station in Silverbell for 1906 through 1960 show an average annual rainfall of less than 13 inches with over 5 inches of this occurring in July and August. September has an average of slightly over one inch of rainfall.

Description of the Grid

Grids were set up and operated as per Grodziński et al. (1966). Each consisted of 256 trap stations arranged in 16 rows, 15 meters apart, and 16 lines also 15 meters apart and perpendicular to the rows. Spacing stations was accomplished with a spool of twine flagged with plastic tape at 15 meter intervals. Plastic flagging was tied to a bush near each station to aid in locating it. The grid, including a half of a row boundary area on each side, was a square, 240 meters on a side (total area equal to 5.76 hectares or 14.23 acres). Two kill traps, one standard sized rat trap and one smaller "museum special", were placed at each station and marked with a felt marker to identify the station. With two traps at each of 256 stations, 512 traps were utilized. Trap rows were designated with letters A through P and lines with numbers 1 through 16 giving each station a unique letter-number designation.

Operation of the Grid

After the grid was set up, flagged, and marked, each station was prebaited with a mixture of rolled oats, peanut butter, and water. Approximately one half gram of the bait was placed on the treadle of one of the traps at each station for two nights immediately preceding the trapping period.

The originally proposed prebaiting period was 7 days and later shortened to 5 days (Grodziński et al., 1966) but Cockrum (personal communication) felt that a two day prebaiting period would be sufficient in this area. The prebaiting procedure was altered at the Santa Rita September 1973, and Red Hill September 1973 tests, when no prebaiting period preceded trapping, and Red Hill September 1974 when a 3 day prebaiting period preceded trapping. Traps were baited before dark and checked at 6:00 a.m. during all trapping periods except those in 1973. In 1973 at both sites, traps were checked at 11:00 p.m. and again at 6:00 a.m. No traps were reset during the 11:00 p.m. check in order to restrict variation in the experimental method.

A different plastic bag was used to contain the catch at each station. The animals, along with a tag listing the trap number (and the trap type on the November 1972 Santa Rita and the September 1974 Red Hill samples) were sealed in the bag and brought to the laboratory where species, sex, age, weight, trap type, trap station, and date of capture were recorded.

CHAPTER 3

RESULTS AND DISCUSSION

Species of the Area

Thirty-nine trapping nights on the two sites made a total of 19,968 trap nights and yielded a total of 1,626 nocturnal desert rodents. The catches from Red Hill included 12 species representing 8 genera in 3 families. Members of the family Heteromyidae made up more than 80% of the catch in all cases on this site. Rodent species common at Red Hill during the four capture periods were Perognathus baileyi baileyi Merriam, Perognathus penicillatus pricei Allen, Perognathus intermedius intermedius Merriam, Perognathus amplus taylori Goldman, Dipodomys merriami merriami Mearns, Peromyscus eremicus eremicus (Baird), Neotoma albigula albigula Hartley, Ammospermophilus harrisi harrisi (Audobon Bachman), and occasional captures of Sigmodon hispidus arizonae Mearns, Onychomys torridus torridus (Coues), Peromyscus maniculatus sonoriensis (Le Conte), and Mus musculus subsp.

Captures from Santa Rita included 11 species representing 7 genera in 3 families. Members of the family Heteromyidae made up 64% of the catch in November 1972 and 95% in September 1973. Small mammal species represented by trapping at this site were Dipodomys merriami merriami Mearns, Perognathus baileyi baileyi Merriam, Onychomys torridus torridus (Coues), Reithrodontomys fulvescens fulvescens

Allen, Reithrodontomys montanus montanus (Baird), Reithrodontomys megalotis megalotis (Baird), Notiosorex crawfordi crawfordi (Coues), Peromyscus maniculatus sonoriensis (Le Conte), Perognathus penicillatus pricei Allen, Perognathus amplus taylori Goldman, and Perognathus flavus flavus Baird. Tables 1 - 6 list captures by site and trapping period.

Six different samples by the Standard Minimum Method on the two sites yielded widely varying estimates of populations. This is not surprising when one examines the annual variation in rainfall, hence availability of forage and cover common to these desert regions. The four samples from Red Hill yielded total captures of 164 animals in September 1972, 207 in September 1973, 774 in September 1974 and 238 in October 1974. At Santa Rita 111 animals were caught in November 1972 and 134 were caught in September 1973.

Fluctuations in the species present and their percentages of the total catch show that substantial variation in community structure can occur annually. Tables 7 and 8 show the species present and their per cent of the total catch from each of the six trapping periods.

Trap Type Effectiveness

As previously mentioned two trap types were used in the tests. Each trap station had one museum special and one rat trap. Data from Santa Rita November 1972 and Red Hill September 1974 on differential trap success (museum specials versus rat traps) showed highly significant differences by estimation of a proportion. Santa Rita November 1972 had a total capture of 111 animals, 70 in museum specials and

TABLE 1. Nightly captures of species at Red Hill September 1972.

Species	Number captured per night of removal						
	1	2*	3	4	5	6	Total
Perognathus baileyi	26	14	8	7	3	1	59
Perognathus amplus	10	4	3	1	5	3	26
Perognathus intermedius	10	5	1	1	2	3	22
Dipodomys merriami	11	4	4	0	0	1	20
Mus musculus	1	6	4	2	1	0	14
Perognathus penicillatus	2	4	2	1	0	0	9
Neotoma albigula	2	2	0	1	0	0	5
Ammospermophilus harrisi	1	1	0	0	0	0	2
Sigmodon hispidus	0	2	0	0	0	0	2
Peromyscus eremicus	0	1	3	0	0	1	5
Totals	63	43	25	13	11	9	164

*Due to the influence of heavy rainfall, captures from the second and third nights of trapping were summed and presented as the capture on night two.

TABLE 2. Nightly captures of species at Santa Rita November 1972.

Species	Number captured per night of removal						
	1	2	3	4	5	6	Total
Dipodomys merriami	25	5	2	1	5	0	38
Perognathus baileyi	24	5	1	1	1	1	33
Onychomys torridus	11	3	0	1	0	3	18
Reithrodontomys fulvescens	7	2	0	1	2	0	12
Reithrodontomys montanus	1	0	1	0	0	0	2
Reithrodontomys megalotis	1	0	0	0	0	0	1
Notiosorex crawfordi	0	2	0	0	2	2	6
Peromyscus maniculatus	0	0	0	0	1	0	1
Totals	69	17	4	4	11	6	111

TABLE 3. Nightly captures of species at Red Hill September 1973.

Species	Number captured per night of removal						
	1	2	3	4	5	6	Total
Perognathus baileyi	22	15	22	12	6	9	86
Perognathus amplus	10	13	13	12	11	12	71
Dipodomys merriami	8	2	2	4	2	1	19
Perognathus intermedius	5	1	4	1	0	1	12
Perognathus penicillatus	0	5	0	1	1	2	9
Neotoma albigula	5	1	0	0	0	0	6
Peromyscus eremicus	0	2	0	0	0	0	2
Peromyscus maniculatus	1	0	0	0	0	0	1
Ammospermophilus harrisi	0	1	0	0	0	0	1
Totals	51	40	41	30	20	25	207

TABLE 4. Nightly captures of species at Santa Rita September 1973.

Species	Number captured per night of removal						
	1	2	3	4	5	6	Total
Perognathus baileyi	20	25	11	11	7	2	76
Perognathus penicillatus	4	6	5	0	2	2	19
Perognathus amplus	4	2	7	1	2	2	18
Dipodomys merriami	3	4	3	1	3	1	15
Reithrodontomys montanus	0	0	3	0	0	0	3
Reithrodontomys megalotis	0	0	0	1	0	0	1
Perognathus flavus	0	0	0	1	0	0	1
Onychomys torridus	0	0	1	0	0	0	1
Totals	31	37	30	15	14	7	134

TABLE 5. Nightly captures of species at Red Hill September 1974.

Species	Number captured per night of removal										
	1	2	3	4	5	6*	7	8	9	10	Total
Perognathus baileyi	182	68	34	28	20	29	17	11	20	14	423
Perognathus penicillatus	29	24	8	4	17	8	4	4	4	8	110
Perognathus amplus	18	22	17	6	5	8	2	4	3	3	88
Perognathus intermedius	10	15	2	8	10	8	2	7	4	1	67
Dipodomys merriami	12	7	2	5	2	6	3	0	2	5	44
Peromyscus eremicus	2	1	2	2	0	4	3	1	0	3	18
Neotoma albigula	3	4	2	1	2	2	1	0	0	0	15
Ammospermophilus harrisi	0	0	1	0	1	3	0	2	0	0	7
Onychomys torridus	0	0	0	0	0	0	0	1	0	1	2
Totals	256	141	68	54	57	68	32	30	33	35	774

*Due to the influence of heavy rainfall, captures from the sixth and seventh nights of trapping were summed and presented as the capture on night six.

TABLE 6. Nightly captures of species at Red Hill October 1974.

Species	Number captured per night of removal 1	2	3	Total
Perognathus baileyi	74	26	4	104
Dipodomys merriami	32	6	2	40
Perognathus intermedius	19	13	1	33
Perognathus penicillatus	18	7	3	28
Perognathus amplus	7	3	2	12
Peromyscus eremicus	8	3	4	15
Neotoma albigula	2	1	1	4
Onychomys torridus	0	1	1	2
Totals	160	60	18	238

TABLE 7. Species percentages of total catch for each Red Hill test.

Species	Sept. 1972	Sept. 1973	Sept. 1974	Oct. 1974
Perognathus baileyi	35.9	41.5	54.7	43.7
Perognathus amplus	15.9	34.3	11.4	5.0
Perognathus intermedius	13.4	5.8	8.7	13.9
Dipodomys merriami	12.2	9.2	5.7	16.8
Mus musculus	8.5	absent	absent	absent
Perognathus penicillatus	5.5	4.3	14.2	11.8
Neotoma albigula	3.0	2.9	1.9	1.7
Ammospermophilus harrisi	1.2	present	present	absent
Sigmodon hispidus	1.2	absent	absent	absent
Peromyscus eremicus	3.0	present	2.3	6.3
Peromyscus maniculatus	absent	present	absent	absent
Onychomys torridus	absent	absent	present	present

present = less than 1.0 per cent

TABLE 8. Species percentages of total catch for each Santa Rita test.

Species	Nov. 1972	Sept. 1973
Dipodomys merriami	34.2	11.2
Perognathus baileyi	29.7	56.7
Onychomys torridus	16.2	present
Reithrodontomys fulvescens	10.8	absent
Notiosorex crawfordi	5.4	absent
Reithrodontomys montanus	1.8	2.2
Reithrodontomys megalotis	present	present
Peromyscus maniculatus	present	absent
Perognathus penicillatus	absent	14.2
Perognathus amplus	absent	13.4
Perognathus flavus	absent	present

present = less than 1.0 per cent

41 in rat traps ($Z = 2.75$, $P < .01$). Red Hill September 1974 had a total capture of 774 animals; 585 in museum specials and 189 in rat traps ($Z = 14.2$, $P < .001$).

Accuracy Influencing Factors

Population estimates were calculated using the regression method of DeLury (1947) and Hayne (1949). The accuracy of estimates made using this method is based on several assumptions, primarily that the probability of capture remains constant for the entire trapping period. This assumption has been found not to hold true under certain conditions tested due to factors such as edge effect, immigration, weather conditions, and interspecific interaction which substantially influence trapping results and in certain cases require that adjustments to the estimates be made (Gentry and Odum, 1957; Chelkowska and Ryszkowski, 1967). Circumstances involved in each trapping period should determine the methods of estimation used and corrections necessary to the Standard Minimum Method. Adjustments or estimate corrections, in the form of exclusion of the catch of from one to three outer trap belts, shortening the number of nights used in calculation of the regression (Grodziński et al., 1966; Ryszkowski, Andrzejewski, and Petrusewicz, 1966; Chelkowska and Ryszkowski, 1967), and attempting to estimate the actual area being sampled by the grid by estimating the home ranges of species present (Hansson, 1969; Smith, Gentry, and Golley, 1969), were used to increase the accuracy of the estimates in the present study.

Edge Effect

"Edge effect" is a term used to indicate the increased probability of capture in the outer trap belts that exists throughout the trapping period. It is caused by the capture of sedentary animals with part of their home range outside the sampling area (Chelkowska and Ryszkowski, 1967; Adamczyk and Ryszkowski, 1968).

Numerous investigators (Dice, 1938; Stickel, 1946a, 1954; Brant, 1962; and others) have attempted to improve the accuracy of density estimates by adding or subtracting a belt around the trapping area. In the present study density estimates were calculated using the boundary areas estimated as per Smith et al. (1969) and compared with those calculated using only the animals captured within the inner homogeneous square. The average difference between the two methods was 9.54% with the inner homogeneous square having the higher estimate in 83% of the comparisons. The method of belt subtraction often eliminates over 50% of the total catch from the calculations. Both estimates were calculated for captures of total animals as well as for captures of major species whenever they demonstrated a constant probability of capture. Figures 1 - 5 show the effect of the edge as increased captures per trap in the outer trap belts. From a visual analysis of these figures a belt up to 30 meters in width is apparent in most cases, although a more conservative boundary of 15 meters was used for density calculations of species displaying an edge effect. Perognathus amplus at Red Hill in 1972 was the only species which did

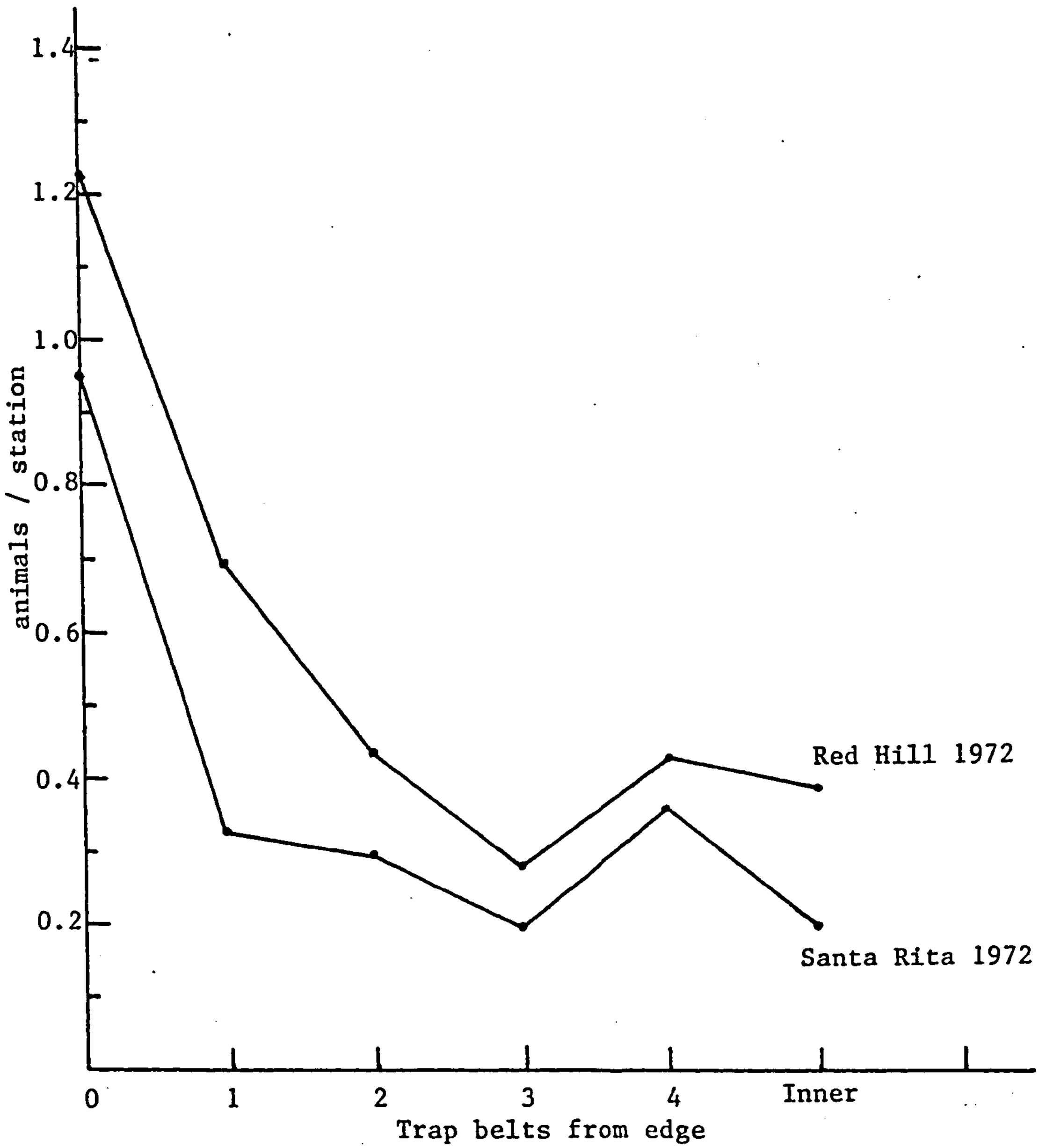

Fig. 1. Edge effect for total animals at Red Hill and Santa Rita 1972.

A graphical representation of the increased rate of capture near the edge for all animals and the entire trapping period.

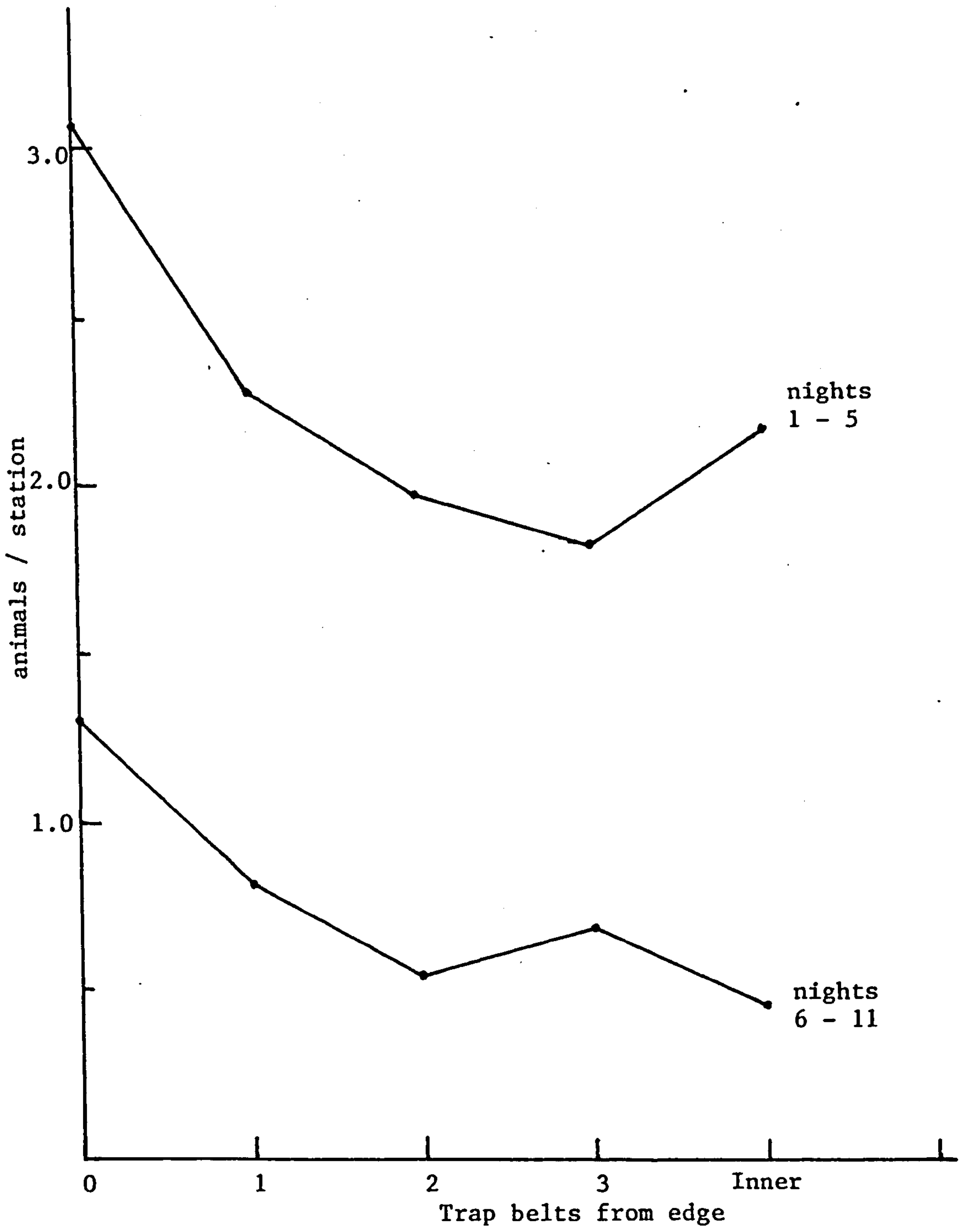

Fig. 2. Edge effect for total animals at Red Hill September 1974.

A graphical representation of the increased rate of capture near the edge for all animals on nights 1 - 5 and 6 - 11.

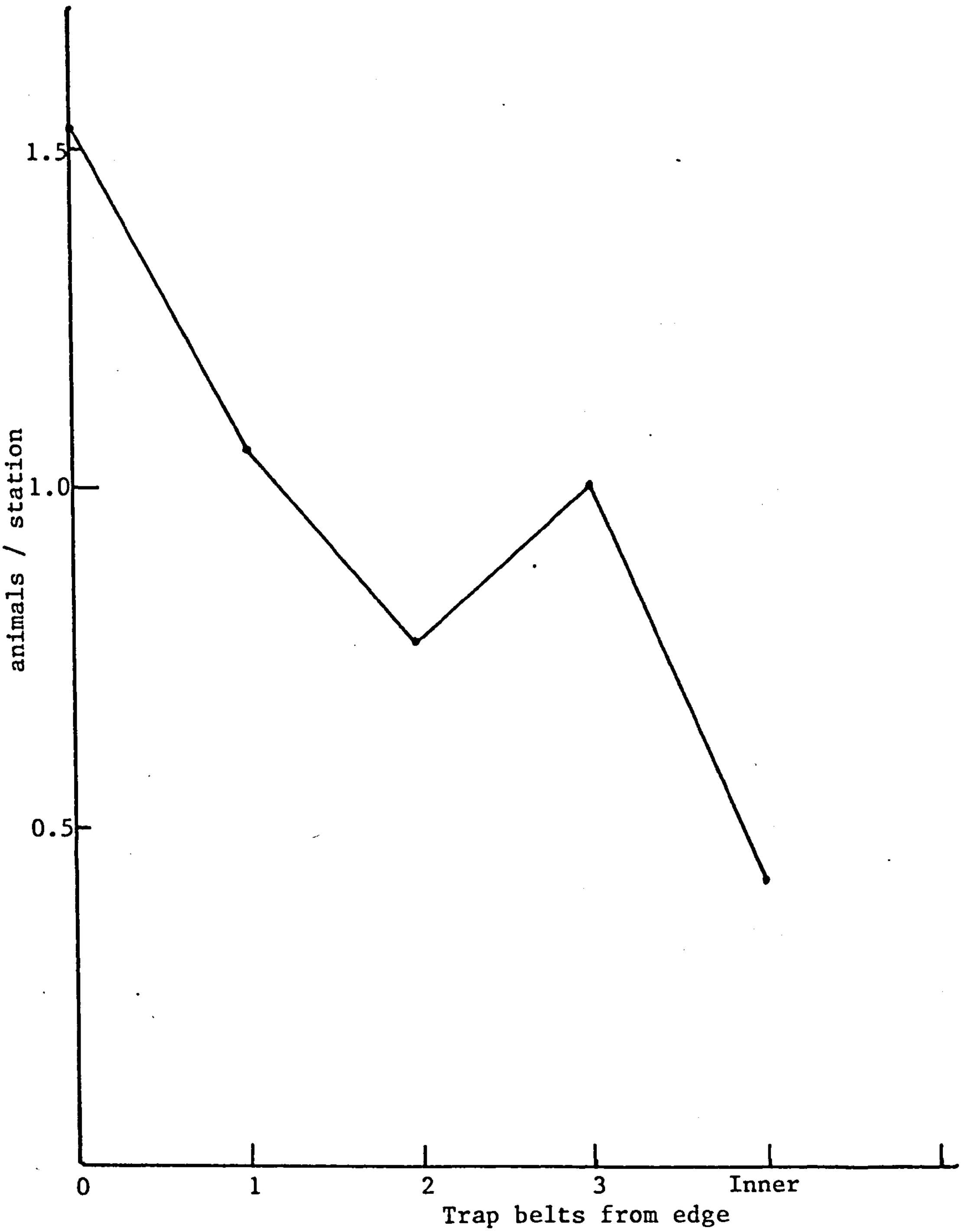

Fig. 3. Edge effect for total animals at Red Hill October 1974.

A graphical representation of the increased rate of capture near the edge for all animals and the entire trapping period.

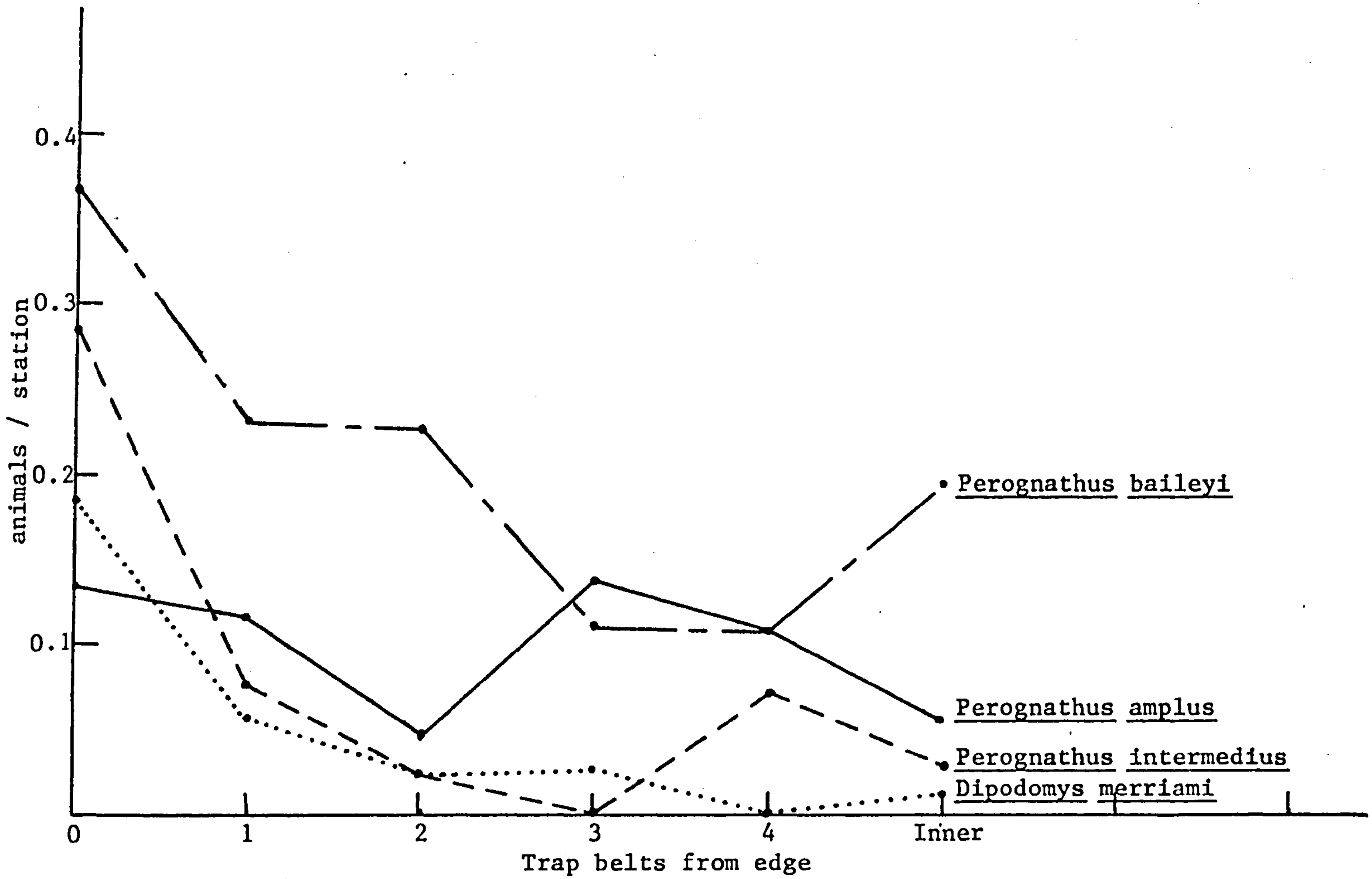

Fig. 4. Edge effect for major species at Red Hill 1972.

A graphical representation of the increased rate of capture near the edge for major species and the entire trapping period.

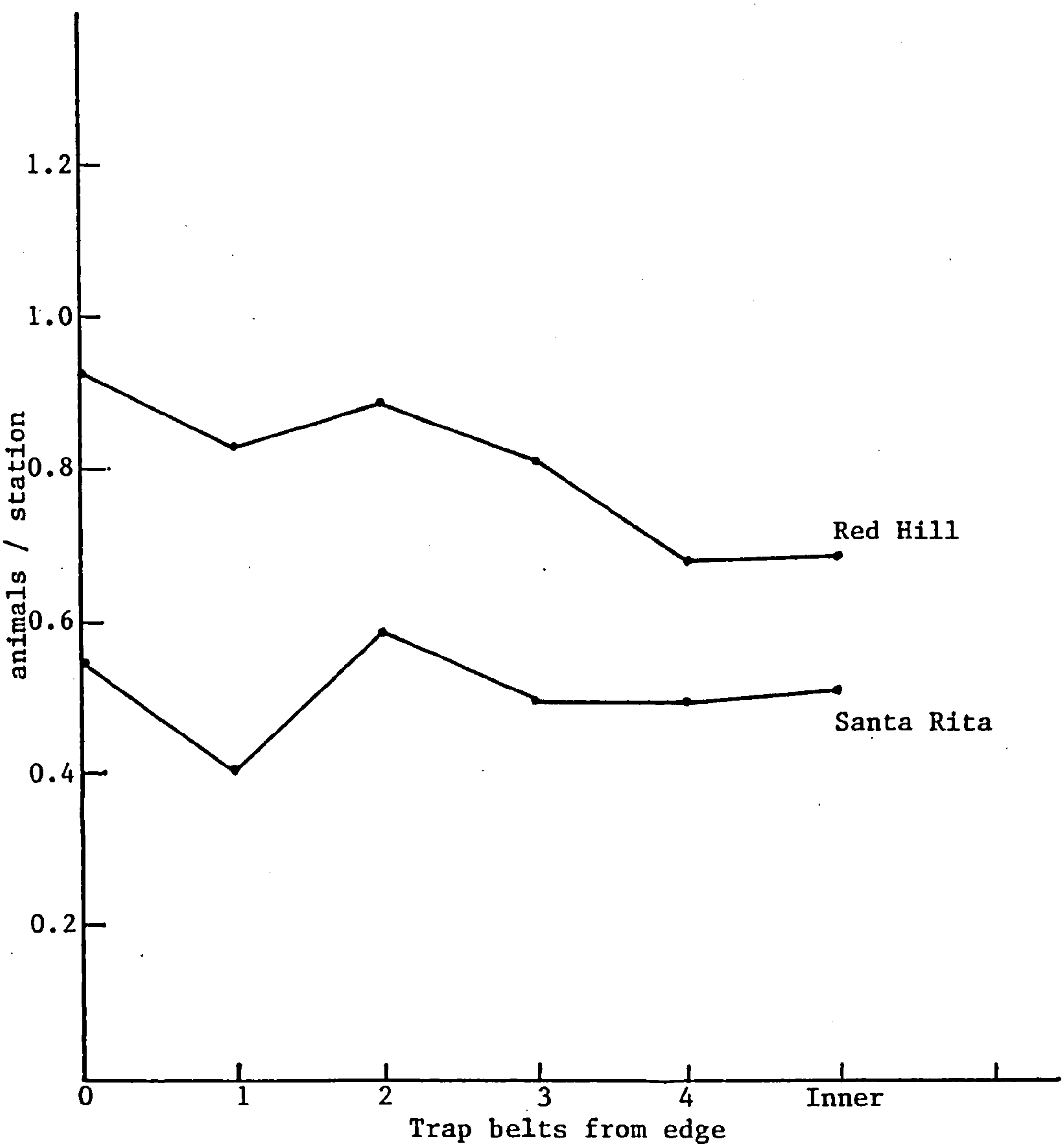

Fig. 5. Edge effect for total animals at Red Hill and Santa Rita 1973.

A graphical representation of the capture success relative to the grid perimeter.

not demonstrate a substantial edge effect. This is apparently due to its small home range.

Immigration

A second possible source of error in estimation is due to immigration; defined as movement onto the grid of animals with their entire home ranges outside the sampling area. After the complete removal of animals from the sampling area, Chelkowska and Ryszkowski (1967) noted immigration by dividing their trap area into an external three row belt and an internal 10 x 10 square and analyzing captures in terms of their previous catch-mark-release data. Gentry et al. (1968) concluded that there was no significant edge effect or immigration in their study by comparing averages of animals captured per trap station in the outer versus the inner rows. Two of the major species on their site were Blarina brevicauda and Sorex longirostris. Aulak (1967) found a significant increase in captures of most species in the outer belt, but showed no significant difference for shrews.

Since the Standard Minimum Method had not previously been used with heteromyid rodents, or in any desert or desert-grassland vegetative types, it was unknown whether immigration or edge effect would be significant. Two methods were used to detect immigration. Dice (1938), Stickel (1946b), and others have indicated that often the males of many rodent species are more mobile and have larger home ranges than the females. From this it can be inferred that if immigration is appreciable, the cumulative male/female ratio of animals captured in outer rows, hence that of the entire grid, should have a positive slope when plotted against successive trapping nights. Figures 6 and 7 exhibit the male/female ratio at Red Hill and Santa Rita 1972 and 1973. Neither of the tests at Santa Rita show any uniform tendency toward a positive slope but both samples from Red Hill have a similar tendency to rise from night three to night six, suggesting slight immigration. Red Hill September 1973 shows the most significantly positive slope based on relatively high numbers of captures. The male/female ratio was significantly higher than the expected of 1.0 for Dipodomys merriami at Santa Rita November 1972, and for Perognathus penicillatus at Red Hill October 1974 ($P < .05$). Total animals at Santa Rita November 1972 showed a male/female ratio higher than expected at $P < .07$.

The second method used to test for immigration involved plotting the capture ratio of the outer over inner rows versus the trapping night (Grodziński et al., 1966; Gentry et al., 1968). If significant immigration occurs, a positive slope should be evident. Figures 8 and 9, depicting the ratios of captures in the outer versus the inner rows from tests at Red Hill in September 1972, September 1973, and September 1974, all showed a slight, uniform tendency toward a positive slope. Figure 10 shows that neither of the tests conducted at Santa Rita show any uniform positive slope.

The agreement in results between the two methods employed in detecting immigration lends further credibility to the hypothesis that immigration is minimal. Both methods demonstrate only slight movement

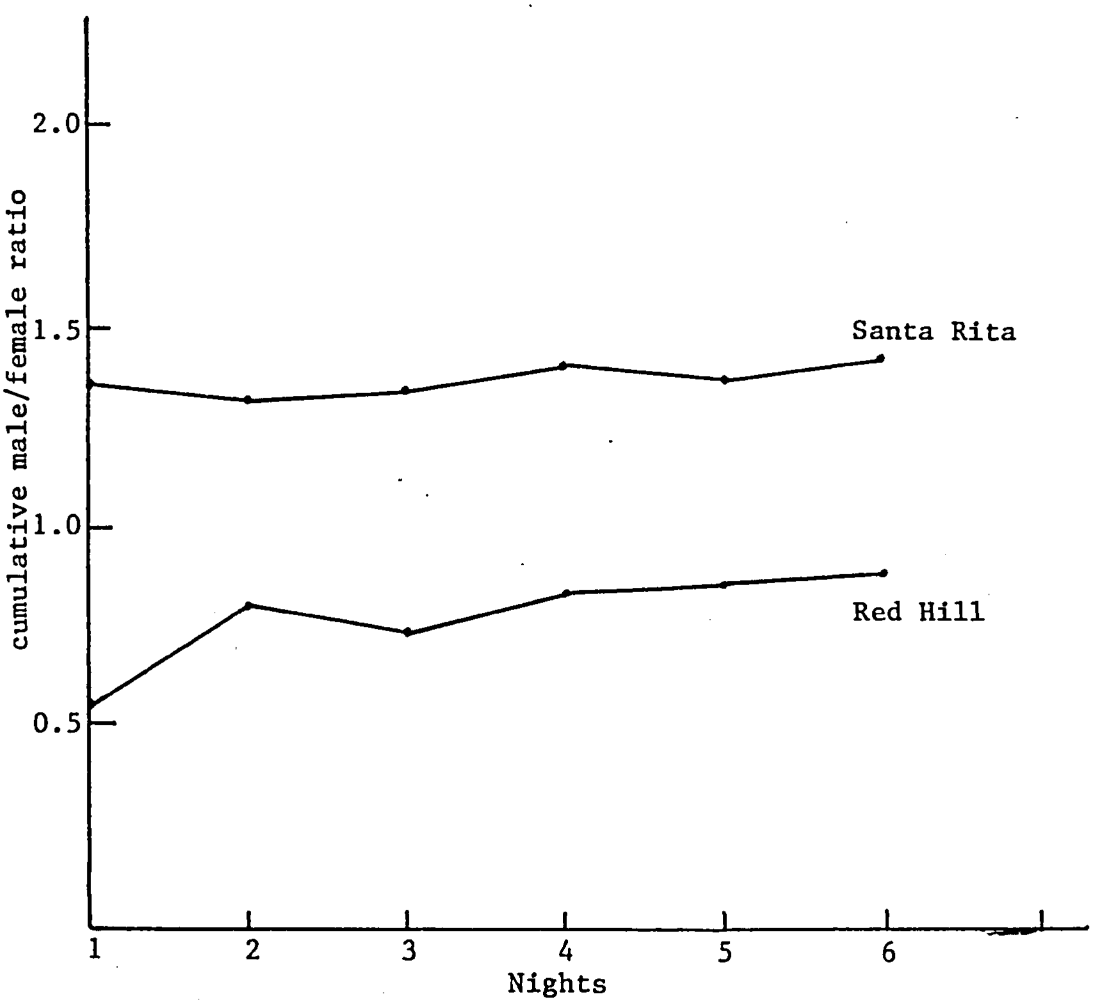

Fig. 6. Sex ratios at Red Hill and Santa Rita 1972.

Cumulative male/female ratios versus trap night for total animals.

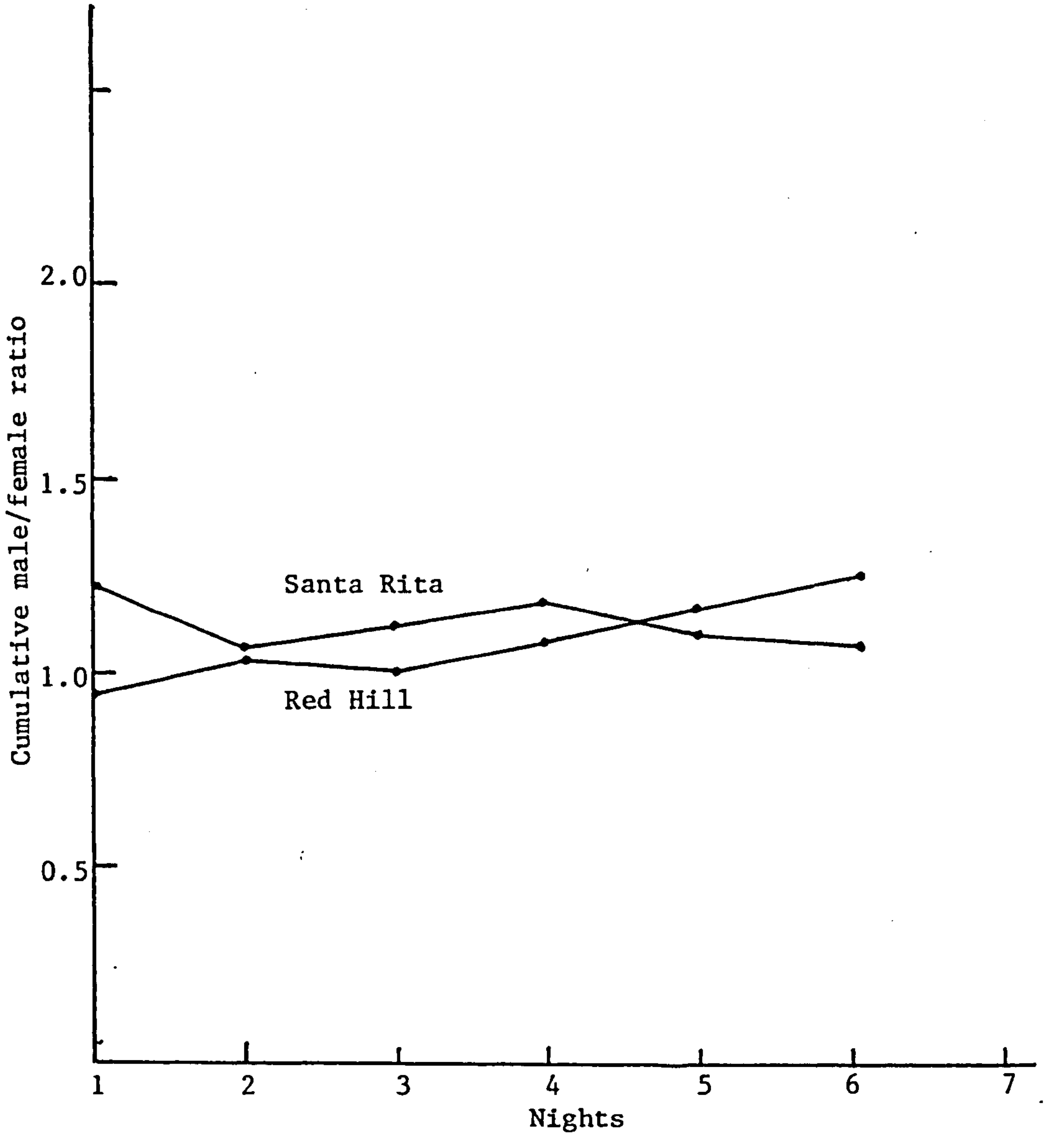

Fig. 7. Sex ratios at Red Hill and Santa Rita 1973.

Cumulative male/female ratios versus trap night for total animals.

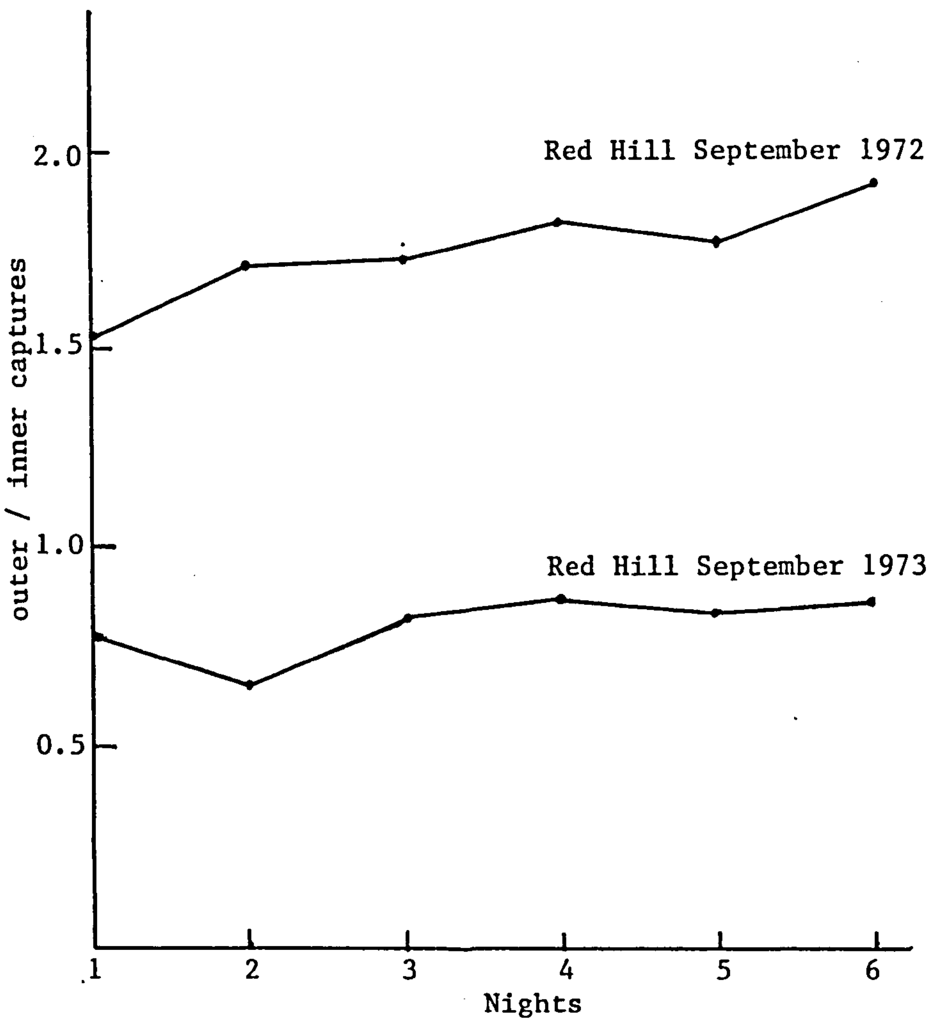

Fig. 8. Trap success of outer over inner rows at Red Hill 1972 and 1973.

Cumulative capture ratio of the two outer over all inner rows versus trap night.

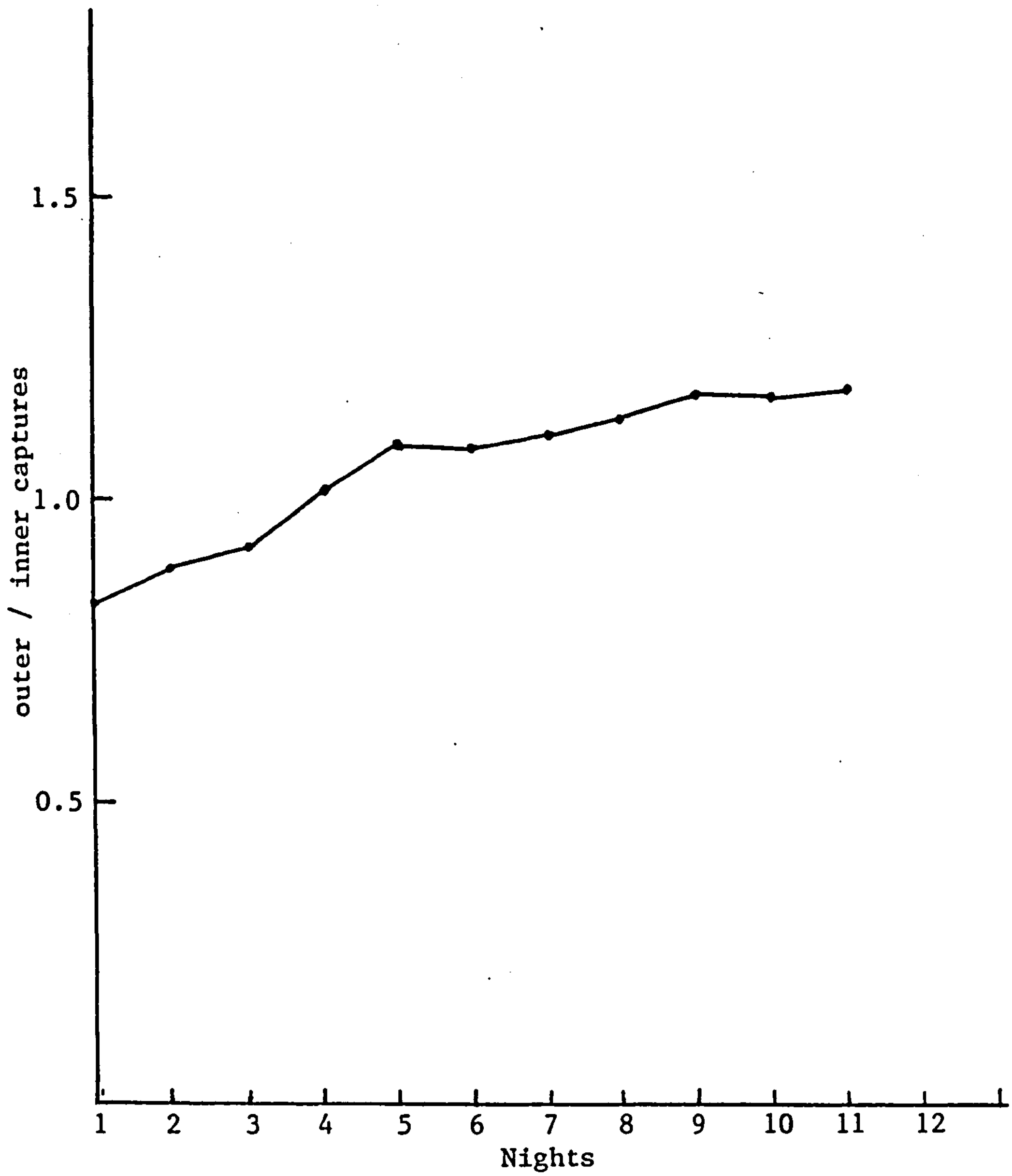

Fig. 9. Trap success of outer over inner rows at Red Hill September 1974.

Cumulative capture ratio of outer over inner rows versus trap night.

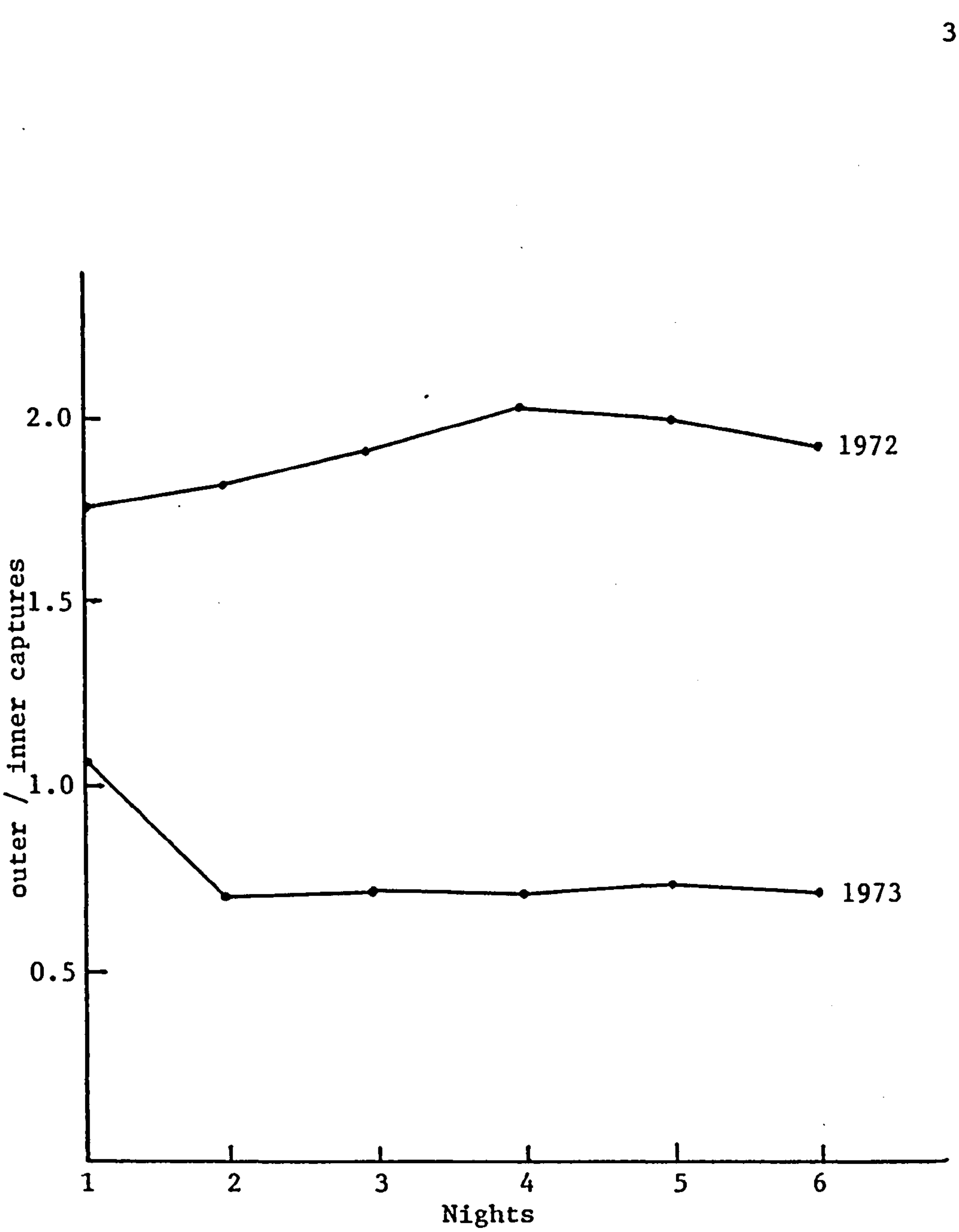

Fig. 10. Trap success of outer over inner rows at Santa Rita 1972 and 1973.

Cumulative capture ratio of the two outer over all inner rows versus trap night.

onto the grid at Red Hill and no immigration at all onto the Santa Rita grid.

Weather Conditions

Since all but one of the tests were conducted in September, the most common adverse weather condition encountered was rainfall. O'Farrell (1974) reported that rains, depending of their severity, had an increasingly negative effect on desert rodent activity. Three heavy rains as well as several lighter showers occurred during the six trapping periods. The light rains had little noticeable effect on the night's catch but the heavy rains had significantly negative effects depending on the time of night, duration, and severity of the rain. The effect on the catch seems due to two factors. First, the two most severe rains encountered, night two of trapping at Red Hill September 1972, and night six at Red Hill September 1974, were hard enough to set off more than 50% of the traps on the grid. The museum specials, which have a higher capture success than rat traps, were especially affected. Secondly, both of these rains occurred during the peak period of rodent activity, just after sunset (O'Farrell, 1974). The combination of these effects lowered the catch to five animals on night two at Red Hill 1972. The expected value calculated by regression was 41 animals. The actual catch on night six 1974 was eleven rodents and although this was in the period when the catch was leveling off, the previous night's catch of 56 and the following night's catch of 50 indicate that the magnitude of the error caused by the rain was significant.

When the catch was altered substantially from the expected value due to weather conditions, as on these two occasions, the sum of the number caught on the night of the rain and the number caught the following night was used in regression calculations as one night's catch.

A third rain occurred on the second trap night at Santa Rita November, 1972. This shower began near midnight and was not as severe as the two previously discussed. The predicted catch on this night was 22 and the actual catch was 17. The subdued effect of that night's rain on the catch is attributed to two factors. First, the rain was less forceful than those that occurred at Red Hill, and secondly, it began after the end of the evening activity period.

These instances demonstrate the severe effect that heavy rainfall may have in influencing probability of capture.

Interspecific Interaction

Under some circumstances interspecific interaction may cause the probability of capture of some species to be so variable as to render estimation by regression impossible.

Data from a 30 day removal study (Calhoun, 1964) suggests the presence of dominant and subordinate species of small mammals. Dominant species have larger home ranges and are more likely to be captured first. This should be especially true when competition is keenest, such as during periods when population densities are high and food supplies are low. It would follow that, under circumstances such as these, subordinate species would have an increased rate of capture later in the trapping period as their home ranges are allowed to expand and as more traps are made available to them. This variation in the probability of capture of subordinate species was most obvious during the September 1974 sample at Red Hill when the number of rodents captured was 374% higher than the previous year. Although the probability of capture for total animals remained constant through the fifth night of trapping, there was a variable probability of capture noted in some of the subordinate species, making estimation of their numbers by regression impossible. Figures 11 and 12 depict the variation encountered in rate of removal, expressed as the nightly percentage of each species total capture, implying variation in probability of capture of subordinate species in a year of low or normal population densities (1972), versus a year of extremely high population densities (1974). The dominant species in terms of total numbers, physical size, and estimated home range size was *Perognathus baileyi*, representing 35.9% and 54.7% of the total catch from Red Hill 1972 and 1974, respectively. Other species present in September 1974 were *Perognathus penicillatus* (14.2%), *Perognathus amplus* (11.4%), *Perognathus intermedius* (8.7%), *Dipodomys merriami* (5.7%), *Peromyscus eremicus* (2.3%), *Neotoma albigula* (1.9%), and *Onychomys torridus* (less than 1.0%).

This interaction, although not significantly influencing the estimates of total animals, eliminates the possibility of estimating some of the subordinate species by regression. In these cases estimates must be made on the basis of total captures. Accuracy of this

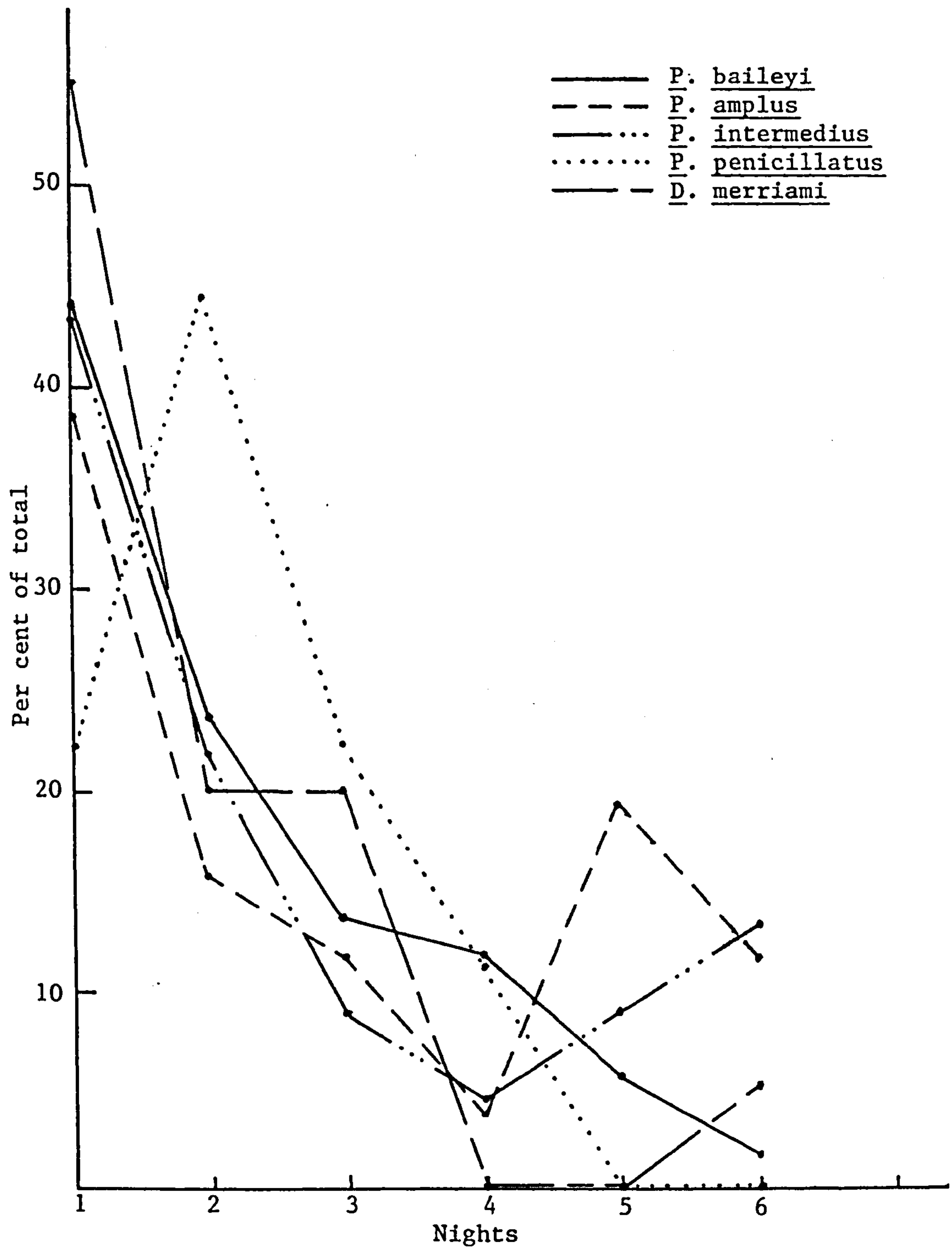

Fig. 11. Nightly per cent of the total catch for each species at Red Hill 1972.

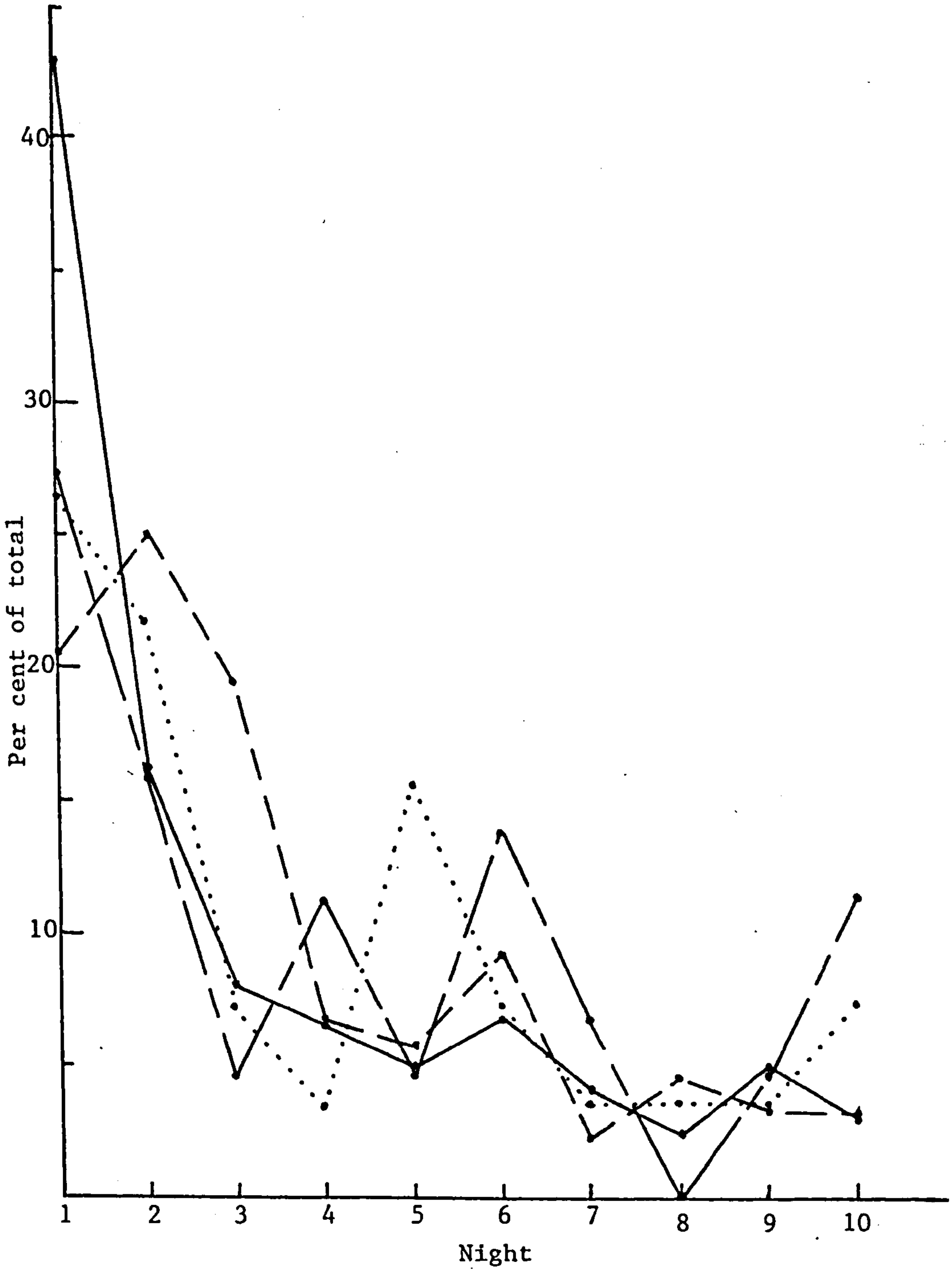

Fig. 12. Nightly per cent of the total catch for each species at Red Hill September 1974.

Due to the influence of heavy rainfall, data from the sixth and seventh days of trapping were summed and presented as day six. See Fig. 11 for legend.

method depends on the correctness of the assumption that nearly all the animals have been caught.

Regression

Estimates of populations were made using the regression method of DeLury (1947) and Hayne (1949). The population estimate is defined as the x intercept (a_x) of the line formed by plotting the number of animals captured per night on the Y axis versus the total number caught on previous nights on the X axis. Slopes (b_{xy} and b_{yx}), means of x and y ($\overline{X},\overline{Y}$), correlation coefficients (r), and intercepts were all computer generated using a CDC 6400. Regression estimates were calculated for varying numbers of nights and portions of the grid in order to reduce the influence of edge effect and immigration. Population densities were calculated from these estimates. Estimation by regression is possible when the animals display a uniform probability of capture for the major portion of the trapping period. Figures 13 - 15 demonstrate regressions of total species and several of the major species at Red Hill September 1972, Santa Rita November 1972, and Red Hill September 1974.

Regression estimates of total species were possible for all samples, although both estimates from 1973 must be considered less reliable due to the lack of prebaiting prior to trapping. This appears to be the cause for the variable probability of capture evident in both of these samples. No successive decrease in captures was noted for the first three nights of either test, causing the

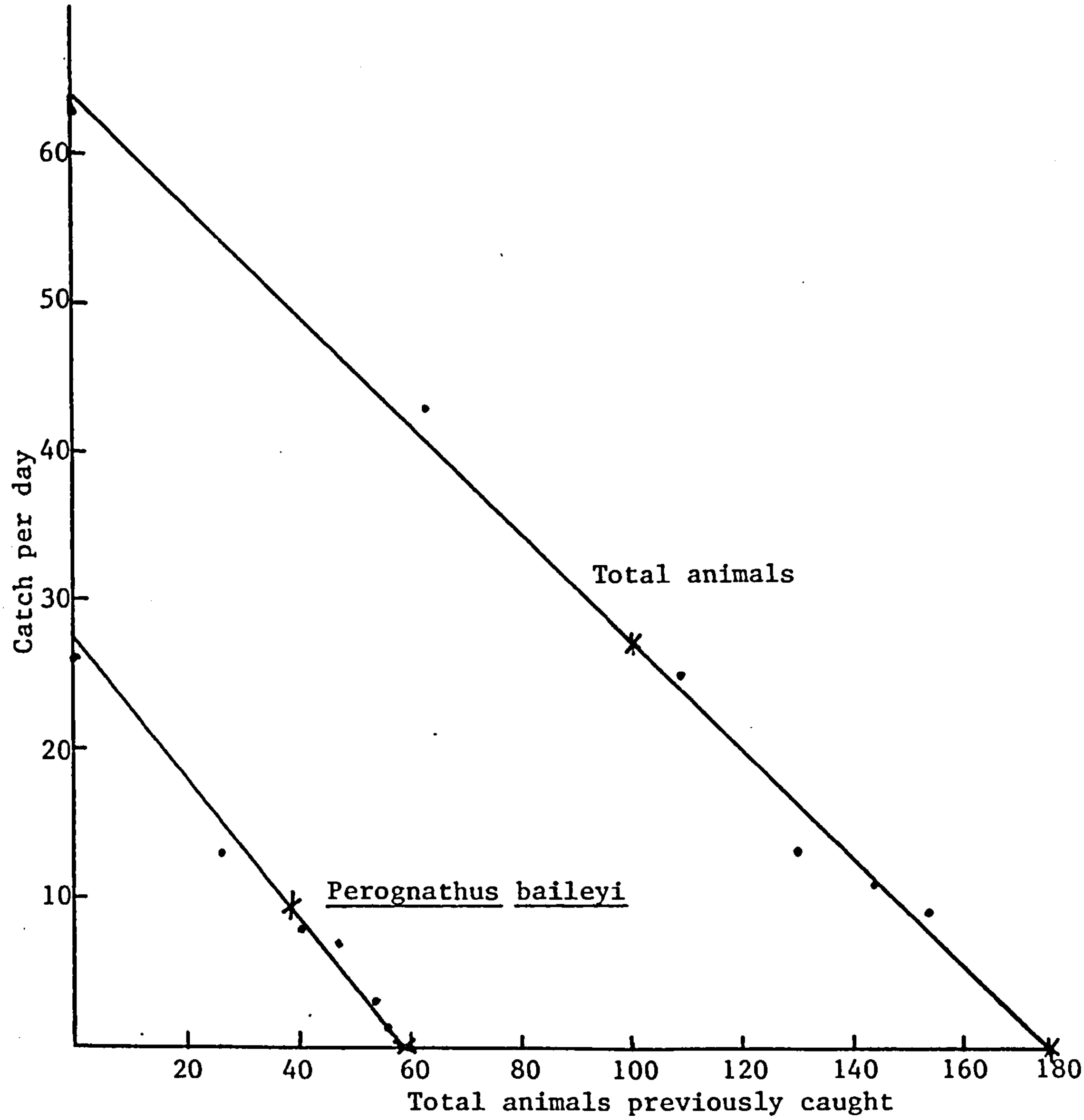

Fig. 13. Regression lines for total animals and Perognathus baileyi at Red Hill 1972.

Both regressions are for all rows and the entire trapping period. For Perognathus baileyi Y = -.4195X + 25.258, (r = .993). For total animals Y = -.3654X + 63.8124, (r = .996).

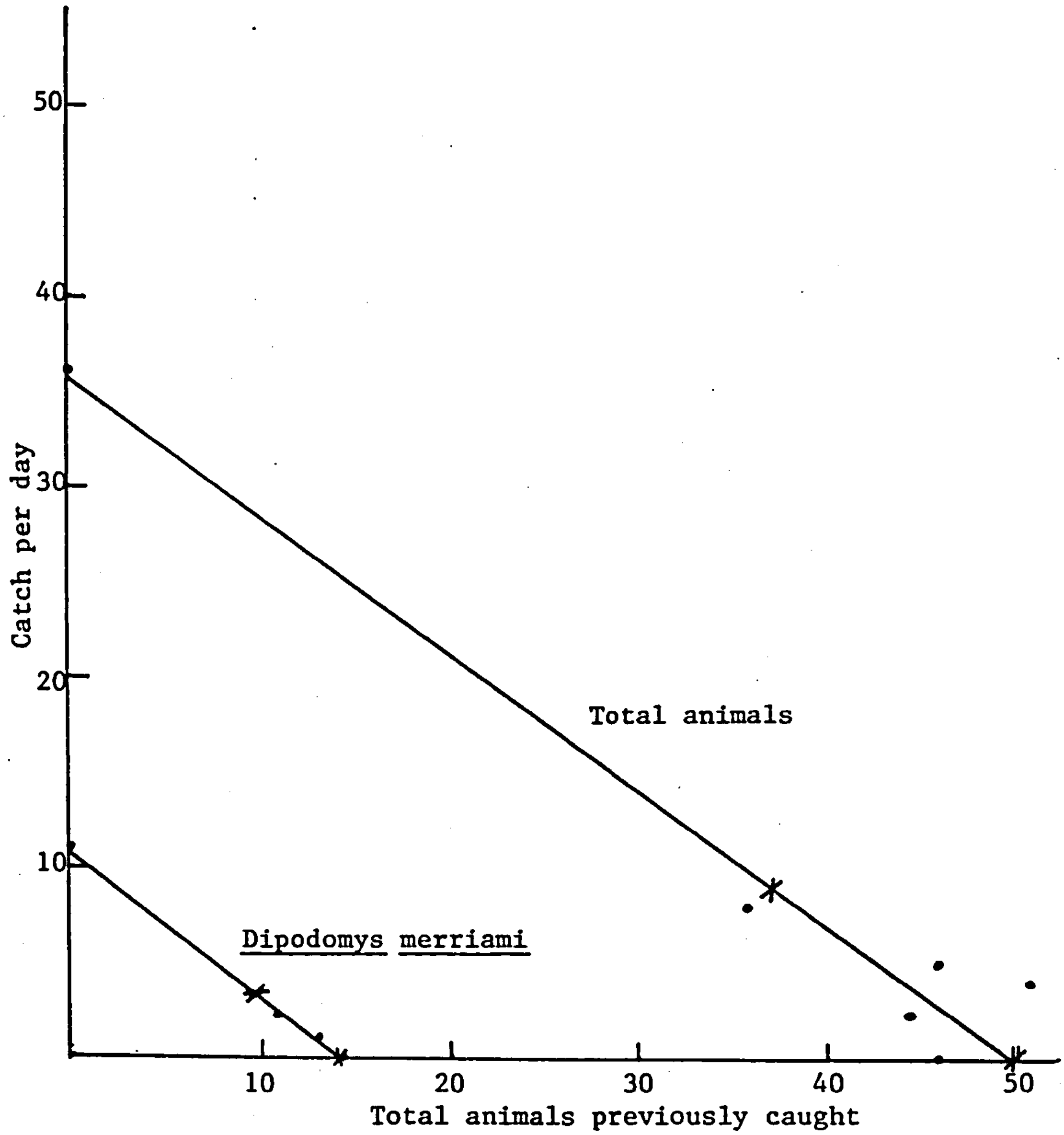

Fig. 14. Regression lines for total animals and _Dipodomys merriami_ at Santa Rita 1972.

Both regression lines represent the capture of animals in all but the outer row. The regression for total animals was calculated for the entire trapping period ($Y = -.6946X + 34.982$; $r = .952$). The line for _Dipodomys merriami_ is for the first four nights ($Y = -.7840X + 10.9$; $r = .998$).

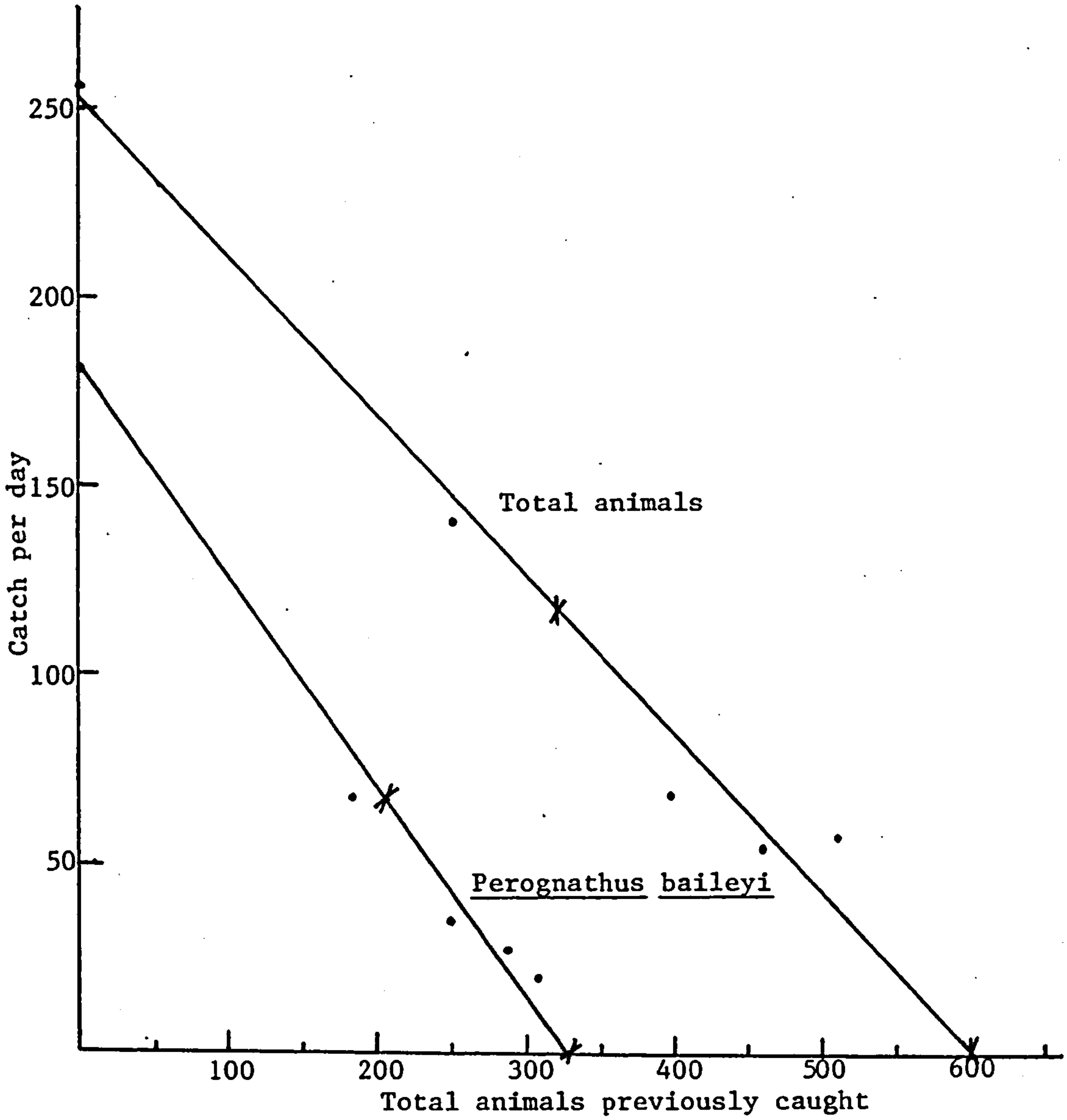

Fig. 15. Regression lines for total animals and *Perognathus baileyi* at Red Hill September 1974.

Both regression lines are for captures from the first five nights of trapping and all rows. For total animals $Y = -.4098X + 249.36$, ($r = .986$). For *Perognathus baileyi* $Y = -.5347X + 175.817$, ($r = .990$).

estimates to be substantially higher than the actual number of animals captured.

Index A (Grodziński et al., 1966) was used to compare estimates by regression (N_1) with the numbers of rodents removed during the entire trapping period (N_2). (Index A = $|N_2 - N_1| \times 100/N_2$). Grodziński et al. (1966) had an average index A value of 10.3 which they felt was acceptable. Index A values averaged 8.6 for all samples excluding the unusual cases in 1973 which raised the average to 13.6. Regression estimates and index A values for all tests of the grid in southern Arizona are reported in Tables 9 - 14. Correlation coefficients for all regressions calculated were high due to the dependent nature of the X and Y values. All r values except one were significant at $P < .001$ and that was significant at $P < .05$.

Density Estimates

Accurate estimates of density for certain species in their preferred habitat was not possible for the Red Hill site, due to the variability in habitat being sampled. This site was purposely selected to include several vegetative and physical types. A homogeneous site is a prerequisite for accurate density estimates, but homogeneity is relative when used to indicate an animal's ecological preferences. For example *Perognathus baileyi* appear to utilize all areas of the Red Hill site uniformly, relative to the trap interval of 15 meters. This contrasts with species such as *Perognathus amplus* and *Perognathus intermedius* which are found on opposite ends of the grid, due possibly to more specific vegetative and edaphic preferences

TABLE 9. Density estimates and associated index A values for Red Hill 1972.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus amplus	4	5.76	18.9	3.3	26	4.5	27.2
Perognathus amplus	6	5.76	27.8	4.8	26	4.5	6.9
Perognathus baileyi	6	4.41	36.8	8.3	36	8.2	2.2
Perognathus baileyi	6	7.29	60.2	8.3	59	8.1	2.1
Perognathus intermedius	6	7.29	20.3	2.8	22	3.0	7.8
Dipodomys merriami	4	7.29	19.9	2.7	20	2.7	0.0
Total species	6	4.41	94.3	21.4	90	20.4	4.8
Total species	6	7.29	174.6	23.9	164	22.5	6.5

TABLE 10. Density estimates and associated index A values for Santa Rita 1972.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus baileyi	3	4.41	17.0	3.9	17	3.9	0.0
Dipodomys merriami	4	4.41	14.0	3.2	14	3.2	0.0
Onychomys torridus	3	7.29	14.4	2.0	18	2.4	20.0
Reithrodontomys spp.	6	7.29	14.2	2.0	15	2.1	5.2
Total species	6	4.41	50.4	11.4	55	12.5	8.4

TABLE 11. Density estimates and associated index A values for Red Hill 1973.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus baileyi	6	4.41	78.4	17.8	61	13.8	28.7
Perognathus baileyi	6	7.29	121.2	16.6	86	11.8	40.9
Perognathus intermedius	5	4.41	8.4	1.9	8	1.8	4.5
Dipodomys merriami	6	7.29	20.1	2.8	19	2.6	6.0
Total species	6	4.41	219.3	49.7	154	34.9	42.4
Total species	6	7.29	320.8	44.0	206	28.3	55.7

TABLE 12. Density estimates and associated index A values for Santa Rita 1973.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus baileyi	6	4.41	65.3	14.8	57	12.9	14.6
Perognathus baileyi	6	7.29	90.1	12.4	76	10.4	18.6
Total species	6	4.41	124.0	28.1	101	22.9	22.8
Total species	6	7.29	176.9	24.3	134	18.4	32.0

TABLE 13. Density estimates and associated index A values for Red Hill September 1974.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus baileyi	5	4.41	231.0	52.4	292	66.2	20.0
Perognathus baileyi	11	4.41	264.7	60.0	292	66.2	9.3
Perognathus baileyi	5	7.29	328.8	45.1	423	58.0	22.3
Perognathus baileyi	11	7.29	388.6	53.3	423	58.0	8.1
Total species	5	4.41	401.6	91.1	509	115.4	21.1
Total species	11	4.41	473.3	107.3	509	115.4	7.0
Total species	5	7.29	608.5	83.5	774	105.9	21.3
Total species	11	7.29	739.4	101.4	774	105.9	4.5

TABLE 14. Density estimates and associated index A values for Red Hill October 1974.

Species	Days included for regression	Area of estimate (hectares)	Number estimated		Number caught		Index A
			Whole Area N_1	Per hectare	Whole Area N_2	Per hectare	
Perognathus baileyi	3	4.41	75.9	17.2	73	16.6	4.0
Perognathus baileyi	3	7.29	108.3	14.9	104	14.3	4.2
Dipodomys merriami	3	4.41	30.5	6.9	30	6.8	0.0
Total species	3	4.41	151.7	34.4	146	33.1	3.9
Total species	3	7.29	250.4	34.3	238	32.6	5.2

or adaptations than those of Perognathus baileyi. Perognathus amplus were caught in significantly higher numbers in lines 1 - 8 than in lines 9 - 16 (P = .002 by the 50% probability test). Using the 50% probability test, Perognathus baileyi was shown to be the only species at the Red Hill September 1974 sample which was roughly homogeneously distributed. Results of subunit analysis of the grids are displayed in Tables 15 - 17.

Due to the non-uniform distribution of many of the species, estimates of their density indicate average densities on this grid only, allowing estimation of the relative numbers of each species in the type of diverse habitat tested. Sub-units of the grid which contain a more homogeneous distribution of animals could be used to obtain densities of these species in their preferred habitat types.

The areas used to calculate densities were determined by the width of the belt of increased captures near the edge (see edge effect). The standard 16 x 16 grid has an area of 5.76 ha., including a 7.5 meter boundary on all sides. Density estimates using this area include captures from the entire grid. The inner 14 x 14 grid has an area of 4.41 ha., including a 7.5 meter boundary, and the densities calculated using this area involve captures only from this portion of the grid. The 7.29 ha. area is that of the 16 x 16 grid plus a 22.5 meter boundary. Densities in this case are derived from total grid captures and are based on the assumption that the area actually being sampled, as determined by edge effect analysis, was 30 meters wider than the standard grid.

TABLE 15. Subunit analysis of captures of major species at Red Hill September 1973.

Species	Number caught: Lines 1 - 8	Number caught: Lines 9 - 16	Significance Level
Perognathus baileyi	42	44	n.s.
Perognathus amplus	49	22	<.002
Perognathus intermedius	7	7	n.s.
Dipodomys merriami	16	3	<.01
Perognathus penicillatus	8	1	=.05

n.s. = not significant

TABLE 16. Subunit analysis of captures of major species at Santa Rita September 1973.

Species	Number caught: Lines 1 - 8	Number caught: Lines 9 - 16	Significance Level
Perognathus baileyi	31	45	n.s.
Perognathus amplus	8	10	n.s.
Perognathus penicillatus	8	9	n.s.
Dipodomys merriami	6	6	n.s.

n.s. = not significant

TABLE 17. Subunit analysis of captures of major species at Red Hill September 1974.

Species	Number caught: Lines 1 - 8	Number caught: Lines 9 - 16	Significance Level	Number caught: Rows A - H	Number caught: Rows I - P	Significance Level
Perognathus baileyi	204	219	n.s.	216	207	n.s.
Perognathus penicillatus	64	46	n.s.	29	81	<.002
Perognathus amplus	61	27	<.002	32	56	<.05
Perognathus intermedius	62	5	<.002	43	24	<.05
Dipodomys merriami	36	8	<.002	20	24	n.s.

n.s. = not significant

Calculated densities for Perognathus amplus at Red Hill 1972 were 3.3 and 4.8 animals per hectare. Density estimates for Perognathus baileyi ranged from 8.3 to 60.0 ($\overline{X}$ = 28.7) animals per hectare at Red Hill 1972 - 1974, excluding the captures during October 1974. Calculated densities for Perognathus intermedius at Red Hill 1972 and 1973 were 2.8 and 1.9 animals per hectare, respectively. Dipodomys merriami densities were estimated at 2.7 animals per hectare at Red Hill 1972 and 2.8 at Red Hill 1973. Total species estimates at Red Hill, excluding the October 1974 sample, ranged from 21.4 to 107.3 ($\overline{X}$ = 59.4) animals per hectare. All mean values were calculated using estimates by boundary area exclusion. All density values calculated are displayed in Tables 9 - 14 along with regression estimates and index A values.

Perognathus baileyi was the most uniformly distributed and abundant species on the Red Hill grid. Calculations of its density are assumed to be accurate due to its uniform distribution and probability of capture.

The effect caused by heterogeneous habitat was not encountered to any great extent at Santa Rita since the natural physical and vegetative variation is not as intense as that at Red Hill. A desert grassland exists over the entire grid, and although half of the area was chained, substantial woody growth still occurs in the major arroyos.

CHAPTER 4

CONCLUSIONS

The problem of developing a small mammal census method that would be accurate and economical under a wide range of conditions has been a long standing goal of biologists. Such a system would facilitate comparison of data from different vegetative, geographic, and temporal zones.

The Standard Minimum Method, developed for use in the International Biological Program, is one of the latest such attempts. It has been tested in several different vegetative areas including a Polish hardwood forest, a Polish meadow, and a southeastern United States upland hardwood and lowland hardwood-swamp forest. These tests primarily involved members of the families Cricetidae, in the case of the Polish hardwood forest, and Soricidae in the southeastern hardwood-swamp. The present study was undertaken to determine the effectiveness of the method in the desertscrub and desert-grassland communities of southern Arizona, with its predominantly heteromyid rodent communities.

Reliability of estimates using this method depend on the correctness of the following assumptions; 1) animals demonstrate a uniform probability of capture throughout the test period, 2) little or no immigration or emigration or both occurs on the capture area, 3) reproduction and mortality remain minimal during removal, and 4) weather influences are not highly variable. These conditions are rarely uniform from one test to another and the influence of their variation on the estimates is a matter which must be analyzed with each sample. Uniform probability of capture was observed for total animals and major species in the majority of cases, and for these groups estimates by regression were calculated.

Uniform probabilities of capture were observed for total species and the following major species at Red Hill September 1972. Estimates were made for total animals and the most abundant species, Perognathus baileyi, Perognathus amplus, Perognathus intermedius, and Dipodomys merriami, since they displayed uniform probabilities of capture. Although all of these species except Perognathus baileyi were found to be associated with certain areas of the grid more than others, the area sampled was indicative of their overall habitat type and the overall densities obtained are probably indicative of those in that area. Densities for Perognathus penicillatus and several minor species were not calculated by regression due to their non-uniform probabilities of capture and low numbers.

No uniform probability of capture was evident at Red Hill 1973 (one of two samples without prebaiting) for either total animals or major species. Nor were numbers sufficiently low at the end of the trapping to allow the assumption that the total catch accurately represented the total animals present on the grid during that period. None the less, regression lines were fit to the data, with the result that index A values of the estimates are much larger than those of the other samples.

The Red Hill September 1974 sample shows total animals and Perognathus baileyi having a uniform probability of capture through night five. Regression estimates were possible for these groups.

Regression estimates were possible for Perognathus baileyi, Dipodomys merriami, and total animals at the Red Hill October 1974 sample. Edge effect was most obvious during this sample as could be expected since the same grid was operated for eleven days only one month previously.

At Santa Rita the following groups showed uniform probabilities of capture in November 1972; Perognathus baileyi, Dipodomys merriami, Reithrodontomys spp. (R. fulvescens, R. megalotis, and R. montanus), Onychomys torridus, and total animals.

During the Santa Rita 1973 sample neither total animals nor any single species showed a uniform probability of capture, probably due to the lack of prebaiting. Regression lines were calculated for Perognathus baileyi and total species and index A values averaged only 22.0. The catch dropped off sufficiently by the sixth night of trapping to indicate that the total captures were indicative of the resident population.

One of the purposes of this study was to be able to make recommendations for future researchers using this method under similar conditions. Variables such as the number of days of prebaiting and trapping, and type of trap used were considered. Prebaiting periods of 0, 2, and 3 days were tested. It was shown that when no prebaiting preceded the trapping period there was no tendency toward a uniform probability of capture, hence no regular decrease in numbers captured on successive nights. This made estimation by regression much less meaningful than in the other samples. In both samples of 1973 the estimates by regression were substantially higher than the actual number captured but since the catch on the last night of trapping was still relatively high, especially at Red Hill, it is possible that these estimates were not grossly incorrect. However, where two or three nights of prebaiting preceded trapping, regressions were far more uniform and since no difference was noted between these, two nights was an adequate prebaiting period under the conditions tested.

Heavy rainfall or greatly decreased temperatures have an adverse effect on the uniformity of probability of capture. This seems due to an overall decrease in small mammal activity on extremely cold nights as well as to a slight decrease noted on rainy nights. Heavy rainfall was found to set off more than 50% of the traps on two occasions during the study. In these instances the majority of the museum specials and quite a few of the rat traps were tripped. The estimate is significantly altered when the catch is decreased severely from the expected value, especially if the night is early in the trapping period, as was the case on the second night of the Red Hill September 1972 sample. In this case the sum of the captures from nights two and three were utilized as the capture for night two in the regression calculations. The data from Red Hill September 1974 were handled similarly to minimize the effect of the rain on night six. Other options would be to terminate trapping on the night of the rain, if it were one late in the trapping period, and the previous catch had dropped off sufficiently, or to eliminate the rainy night's catch from the calculations entirely. Circumstances surrounding each instance must be subjectively analyzed by the investigator.

Trap spacing was felt to be adequate with a minimum of six trap stations per home range. Having two traps per station gave a trap density that allowed adequately rapid removal with a minimum of competition for traps in all instances but one.

The effectiveness of museum specials was shown to be significantly higher than that of the rat traps. This indicates that unless high numbers of large rodents are expected, two museum specials per station rather than one rat trap and one museum special, would increase the rate of removal, prevent escapes, and decrease the number of trap shy animals.

Accuracy influencing factors such as edge effect, immigration, weather conditions, and interspecific interaction exerted varying influences depending on the site, species, and time of year. The rate of removal influenced by these factors is the primary determinant of the length of the trapping period required. Grodziński et al. (1966) originally tested the Standard Minimum Method by removal trapping for seven days. As a result of their tests they felt that a five day removal period would be adequate. Removal periods of from 3 to 11 days were tested in this study and all samples over five days demonstrated that, although not all of the mammals were removed by day five, the catch after this point asymptotically approaches the x axis. These later catches generally appeared to be composed predominantly of edge captures and a few trap shy individuals throughout the grid. These effects are proportional to the entire population present during a given trapping period as was shown by comparing data from Red Hill September 1972 with Red Hill September 1974.

Another major test as to the length of trapping required should be whether or not new species turn up after the proposed period. In only one instance did a new species appear in the catch after day five. On nights 9 and 11 of the Red Hill September 1974 sample, a male and female Onychomys torridus were caught, both in the outer belt of traps. This species had not been recorded from any other sample on this grid and so can be assumed to be a very minor species of this community. Since this was a period of unusually high populations it may be proposed that its occurence in the area of the grid is marginal. Since this was the only case of a new species introduced after day five, and since the catch approaches an asymptotic relation with the x axis after this point, a five day trapping period was sufficient in all cases.

The estimates, however, as indicated by index A values, did not always agree closely with the total actually captured. This was especially true on the Red Hill September 1974 sample. By all indications, 11 nights of trapping did not remove all of the rodents from the grid. Small mammal densities of this sample were the highest ever obtained by this method and it is felt that removal could have been more rapid if more than two traps per station had been used.

Index A values ranged from 0.00 to 55.7. The average value of 13.6 was slightly higher than that deemed acceptable in the tests of the Polish ecologists. The highest values, averaging 26.6, were noted at Red Hill September 1973 and Santa Rita September 1973 when no prebaiting period preceded trapping. These high values were the primary cause of the high overall index A average. Other causes could include a high immigration rate, substantial interspecific interaction, or high numbers of trap resistant animals.

The Standard Minimum Method was found to be an accurate censusing tool for the southwestern desert regions. In the cases where the probability of capture varied to the extent where regression was useless, the extreme size of the grid usually allowed accurate density estimates merely on the basis of total captures. The grid size and trap spacing were felt to be adequate. A prebaiting period of at least two days is recommended followed by five to seven trapping days depending on the rate of removal encountered.

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