EFFECTS OF PESTICIDES ON SMALL MAMMAL POPULATIONS
PHASE II

by 4589

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INTRODUCTION

One of the chief causes of concern in any industrial nation is environmental pollution. And, in a highly developed agricultural country, important pollutants are control chemicals such as pesticides and herbicides.

The position of ecologists, with regard to the use and effects of pollutants was aptly stated by Rudd and Genelly (1956) as being that of insisting that control-chemical use be studied and regulated to insure the promotion of the interests of all concerned.

In keeping with the idea of studying the uses of control chemicals, the Departments of Entomology and Zoology at Kansas State University began a joint study with the Kansas Agricultural Experiment Station. This study was performed on an area where no detectable pesticide residues could be found in 1965. The area was located in Ellis County, approximately 12 miles south and 5 miles west of Hays, Kansas, and is termed the "Cedar Bluffs Irrigation District" in this thesis. Under the title "Reduction of Hazards Associated with the Presence of Residues of Insecticidal Chemicals in the Environment", the project commenced in June 1965. The studies conducted by the Department of Zoology included work on small mammal population dynamics and fish populations, while soil and plant contamination studies were conducted by the Department of Entomology. The Kansas Water Resources Research Institute, the U. S. Department of Interior's Office of Water Resources Research and the Kansas Department of Health studied ground- and surface-water contamination in relation to measured applications of insecticides.

The study of small mammal population dynamics was done on a comparative basis using two similar areas. One area received normal pesticide applications during the 4-year study; the other received no direct pesticide applications. The results presented in this paper are an accumulation of 17 trapping periods on the two study areas. Trapping was conducted by Larry Robinson in 1965; Clayton Stalling in 1966 and April and May of 1967 (he completed Phase I of this study); and Kent Monti in June, July and August of 1967. The author took over data collection in September 1967, and concluded this portion of the study in September 1968.

Following is an explanation and discussion of information gathered from June 1965 through September 1968 on these two areas for the small-mammal study.

LITERATURE REVIEW

The commercial production of DDT (Dichloro-dimethyl trichloro ethane), the first widely available insecticide, was begun in 1934 (DeWitt and George, 1960). Since that time, the formulation and use of insecticides, herbicides, rodenticides and other pesticides has skyrocketed to astronomical proportions.

However, long-term ramifications of manmade toxicants in the environment remain largely unknown. Therefore, insecticides and their usage cannot be wholly condemned; rather, malpractices need to be detected and eliminated (Decker, 1960). In his book <u>Pesticides, Blessing or Curse?</u>, Gabrielson (1958) stated that the Federal Government cannot cover the entire field of pesticide control, and that too few states provide protection for living creatures against the indiscriminate use of dangerous poisons. For these reasons, the careful study of uses and controls of chemical pollutants may well become the magnum opus of the ecologist.

According to Decker (1963), pesticidal contamination of animal populations can occur by any one of three methods: Ingestion, inhalation or absorption. The threat of pesticides, therefore, is more serious than a single exposure at application time. The accumulative nature of pesticide compounds (Storer, 1946) has been known since early in their existence, but the lack of accurate knowledge about the persistent nature of pesticides could be cause for additional concern.

Many studies have been devoted to this persistent nature. While studying the persistence of DDT in crayfish in a natural environment, Diamond, et al. (1968) found that 1 pound of DDT applied to each acre of forested watershed yielded 0.1 ppm in crayfish tissue after 10 years. Some of the more diverse uses of control chemicals include dieldrin in concrete mixtures for termite control (Allen, et al., 1964) and carbamate insecticide for repelling pheasants from sprouting corn (West, et al., 1969).

However, insecticides do not always give the desired results. Luckmann (1960) found that the number of European corn borers (Pyrausta nubilalis) increased following soil application of large amounts of dieldrin; the treated area had 2.6 more borers per stalk than the untreated area. When aldrin was applied in granular form at the rate of 2 pounds per acre, Labisky and Lutz (1967) found, after 1 month, that 25 to 50 percent of the pheasants (Phasianus colchicus) on the area were killed and reproduction was depressed; more than half of the hens on the area were broodless. They also found that when no further insecticide was used for 2 or 3 years, the production appeared to approach pretreatment levels.

Effects other than death at the time of chemical application vary. When studying acute toxicity effects of dieldrin and malathion on wild, sharp-tailed grouse (Pedioecetes phanianellus), McEwen (1967) found that the treated birds were more susceptible to predation after treatment than before; the control birds in his study behaved normally. While studying New Brunswick woodcocks (Philohela minor), Wright (1965) found that the embryos were contaminated before they hatched, and they contained 4.3 ppm heptachlor epoxide and 7.0 ppm DDT by fall. These compounds were found to make a significant difference in the reproduction of the species. Stickel, et al. (1965) observed that when woodcocks ate worms containing 2.86 ppm heptachlor epoxide, 50 percent died before 35 days had lapsed; 82.5 percent died before 53 days had lapsed.

Although individuals may appear healthy, they may contain a total body dose of a pesticide that would be lethal if the body fat were metabolized (Jefferies and Davis, 1968). In observing DDD (Dichloro-dimethyl dichloro ethane) applications on Clear Lake in California, Hunt and Bischoff (1960) found that all samples analyzed (including varied species of fishes, birds and amphibians) had residues exceeding the specified rate of diluted active insecticide in the lake's water on a ppm basis. They thus concluded that the effects of pesticides on wildlife are insidious and often the effects are entirely unnoticed, or not discernable for long periods after initial contact with a toxic material. Another study showing indiscernable effects of control chemicals was conducted in South Dakota where DDT was found to be present in 85 percent of the terrestrial mammals, as demonstrated by the samples of big game (_Odocoileus virginianus_, _O. hemionus_, _Cervas canadensis_ and _Antilocapra americana_) taken by Raymond, _et al_. (1967).

One of the most noticeable effects of pesticide application is the death of wildlife. Benton (1951) found that when a 2 percent DDT spray was used for the control of Dutch elm disease, young birds, some older birds (a total of 30 species) and squirrels (Sciurus carolinensis) were killed. Lay (1959) reported heavy losses of wildlife after application of 2 pounds of heptachlor for the eradication of fire ants. Spencer and Spencer (1952) found that dieldrin ground sprays applied at the rate of 2 pounds per acre gave a complete kill of Microtus ochrogaster. Ground squirrel (Citellus tridecemlineatus and C. Franklinii) populations within an area treated with dieldrin, at the rate of 3 pounds per acre, were virtually annihilated in a study by Scott, et al. (1959). Cottam and Higgins (1946) reported that high concentrations of DDT resulted in pronounced mortality of wildlife.

In a laboratory study of Mus musculus, Bernard and Gaertner, (1964) fed test animals 100 to 300 ppm DDT; the animals were able to survive for extended periods of time. Bernard and Gaertner, however, concluded that reproductive failures in this species may occur following exposure to sublethal quantities of DDT at the 100 to 300 ppm levels.

Many studies have been made on the effects of DDT on the individual. Serenryanaya (1950) found that the LD_{50} of DDT is similar for all mammals including man, i.e., about 300 mg/kg.

Kagan, et al. (1969:53) stated "All this data (sic) may serve as a warning urging the necessity of studying the influence of organochlorine compounds upon the reproductive function and on the development of progeny". Sazonona (1951) reported the death of kittens when the female was given 0.2 mg/kg of DDT, a nonlethal dose.

Kaprinski (1950) reported that DDT can cause subcutaneous hemorrhages and reduce the number of thrombocytes. DDT has been observed to cause irregular distribution of RNA in parenchymatous organs and glands of inner secretion, especially the liver (Rapoport, 1967). This control chemical also is believed to provoke changes in most organs; some of the most pronounced changes have been observed in cerebellum, medulla oblongata, liver, kidneys and suprarenals with morphological changes similar for man and other animals (Makovskaya, 1967). Similar observations were reported by Rybakova (1967) in that DDT caused functional and morphological change in hypophysis, adrenal glands, thyroid glands and sex glands of white rats, disturbed estral cycles and increased corpra lutea and follicular atresia.

In their natural surroundings, contamination of food appears to be the primary source of exposure of wildlife to insecticides (Kieth and Hunt, 1966). The main source of food for small mammals consists of seeds and insects (Jameson, 1952; Williams, 1959), with the proportions in the diet depending on species of wildlife and availability of food.

The survival of small mammals is nearly uniform throughout the year (Blair, 1948) with the winter reduction in populations apparently due to the failure of each species to breed. Jameson (1953) believed food to be a basic determinant of autumn reproduction of the genus Peromyscus, and Sealander (1952) found that food consumption varied inversely with air temperature for all species. Sealander (1952) demonstrated that in cold weather, when food is in short supply, the energy demand is greater. Baker (1946) found 70 percent of the rodent population (*Mus musculus*, *Rattus mendanensis*, *R. exulans*) was new each month, giving an inverse longevity of 1.4 months. Getz (1960) found that adult *Microtus pennsylvanicus* were recorded on his study area for an average of 2 months.

While laboratory experiments give the quickest reliable information concerning the effects of a variety of chemicals on many species of wildlife (Leedy, 1962), major research to determine the effects of pesticides on wildlife in natural communities is sorely needed (Leedy, 1962; Kieth and Hunt, 1966).

METHODS AND MATERIALS

Study Area

The study area was located approximately 12 miles south and 5 miles west of Hays, Kansas, and consisted of two fields; one received normal applications of commercial insecticides, the other received no direct application of these chemicals. Prior to 1965, no detectable control-chemical residues could be found on either of the two study areas. The treated area consisted of 19.5 acres in S ½, SW ¼, section 7, T 14S, R19W, Ellis County, Kansas. Three step-down terraces running the width of the study area allowed for irrigation of the field (Fig. 1). Since 1965, this area has received treatment with several different pesticides (Table 1; for complete data, see Knutson, *et al.*, in press).

The untreated area encompassed 22.7 acres situated approximately 1 mile south of the treated area in N ½, NW ¼, section 31, T14S, R19W, Ellis County, Kansas, (Fig. 1). This area was unterraced and was irrigated.

The crops produced on both areas during the study period were corn (*Zea mays*),* and sorghum (*Sorghum vulgare*). The most conspicuous vegetation on the terraces and areas bordering the crops was small Kochia (*Kochia scoparia*). Other species present in lesser amounts included dandelion (*Taraxacum officinale*), giant foxtail (*Setaria faberii*), yellow foxtail (*S. letuscens*), goldenrod

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*Scientific and common names of vegetation follow Anderson and Owensby (1969).

(*Solidago* spp.), ragweed (*Ambrosia* spp.) and sandbur (*Cenchrus pauciflorus*).

Because of their proximity to one another, the two areas were assumed to have the same weather conditions. Weather, therefore, was not considered in the computation of population differences. A silty, clay loam soil type predominates; more complete soil information is available in Knutson, *et al*. (in press).

Traps and Trapping

There are two major methods for studying small mammal populations: Snap traps and live traps. Goodnight and Koestner (1942) considered the methods to be equally reliable for population estimations, but found that snap traps gave estimates in 3 days while live traps required 6 or 7 days to produce comparable data. Buckner (1957) found that snap traps gave reliable population estimates except in early summer; therefore, this method was not recommended for long-term studies.

The live-trap method was used in this study, incorporating 10-day trapping periods. The traps used in this study were of the same general type described by Scheffer (1934); they consisted of a metal quart oil can, an attached Museum Special snap trap with an elongated trigger and a perforated stainless-steel door.

Sixty-food intervals were used in placing traps, as indicated in Figs. 1 and 2. This distance was recommended by Blair (1940) as being long enough to trap large areas and short enough that all animals had a possibility of being captured. To prevent water from entering the traps in case of rain, an effort was made to situate each trap with its mouth slightly declined. Traps were placed so that the door snapped downward. Because of the agricultural activity and farm machinery in the study areas, traps could be placed only on untilled regions (the periphery of both areas and on the terraces of the treated area). The location of each trap was indicated by a surveyor's red flag. Each of the 2½- x 3½-inch plastic flags was marked with the trap location (Stalling, 1968). There was a combined total of 215 traps on the two areas, 151 on the treated and 64 on the untreated area.

A mixture of rolled oats and peanut butter was used for bait. This bait was recommended by Gier and Bradshaw (1957) in proportions such that the peanut butter was no longer sticky (approximately equal volumes of peanut butter and rolled oats). Bait from the previous day was removed before a new ball (approximately ½ inch in diameter) of the mixture was put in each trap. As recommended by Howard (1951), additional bait was placed in each trap on cold days.

The trapping procedure and data recording were those used by Stalling (1968) in Phase I of this project. Traps were placed and baited the afternoon prior to data-collection day 1, and were retrieved on day 10 of each trapping period.

Trapping was conducted mainly during the summer months (Fig. 3). Trapping periods consisted of 10 days of continuous trapping, except when heavy rain forced early conclusion of a period, or if rain occurred in the first part of a trapping period causing the period to be extended an additional day. Traps were checked each morning at first light and were baited and set each evening about two hours before sunset. Traps were left unset during the day to avoid animal mortality from excess heat.

Marking

When marking captured individuals in the field, a means of identification must be found that is inexpensive, quickly and easily applied, humane, conspicuous and permanent (Manville, 1949). Some acceptable methods that have been used are ear punches and fingerling tags (Bucker, 1957) and toe clips (Taber and Cowan, 1963). Ear notches were used by Stalling (1968).

In this study, a combination of toe clipping and ear notching was used in marking captured individuals. Each captured animal was toe clipped beginning from the left side in 1965. In 1966 and following years, toe clipping was begun from the individual's right side (when held supine), as described by Taber and Cowan (1963). A total of nine different combinations of ear notches was used with the toe clipping to give a large sequence of possible available numbers. By using either front, top, back or no notches on either or both ears, each number combination was repeated about once every two years. The nine ear notches were used serially so that repetition was minimized.

Longevity

An important aspect of longevity is the annual carryover, i.e., the portion of the population surviving from fall to the next spring. One factor associating pesticides with longevity is high total body doses located in fat deposits. When these deposits are metabolized (winter conditions), the total effect could be lethal (Jefferies and Davis, 1968). McEwen (1967) demonstrated that individuals were more subject to predation after sublethal doses of pesticides than before, thus possibly contributing to a decrease in longevity.

Data Recording

All trapped animals were identified to genus and species following the nomenclature of Hall (1955). Data were recorded on field sheets with each animals identified by species, sex, reproductive condition (pregnant, lactating, testes descended), age (adult or juvenile, as determined by observation) and location of capture.

The first time an individual was captured, it was recorded as a "new capture" and was marked. An individual captured again during the same trapping period was a "recapture". If it was captured during a subsequent trapping period, the individual was recorded as a "new recapture" the first time and a "recapture" each subsequent time during that trapping period.

To facilitate analysis, all data were placed on computer input cards. The format for punching the cards was the same as that used by Stalling (1968), as outlined by Brotzman and Giles (1966), except for the addition of light transmittance data. A copy of the format used in this study is presented in Appendix A. All data were analyzed on an IBM 360/50 computer.

Population Dynamics

To arrive at a working number of individuals present on the study areas, two population estimation procedures were used: Schnabel (1938) and Schumacher-Eschemeyer (1943). Total small rodent population estimates and an estimation of the population of the most common mammal on the study areas, *Peromyscus maniculatus*,* were determined for each area. In addition to *P. maniculatus*, the total estimate consisted of *Mus musculus*, *Sigmodon hispidus*, *Microtus ochrogaster*, *Onychomys leucogaster*, *Reithrodontomys megalotis*, *R. montanus*, *Perognathus flavus*, *P. hispidus*, *P. flavesens*, *Spermophilus tridecemlineatus*, *Dipodomys ordii* and *Sylvilagus floridans*.

Residue Analysis

Two specimens of *Peromyscus maniculatus* and one of each of the other species (when available) were collected on each area during each trapping period of the 4-year study. These individuals were frozen at -20^{o}F. until they could be analyzed for pesticide residues.

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*Scientific names follow Hall (1955).

Prior to analysis, the whole, unskinned specimen was allowed to thaw and then was homogenized in a high-speed Waring blender. (In 1965, tissue samples rather than the whole individual were homogenized and analyzed.) After homogenization, a 10g sample of each homogenized animal was analyzed by the Pesticidal Residue Laboratory at Kansas State University. Gas-liquid chromatographic methods were used in the analysis process (Kadoum, 1967). The stock solutions for the gas chromatographs were prepared in hexane with activated high purity grade 950 (60-200 mesh) silica gel as the column adsorbent (Kadoum, 1967). The extracts of the animal tissues were prepared by standard techniques (Burchfield and Johnson, 1965). The method used could detect as low as 0.01 ppm diazinon; parathion; malathion; endrin; aldrin; dieldrin; heptachlor epoxide; DDE; DDT O,P and DDT P,P.

RESULTS

Trapping Data

During the course of the study, 13 different species of small mammals were captures: Peromyscus maniculatus, Mus musculus, Sigmodon hispidus, Microtus ochrogaster, Onychomys leucogaster, Reithrodontomys megalotis, R. montanus, Perognathus flavus, P. flavesens, P. hispidus, Spermophilus tridecemlineatus, Dipodomys ordii and Sylvilagus floridanus.

Seventeen trapping periods on the two study areas, with 215 traps, resulted in a total of 25,670 trap nights on the treated area and 10,880 trap nights on the untreated area. Totals of 6,888 and 2,426 small mammals were captured on the treated and untreated areas, respectively (Table 2). The percentages of individuals captured once and twice are relatively similar and consistent for both areas during all months (Table 3).

The largest number of actual captures per 1000 feet of trap line occurred on the treated and untreated areas in June 1966 (72.1 and 47.5, respectively). The lows on these respective areas occurred in September 1966 and May 1967 (Table 4).

Peromyscus maniculatus was the predominant species on both areas; the species comprised from 65 to 91 percent of the small mammals captured during any one trapping period. The average P. maniculatus capture for both areas was 74.0 percent.

The greatest number of P. maniculatus captures per 1000 feet of trap line was in April 1967 on the treated area (54.4) and in

July 1968 on the untreated area (39.1). The lowest numbers of this species (16.3 and 13.7) were captured in September 1966 and September 1965 on the treated and untreated areas, respectively. The number of _P. maniculatus_ captured during the latter part of any trapping year was substantially lower than the number captured earlier in the year (Table 5).

The cotton rat (_Sigmodon hispidus_) averaged less than 10 percent of the total catch, but comprised 26.7 percent (95 animals) of the captures on the treated area during the August-September 1967 trapping period. During the trapping period immediately preceeding this (July 1967), _S. hispidus_ comprised 9.6 percent (41 animals) of the total capture, and during the first period of the following year (June 1968), _S. hispidus_ comprised 10.0 percent of the total individuals trapped. The number of this species trapped on the untreated area did not exhibit this type of increase in any month. _S. hispidus_ were not captured on the untreated area during four trapping periods; five or less were captured during each of eight other trapping periods.

A combined total of 768 captured _Mus musculus_ was recorded from the two areas during the study. Of this number, 70 percent (536) were captured on the treated area and 30 percent (232) on the untreated area. Out of the total mammal captures, _Mus Musculus_ captures varied from 1.5 percent (6 individuals) to 13.7 percent (86 individuals) on the treated area and from 0 individuals to 59 (37.3 percent) on the untreated area during the monthly trapping periods. These extremes occurred in June 1965 and May 1967, and June 1965 and September 1965 on the respective areas.

The number of captures of the northern grasshopper mouse (*Onychomys leucogaster*) was 1.4 percent of the total capture (2 individuals on the treated area and none on the untreated area) in June 1965. The maximum number of *O. leucogaster* captured in any period was 48 (11.7 percent) in August 1968 and 22 (18.8 percent) in August 1966 on the treated and untreated areas, respectively.

Microtus ochrogaster were present during the first part of the study (1965 and 1966), but were not captured during any of the four trapping periods of 1967 nor in June 1968. This species was captured infrequently during the remainder of the study.

Other species (*Reithrodontomys megalotis*, *R. montanus*, *Perognathus flavus*, *P. flavesens*, *P. hispidus*, *Spermophilus tridecemlineatus*, *Dipodomys ordii* and *Sylvilagus floridanus*) known to be on the study areas were not captured in enough numbers, or with enough consistency, for separate consideration.

To have an index by which both areas could be compared, the total capture for each area was divided by the number of 1000-foot segments of trap line in that area. The treated area contained a total of 8.7 such 1000-foot segments, while the untreated area contained 3.8 segments. This calculation was performed for the total number of captured individuals on each area and for the number of captured *Peromyscus maniculatus* on the treated and untreated areas.

The greatest number (54.4 per 1000 feet) of *P. maniculatus* was recorded in April 1967 from the treated area. The highest value for the total population for that same area was also in April 1967 (63.6 individuals per 1000 feet). The untreated area showed the highest number of captured P. maniculatus (39.1) in July 1968; however, the largest number of total captured individuals occurred in June 1966 when 44.7 animals were trapped per 1000 feet. In all but four trapping periods (July and September 1965, September 1966 and June 1967), the total number of captured individuals per 1000 feet of trap line was higher on the treated area than on the untreated area (Table 4).

Longevity

Gathering data over a period of four years allowed examination of longevity of animals on both the treated and untreated areas. About half (50.5 percent for the treated area and 43.6 percent for the untreated area) of the total individuals captured on both areas during any one period were not recaptured in any subsequent trapping period. Approximately 20.2 percent and 20.5 percent of the individuals captured on the treated and untreated areas, respectively, were present and captured during two trapping periods (not necessarily successive trapping periods or even two periods in a single year). The average longevity of any species varied from year to year and from one area to the other (Table 6).

The average life expectancy of an individual on the treated area was 1.61 months, with a slightly larger value, 1.73 months, on the untreated area. A Chi-square analysis failed to reveal any significant differences in the above values at any level.

Although the life expectancy of any one individual is relatively short, certain individuals existed on the areas for substantially longer periods. An adult male Sigmodon hispidus, for instance, was recaptured nine traps (540 feet) from where he had been marked as a juvenile 34 months earlier. Also on the treated area, two Peromyscus maniculatus males survived for at least 24 months as they were captured over that time span. Three animals (a Mus musculus, Peromyscus maniculatus and Perognathus hispidus) each survived on the untreated area for a recorded period of 14 months.

Population Dynamics

In the following section, the term "population" is understood to mean "estimated population". Because of the close similarity between the Schnabel and Schumacher-Eschemeyer methods of estimating populations, only the Schnabel method is described; however, results from both methods are shown in Tables 7-12 and Figs. 4-6.

When the study of population dynamics was begun on the Cedar Bluffs Irrigation District in 1965, the rodent population was lowest during the first month (173 in June), and then rose to a level of about 190 during the remaining trapping periods on the treated area. The population appeared to stabilize at this number for the remainder of 1965. However, the number jumped in 1966 to a high of 350 in June (the first trapping period) and then decreased to a low of 112 in September. In 1967, the trapping periods started in April. Again the highest population for the year was recorded during the first trapping period (494). The population fell to a low of 242 individuals in July, but the final trapping period in 1967 (August-September) indicated an increase to 380 individuals on the treated area. The data for 1968 exhibit a similar pattern to that observed in 1967; the first trapping period of the year reflected the highest population (350). The population decreased during July (291) and August (254), but showed an increase in September (325).

In June 1965 the original population on the untreated area was 91. The population then decreased to the low 70's in July and August, but increased in September to 126, the highest level for the year. In 1966, the first trapping period (June) showed a population higher than the previous year, as did the treated area; however, the highest population was recorded during the month of July (144 individuals). The population then decreased to a low of 113 in September.

April, the first trapping period in 1967, presented the highest population (147) for the year, with the lowest occurring in July (83) on the untreated area. The same months were noted, respectively, as high and low population periods on the treated area. In 1968, the June trapping period showed the lowest population (120). The total population increased through September to the highest number of individuals (192) recorded during the study. This population is in contrast with that of the treated area which had the highest population for 1968 during the June trapping period.

Pesticide Residues

Samples from 166 small mammals were analyzed for pesticide residues during the study. Of the 166 individuals analyzed, 38 showed detectable residues of 0.01 ppm or greater. Residues of dieldrin were contained in 35 of the animals, heptachlor epoxide in 8. Twenty-seven of the individuals containing residues were collected from the treated area and eleven from the untreated area; eighteen were *Peromyscus maniculatus*. Of these, 14 had detectable residues of dieldrin, 2 had residues of heptachlor epoxide and 2 had residues of both dieldrin and heptachlor epoxide.

In addition to *P. maniculatus*, the species with the greatest number of individuals having detectable residues were, in decreasing order: *Mus musculus* (7), *Spermophilus tridecemlineatus* and *Onychomys leucogaster* (4 each), *Perognathus hispidus* and *Reithrodontomys megalotis* (2 each) and *Sigmodon hispidus* (1).

The highest concentration of residue recorded was from a *Peromyscus maniculatus* that contained 0.50 ppm dieldrin. A *Mus musculus* captured on the untreated area contained 0.44 ppm dieldrin. One specimen of *Perognathus hispidus* contained 0.28 ppm dieldrin; one *Spermophilus tridecemlineatus* had 0.24 ppm dieldrin and two *Mus musculus* had 0.15 ppm and 0.13 ppm dieldrin. All other specimens contained 0.05 ppm or less detectable residues (Tables 13 and 14).

During the course of this study, the most individuals that had detectable residues were collected in July of all years; 12

of the 38 individuals containing detectable residues were captured during July.

DISCUSSION

The purpose of this investigation was to study the effects of pesticides on the population dynamics of small mammals on an area previously untreated with control chemicals. For many reasons, it is questionable whether this purpose was fulfilled.

Trapping

Ten-day trapping periods (Sanderson, 1950) were used throughout this 4-year study. In an effort to determine the effectiveness of 10-day trapping periods, a 2 x 19 Chi Square contingency table was used. Table 15 compares the total captured small mammals (up to and including the day in question), i.e., day 1 through day 9 with the total on day 10. Trapping beyond 8 days produced no significant new data. Therefore, an 8-day period, which is closer to the 6- or 7-day trapping period recommended by Goodnight and Koestner (1942) would have given accurate population estimations for this study.

The length of time between trapping periods also is of importance. If insufficient time elapses between trapping periods, the animals become accustomed to the traps; some become "trap shy", while others become "trap happy". Getz (1960) recommended 1-month intervals for trapping to avoid continual bias in results.

An additional trapping consideration, with regard to bias, is the trap placement. Dice (1938) concluded that lines of traps were not as effective for giving reliable data, from which to estimate populations, as were quadrats. However, Dice reported that trap lines are useful as an index to animal abundance. Based on data compiled by Calhoun (1950), it is believed that the trap lines used (as shown in Figs. 1 and 2) gave an accurate estimate of the trappable small mammal population. Marten (1970: 292) stated "An approximate right estimate of population size is better than a precise wrong one."

Continued use of traps in the same location might have resulted in low population estimates. Marten (1970) stated that marking and sampling should be independent to avoid bias. Kott (1965) used traps to capture mice for marking, but sampled by use of pitfalls. This procedure resulted in higher estimates than those obtained by sampling with traps.

The same trap placement could have given an elevated estimate of the population, also. In an effort to prevent this, Lidicker (1966) randomly moved traps between trappings to avoid favored locations for marking and sampling. It is hoped that the effect of trap placement was consistant throughout the study.

To give an accurate estimate of population size, animals must remain trapped until marked, recorded and released by the researcher. Because the trap doors used during the first 3 years of the study were constructed of soft aluminum, some animals were able to chew holes through the doors and escape. To prevent this, in 1968 the aluminum doors were replaced with stainless steel, which prevented escape by this route. Faulty trap triggers and badly dented cans were discarded and replaced as necessary to insure efficient functioning of the traps.

Another source of bias inherent with all trapping procedures is weather. Trapping success decreased noticeably during the nights when cold and wet conditions prevailed. While working with the genus Peromyscus, Caldwell and Connell (1968) found that live and snap trap data exhibited a decrease in activity by as much as 42 percent on a clear moonlight night. A further unknown factor on trapping success could be the effect of weather interacting with population density (Gentry, et al., 1966). Due to the variability observed in weather conditions and irrigation on the study areas during parts of some trapping periods, the effect that weather had on any day's catch has not been determined.

Marking

The combination of ear notching and toe clipping in this study proved reasonably effective for identifying recaptured animals. This means of identification proved to be inexpensive, quick and easy to apply, humane, conspicuous and permanent, as recommended by Manville (1949). A few Sigmodon hispidus and Peromyscus maniculatus had torn ears and missing toes, probably as the result of fighting; but a clean-cut ear notch could be separated easily from tears. However, toes lost in fighting were difficult, if not impossible, to discern from toes removed for marking purposes. During the duration of the study, a total of 60 individual observations could not be reconciled with past records and were not included in the capture-recapture information.

Captures

The most abundant species on both areas was *Peromyscus maniculatus*. The majority of the animals captured each period were of this species, constituting an average of 73.4 percent of the total capture of each trapping period. For this reason, data could have been kept for *P. maniculatus* only and would have given an acceptable indication of the total population trend. However, by recording data for other captured species, it was possible to determine the presence and population fluctuations of *Sigmodon hispidus*, *Mus musculus* and other species captured less frequently than *Peromyscus maniculatus*.

In all years except 1965, the first trapping period was the most successful in terms of captures. A general decrease followed this initial success, except in 1967 on the untreated area and 1968 on both areas when a marked increase in the number of captures was recorded (Fig. 3).

Berry (1968) reported that the winter mortality rate is usually higher than the summer rate. This may or may not be in agreement with the observed captures on the study areas. The first trapping period occurred after the onset of the breeding season. Thus, the high initial number of captures could be the result of recruitment into the population. Some winter and early spring breeding does occur following the production of a good food crop the previous fall (Watts, 1969).

Longevity

The length of time an individual remains on a study area was established by Baker (1946) as 1.4 months and by Getz (1960) as 2.0 months. The average longevity of all small mammals on the Cedar Bluffs Irrigation District project was 1.6 months, which is in close agreement with previous work.

During this study, the carryover of marked animals on the treated area varied from a low of 2.4 percent during the 1967-68 winter to a high of 3.5 percent during the 1966-67 winter. The extremes on the untreated area varied from 1.7 to 6.9 percent during the winters of 1965-66 and 1966-67, respectively (Table 16). The mean carryover of small mammals on the two areas was significantly different ($P < 0.005$) during the three winters of the study.

An abundance of corn and sorgham was present on both areas during this study. However, Chitty, et al. (1968) stated that the food shortage is not a necessary antecedent to changes in survival. Microtus surviving the winter gained 10 percent in weight. This led Chitty to the hypothesis that genetically determined aggression in association with food surpluses was in part responsible for population regulation, with some relevant variables and their interaction still unknown.

Predators may have played an important role in controlling the small mammal populations. While studying cotton rat (Sigmodon hispidus) populations, Schenell (1968) found that densities of over 15 per acre resulted in increased rates of predator kill.

He also stated that mobil predator populations are more important, in regulating density, than food, social interaction or weather. Predator activities were observed on both the treated and untreated area. Coyotes were recorded during every trapping period, either by sightings or by the presence of scats commonly containing remains of rodents. Badger activity was also noted. Newly dug holes were continually found on terrace bench areas.

Population Estimates

The Schnabel (1938) and Schumacher-Eschemeyer (1943) methods of estimating populations were used. These estimates were intended to represent the number of trappable animals present, not the total population on the fields. Results of the two methods gave a relative abundance of small mammals as the trapping season progressed from spring to late summer and as the pesticides were applied. As the methods yielded similar population estimates (Fig. 4), those based on the Schnabel method were used for comparison purposes in this study. However, the Schumacher-Eschemeyer method could have been used and would have been easier to use since it is less complex.

No significant difference ($P > 0.95$) was found between the small mammal populations of the two areas. If, however, a difference actually did exist, it might not have been detected because both study areas had trap lines near a roadway that provided adequate cover and favorite sites for migration. When the study sites were selected, it had been thought that the irrigation canals that run part way around each area would provide an adequate barrier; this assumption proved incorrect. Because animals were able to migrate onto the treated area, there was inadequate control provided for the study.

Residues

Some of the animals analyzed for pesticide residues from both the treated and untreated areas contained measurable amounts of pesticide residues (dieldrin and heptachlor epoxide). The presence of these control chemicals in animals collected on the untreated area might be explained by migration from treated fields surrounding this area.

The three animals having the highest dieldrin residues (0.26, 0.28 and 0.44 ppm) on the untreated area were all new captures early in the 1968 trapping season, and all were sampled during their first period on the area. Thus, the contamination could have been introduced from a field outside the control area. This area was probably treated with a large amount of dieldrin early in the season. Such an early treatment would allow time for animals to become contaminated and immigrate to the study area for detection in the June and July trapping periods. Also, some pesticide drift onto the untreated area could have occurred during aerial spraying operations on fields surrounding the untreated area.

As much as 0.44 ppm dieldrin was found in animals from the untreated area, as compared with the highest value of 0.50 ppm dieldrin in animals from the treated area. The first application of pesticides on the treated area each year occurred in mid May. The corresponding increase of residual levels in samples taken occurred in the July sampling period. No difference in residue levels for the sexes could be determined.

Conclusions

Although the study did not fulfill all of its objectives, some definite conclusions can be drawn:

1. The two methods used for population estimations (Schnabel, 1938, and Schumacher-Eschemeyer, 1943) gave similar results. Future studies in similar circumstances need only use one method to provide adequate estimates.

2. Of the samples taken for pesticide residue analyses, results were similar for both areas.

3. No significant difference in longevity of animals on the treated and untreated areas could be found.

4. Carryover on the untreated area was significantly greater at $P < 0.05$ than carryover on the treated area.

5. Trapping periods could be reduced to 8 days without affecting results.

6. <u>Peromyscus maniculatus</u> made up 73.4 percent of the total captures.

7. Irrigation ditches and roads did not provide adequate barriers for animal movement into and out of the study areas.

SUMMARY

A small mammals project was begun in 1965 by the Kansas State University Department of Zoology. The purpose of this study, part of Agricultural Experiment Station project 481, was to determine the effects of pesticides on small mammal populations on a new irrigation district in the Cedar Bluffs Reservoir area of western Kansas. Two study sites were established: A treated area and an untreated area. The areas were located one mile apart and were assumed, because both were leveled irrigated corn fields, to be nearly identical. Ten-day trapping periods were conducted each month during spring and summer from June 1965 through September 1968. A total of 36,550 trap nights were conducted on the two areas and 9,314 small mammals were captured. These animals included _Peromyscus maniculatus_, _Microtus ochrogaster_, _Mus musculus_, _Sigmodon hispidus_, _Onychomys leucogaster_, _Reithrodontomys megalotis_, _R. montanus_, _Perognathus flavus_, _P. flavesens_, _P. hispidus_, _Spermophilus tridecemlineatus_, _Dipodomys ordii_ and _Sylvilagus floridanus_.

The animals captured were marked by a series of toe clips and ear notches and were released at the trap site. Population estimates were made using the Schnabel or Schumacher-Eschemeyer methods. Longevity was determined by recapture records. No significant difference was determined for mean length of time that an animal was present on the untreated versus the treated area. Pesticide residues were found in the tissues of mammals trapped on each of the study areas. Only small concentrations of

pesticide residues were found in the mammals sampled, and no significant differences in residue levels were found between the treated and untreated areas.

The composition of the species was approximately the same for both areas. Peromyscus maniculatus was the predominant species and made up 73.4 percent of the total captured individuals.

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APPENDIX A

Format Used in Punching Data Cards

Column	Data
1-2	Month
3-4	Day
5-6	Year
7	Observer
	(1) Larry Robinson
	(2) Clayton Stalling
	(3) Kent Monti
	(4) Max Westfahl
8	Sky conditions
	(0) Clear
	(1) Partly cloudy
	(2) Light overcast
	(3) Heavy overcast
	(4) No observation
9	Locations where weather observations were made
	(1) Study area (unofficial)
	(2) Ft. Hays Experiment Station (official)
10	Wind direction
	(0) No observation
	(1) North
	(2) Northeast
	(3) East
	(4) Southeast
	(5) South
	(6) Southwest
	(7) West
	(8) Northwest
	(9) Calm (no direction)
11	Wind speed
	(0) 0 mph
	(1) Less than 5 mph
	(2) 5 to 10 mph
	(3) 10 to 15 mph
	(4) 15 to 20 mph
	(5) 20 to 25 mph
	(6) 25 to 30 mph
	(7) 30 to 40 mph
	(8) 40 to 50 mph
12	Dew
	(0) None
	(1) Light
	(2) Moderate
	(3) Heavy
	(4) No observation

Column	Data
13-15	Number of days since last rain
16-18	Maximum temperature
19-20	Minimum temperature
21	Moon phase (0) No observation (1) First quarter (2) Full moon (3) Last quarter (4) New moon
22-24	Number of traps sprung in particular study area
25	Height of vegetation (0) No observation (1) 0 inches (2) 0 to 4 inches (3) 4 to 8 inches (4) 8 to 12 inches (5) 12 to 16 inches (6) 16 to 20 inches (7) 20 to 24 inches (8) 24 to 28 inches (9) More than 28 inches
26-27	Species (01) _Peromyscus maniculatus_ (02) _Microtus ochrogaster_ (03) _Mus musculus_ (04) _Sigmodon hispidus_ (05) _Onychomys leucogaster_ (06) _Reithrodontomys megalotis_ (07) _Reithrodontomys montanus_ (08) _Perognathus flavus_ (09) _Perognathus flavesens_ (10) _Spermophilus tridecemlineatus_ (11) _Perognathus hispidus_ (12) _Sylvilagus floridanus_ (13) _Dipodomys ordii_
28	Recapture code (0) Unknown (1) New capture (2) New recpature (3) Recapture
29	Age and Sex (1) Adult male (2) Juvenile male (3) Adult female (4) Juvenile female (5) Adult unknown (6) Juvenile unknown (7) Male, age unknown (8) Female, age unknown (9) Unknown

Column	Data
30	Reproductive code
	(0) No observation
	(1) Lactating female
	(2) Non-lactating female
	(3) Male, testes descended
	(4) Male, testes ascended
	(5) Pregnant female
	(6) Female in gestation (young also in trap)
31	Releast code
	(1) Released
	(2) Dead in trap; not collected
	(3) Collected (alive)
	(4) Dead in trap and collected
32-34	Number assigned to animals collected
35-39	Trap location
	(001) A
	(002) B
	(003) C
	(004) D
	(005) E
	(006) F
	(007) G
	(008) H
	(009) I
	(010) J
	(011) K
40-61	Results of analyses expressed in 0.00 ppm
	40-41 Diazinon
	42-43 Parathion
	44-45 Malathion
	46-47 Endrin
	48-49 Aldrin
	50-51 Dieldrin
	52-53 Heptachlor
	54-55 Heptachlor Epoxide
	56-57 DDE
	58-59 DDT, O,P
	60-61 DDT,P,P
62-64	Precipitation
	62 Inches
	63 Tenths of an inch
	64 Hundredths of an inch
65-67	Not in use
68-70	Percent of light transmittence through vegetation
71-73	Not in use
74	Area where animal was trapped
	(1) Treated Area
	(2) Untreated Area

Column	Data
75-77	Ear mark given animal (000) No ear mark (001) Left ear clipped (002) Right ear clipped (003) Both ears clipped (004) Right ear notched in front (005) Left ear notched in front (006) Right ear notched on top (007) Left ear notched on top (008) Right ear notched in back (009) Left ear notched in back
78-80	Toes clipped on animal

APPENDIX B

Tables and Figures

TABLE 1. Summary of Pesticides Applied to Treated Area From 1965 Through 1968 (pounds per acre).

	1965	1966	1967	1968
Bench 1*				
Diazinon	0.6	2.29	2.13	3.46
Endrin	0.0	0.30	0.36	0.28
Bench 2				
Heptachlor	0.0	0.67	0.43	0.41
Bench 3a				
Parathion	0.0	1.40	0.79	1.01
Methyl parathion	0.0	0.38	0.50	0.53
Bench 3b				
Aldrin	1.0	1.20	0.84	0.30
Bench 4a				
Aldrin	3.9	0.00	0.00	0.00

*Bench locations are given in Fig. 1.

TABLE 2. Total Captures by Year and Area for Each Month During Which Trapping Occurred.

Period	Treated	Untreated
1965		
June	459	135
July	361	178
August	354	147
September	354	158
1966		
June	626	180
July	462	180
August	334	118
September	175	97
1967		
April	546	150
May	405	83
June	413	146
July	424	148
August-September	358	124
1968		
June	413	129
July	468	177
August	416	153
September	320	123
Totals	6888	2426

TABLE 3. Number of Times an Individual Was Captured During the Year in Which It Was First Captured.

Capture Status	Treated Area		Untreated Area	
	Number	Percent	Number	Percent
	1965			
Total animals captured	498		234	
Animals captured once	189	38.0	101	43.2
Animals captured twice	94	18.9	44	18.8
Animals captured more than twice	215	43.2	89	38.0
	1966			
Total animals captured	675		260	
Animals captured once	320	47.4	130	50.0
Animals captured twice	125	20.0	53	20.4
Animals captured more than twice	220	32.5	77	29.6
	1967			
Total animals captured	883		320	
Animals captured once	397	45.0	177	55.3
Animals captured twice	117	13.2	75	23.4
Animals captured more than twice	369	41.8	68	21.3
	1968			
Total animals captured	636		260	
Animals captured once	258	40.6	135	51.9
Animals captured twice	139	21.9	52	20.0
Animals captured more than twice	239	37.6	73	28.1

TABLE 4. Number of Captures by Species and Area per 1000 feet of Trap Line.

Species*	Treated	Untreated	Treated	Untreated
	June 1965		July 1965	
P. man.	35.6	28.2	26.9	38.7
Mus	9.0	0.0	5.6	1.8
Onych.	0.2	0.0	1.1	0.0
Sig. hisp.	0.3	1.6	0.3	0.5
Mict. och.	0.9	0.5	3.8	5.3
Reith. meg.	1.9	1.1	0.3	0.5
Others	4.4	0.8	3.3	0.0
Totals	52.3	32.2	41.3	46.8
	August 1965		September 1965	
P. man.	25.4	28.7	24.2	13.7
Mus	7.6	6.3	6.8	15.5
Onych.	1.5	0.0	3.0	0.0
Sig. hisp.	1.6	0.3	4.0	5.3
Mict. och.	2.1	2.1	1.5	6.3
Reith. meg.	0.2	1.3	0.3	0.5
Others	2.1	0.3	0.8	0.3
Totals	40.5	39.0	40.6	41.6
	June 1966		July 1966	
P. man.	44.7	29.5	31.7	33.4
Mus	9.9	6.6	3.8	3.4
Onych.	1.3	1.6	0.1	3.9
Sig. hisp.	8.3	7.4	7.7	3.9
Mict. och.	5.9	1.6	8.2	0.5
Reith. meg.	1.5	0.8	0.3	0.8
Others	0.5	0.0	1.3	0.8
Totals	72.1	47.5	53.1	46.7

*Species in order given above: *Peromyscus maniculatus*, *Mus musculus*, *Onychomys leucogaster*, *Sigmodon hispidus*, *Microtus ochrogaster*, *Reithrodontomys megalotis* and others.

Table 4. (cont.)

Species	Treated	Untreated	Treated	Untreated
	August 1966		September 1966	
P. man.	25.4	16.6	16.3	16.3
Mus	1.9	3.2	1.0	2.4
Onych.	0.3	5.8	0.1	1.1
Sig. hisp.	3.9	3.7	0.8	1.3
Mict. och.	5.5	1.3	0.1	1.6
Reith. meg.	0.1	0.0	0.0	0.3
Others	1.1	0.3	1.5	2.4
Totals	38.2	30.9	19.8	25.4
	April 1967		May 1967	
P. man.	54.4	33.9	38.9	18.7
Mus	2.0	3.4	0.6	0.5
Onych.	0.2	0.0	0.2	0.0
Sig. hisp.	1.9	0.0	2.2	0.0
Mict. orc.	0.0	0.0	0.0	0.0
Reith. meg.	5.1	1.3	2.5	1.0
Others	0.0	0.5	0.0	1.3
Totals	63.6	39.1	44.4	21.5
	June 1967		July 1967	
P. man.	38.9	33.3	40.2	35.2
Mus	1.2	3.4	1.5	1.8
Onych.	0.6	0.0	0.6	0.0
Sig. hisp.	2.5	0.0	4.5	0.3
Mict. orc.	0.0	0.0	0.0	0.0
Reith. meg.	1.5	0.3	0.0	0.0
Others	0.0	1.0	0.6	1.3
Totals	44.7	38.0	47.4	38.6
	August-September 1967			
P. man.	26.7	24.0		
Mus	2.0	3.1		
Onych.	0.1	2.1		
Sig. hisp.	10.5	1.3		
Mict. orc.	0.0	0.0		
Reith. meg.	0.0	0.0		
Others	0.2	1.8		
Totals	39.5	32.3		

Table 4. (concl.)

Species	Treated	Untreated	Treated	Untreated
	June 1968		July 1968	
P. man.	41.5	26.0	42.4	39.1
Mus	0.9	2.9	1.7	2.3
Onych.	0.4	1.8	2.4	0.3
Sig. hisp.	5.0	1.8	2.7	1.0
Mict. orc.	0.0	0.0	0.1	1.0
Reith. meg.	0.0	0.0	0.6	1.0
Others	1.4	1.0	1.4	2.3
Totals	49.2	33.5	51.3	47.0
	August 1968		September 1968	
P. man.	35.4	30.2	23.6	16.9
Mus	2.1	1.3	3.1	2.8
Onych.	5.3	3.1	2.4	2.8
Sig. hisp.	1.7	2.6	3.6	4.7
Mict. orc.	0.4	1.3	1.2	0.5
Reith. meg.	0.2	0.0	0.9	0.3
Others	0.3	1.3	0.4	3.9
Totals	45.4	39.8	35.2	31.9

TABLE 5. Total Captures by Month, Species and Area with Percent Composition for Each Month.

Species*	Treated No.	Treated %	Untreated No.	Untreated %	Treated No.	Treated %	Untreated No.	Untreated %
		June 1965				July 1965		
P. man.	310	67.8	107	87.7	234	64.8	147	82.6
Mus	79	17.3	0	0.0	49	13.6	7	3.9
Onych.	2	0.4	0	0.0	10	2.8	0	0.0
Sig. hisp.	3	0.6	6	5.0	3	0.8	2	1.1
Mict. och.	8	1.7	2	1.6	33	9.1	20	11.2
Reith. meg.	17	3.8	4	3.3	3	0.8	2	1.1
Others	38	8.3	3	2.5	29	8.0	0	0.0
Totals	457	99.9	122	100.1	361	99.9	178	99.9
		August 1965				September 1965		
P. man.	221	62.8	109	73.6	211	59.6	52	32.9
Mus	66	18.6	24	16.2	59	16.7	59	37.3
Onych.	13	3.7	0	0.0	26	7.3	0	0.0
Sig. hisp.	14	4.0	1	0.7	35	9.9	20	12.6
Mict. och.	18	5.2	8	5.4	13	3.7	24	15.2
Reith. meg.	2	0.6	5	3.4	3	0.8	2	1.3
Others	18	5.2	1	0.7	7	2.0	1	0.6
Totals	352	100.1	148	100.0	354	100.0	158	99.9
		June 1966				July 1966		
P. man.	389	62.1	112	62.2	276	59.6	127	71.3
Mus	86	13.7	25	13.9	33	7.1	13	7.3
Onych.	11	1.8	6	3.3	1	0.2	15	8.4
Sig. hisp.	72	11.5	28	15.6	67	14.5	15	8.4
Mict. och.	51	8.2	6	3.3	71	15.4	2	1.1
Reith. meg.	13	2.1	3	1.7	3	0.7	3	1.7
Others	4	0.6	0	0.0	11	2.4	3	1.7
Totals	626	100.0	180	100.0	462	99.9	178	99.9

*Species in order given above: Peromyscus maniculatus, Mus musculus, Onychomys leucogaster, Sigmodon hispidus, Microtus ochrogaster, Reithrodontomys megalotis and others.

Table 5. (cont.)

Species	Treated No.	Treated %	Untreated No.	Untreated %	Treated No.	Treated %	Untreated No.	Untreated %
	August 1966				September 1966			
P. man.	221	66.2	63	53.8	143	82.2	62	64.4
Mus	17	5.1	12	10.2	9	5.2	9	9.4
Onych.	3	0.9	22	18.8	1	0.6	4	4.2
Sig. hisp.	34	10.2	14	12.0	7	4.0	5	5.2
Mict. och.	48	14.4	5	4.3	1	0.6	6	6.2
Reith. meg.	1	0.3	0	0.0	0	0.0	1	1.0
Others	10	2.9	1	0.8	13	7.5	9	9.4
Totals	334	100.0	117	99.9	174	100.1	96	100.2
	April 1967				May 1967			
P. man.	493	85.4	130	86.7	352	89.3	72	86.7
Mus	19	3.3	13	8.7	6	1.5	2	2.4
Onych.	2	0.4	0	0.0	2	0.5	0	0.0
Sig. hisp.	17	2.9	0	0.0	20	5.1	0	0.0
Mict. orc.	0	0.0	0	0.0	0	0.0	0	0.0
Reith. Meg.	46	8.0	5	3.3	14	3.6	1	0.7
Others	0	0.0	2	1.3	0	0.0	5	6.0
Totals	577	100.0	150	100.0	394	100.0	83	99.9
	June 1967				July 1967			
P. man.	351	86.9	128	87.7	364	84.8	135	91.2
Mus	11	2.7	13	8.9	14	3.3	7	4.7
Onych.	5	1.2	0	0.0	5	1.2	0	0.0
Sig. hisp.	23	5.7	0	0.0	41	9.6	1	0.7
Mict. orc.	0	0.0	0	0.0	0	0.0	0	0.0
Reith. meg.	14	3.5	1	0.7	0	0.0	0	0.0
Others	0	0.0	4	2.7	5	1.2	5	3.4
Totals	404	100.0	146	100.0	429	100.1	148	100.0
	August-September 1967							
P. man.	242	67.6	92	74.2				
Mus	18	5.0	12	9.7				
Onych.	1	0.3	8	6.5				
Sig. hisp.	95	26.5	5	4.0				
Mict. orc.	0	0.0	0	0.0				
Reith. meg.	0	0.0	0	0.0				
Others	2	0.6	7	5.6				
Totals	358	100.0	124	100.0				

Table 5. (concl.)

Species	Treated No.	Treated %	Untreated No.	Untreated %	Treated No.	Treated %	Untreated No.	Untreated %
	June 1968				July 1968			
P. man.	376	84.3	100	77.5	384	82.4	150	84.7
Mus	8	1.8	11	8.5	15	3.2	9	5.1
Onych.	4	0.9	7	5.4	22	4.7	1	0.6
Sig. hisp.	45	10.1	7	5.4	26	5.6	4	2.3
Mict. orc.	0	0.0	0	0.0	1	0.2	0	0.0
Reith. meg.	0	0.0	0	0.0	6	1.3	4	2.3
Others	13	2.9	4	3.1	13	2.8	9	5.1
Totals	446	100.0	129	99.9	466	100.2	177	100.1
	August 1968				September 1968			
P. man.	321	78.1	116	75.8	214	66.9	65	52.8
Mus	19	4.6	5	3.3	28	8.7	11	8.9
Onych.	48	11.7	12	7.8	22	6.9	11	8.9
Sig. hisp.	15	3.6	10	6.5	33	10.3	18	14.6
Mict. orc.	4	1.0	5	3.3	11	3.4	2	1.6
Reith. meg.	2	0.5	0	0.0	8	2.5	1	0.8
Others	3	0.7	5	3.3	4	1.2	15	12.2
Totals	411	100.2	153	100.0	320	99.9	123	99.8

TABLE 6. Average Longevity for all Captured Individuals. (Given for the Year in Which the Individual Was First Captured and Marked.)

Year	Treated Area (months)	Untreated Area (months)
1965	1.81	1.47
1966	1.42	1.53
1967	1.68	2.13
1968	1.44	1.82
	$\bar{x}$ = 1.61	$\bar{x}$ = 1.73

TABLE 7. Population Estimation for Total Population Using the Schnabel Method, for all Months June 1965 Through September 1968 for Both the Treated and Untreated Areas.

	Treated		Untreated	
	No.	CI*	No.	CI
		1965		
June	173	152-201	91	71-124
July	190	163-227	74	61- 95
August	192	164-231	72	57- 96
September	190	163-228	126	98-176
		1966		
June	350	311-401	131	104-177
July	308	266-365	144	114-196
August	257	215-319	126	92-199
September	122	89-150	113	79-197
		1967		
April	494	434-573	147	111-216
May	287	246-344	111	76-206
June	310	264-375	104	81-145
July	242	210-285	83	66-113
August-September	380	314-479	102	77-151
		1968		
June	350	297-425	120	89-185
July	291	254-341	133	106-179
August	254	218-303	134	103-191
September	329	270-421	192	136-327

*CI = Confidence Interval.

TABLE 8. Population Estimation for Total Population Using the Schumacher-Eschemeyer Method for all Months from June 1965 Through September 1968 for Both the Treated and Untreated Areas.

	Treated		Untreated	
	No.	CI*	No.	CI
		1965		
June	177	±15	94	±22
July	192	±20	77	±11
August	205	± 5	76	±11
September	195	±12	130	±27
		1966		
June	357	±24	138	±25
July	323	±22	145	±26
August	269	±18	132	±34
September	124	± 6	129	±25
		1967		
April	493	±36	174	±46
May	290	±33	120	±16
June	320	±26	105	±17
July	244	±31	88	± 7
August-September	378	±54	105	±16
		1968		
June	342	±55	120	±33
July	311	± 8	138	±15
August	277	±46	143	±30
September	338	±69	203	±57

*CI = Confidence Interval.

TABLE 9. Population Estimations for Total Population per 1000 Feet of Trap Line Using the Schnabel Method for all Months June 1965 Through September 1968 for Both the Treated and Untreated Areas.

Period	Treated	Untreated
1965		
June	19.9	23.9
July	21.8	19.5
August	22.1	18.9
September	21.8	33.2
1966		
June	40.2	34.5
July	35.4	37.9
August	29.5	33.2
September	12.9	29.7
1967		
April	56.8	38.7
May	33.0	29.2
June	35.6	27.4
July	27.8	21.8
August-September	43.7	26.8
1968		
June	40.2	31.6
July	33.4	35.0
August	29.2	35.3
September	37.8	50.5

TABLE 10. Population Estimations for Total Population per 1000 Feet of Trap Line Using the Schumacher-Eschemeyer Method for all Months June 1965 Through September 1968 for Both the Treated and Untreated Areas.

Period	Treated	Untreated
1965		
June	20.3	24.7
July	22.1	20.3
August	23.6	20.0
September	22.4	34.2
1966		
June	41.0	36.3
July	37.1	38.2
August	30.9	34.7
September	14.3	33.9
1967		
April	56.7	45.8
May	33.3	31.6
June	36.8	27.6
July	28.0	23.2
August-September	43.4	27.6
1968		
June	39.3	31.6
July	35.7	36.3
August	31.8	37.6
September	38.9	53.4

TABLE 11. Population Estimations for Peromyscus maniculatus Using the Schnabel Method for all Months from June 1965 Through September 1968 for Both the Treated and the Untreated Areas.

	Treated		Untreated	
	No.	CI*	No.	CI
		1965		
June	110	95-131	61	47- 89
July	108	90-134	59	48- 78
August	78	66- 96	41	32- 57
September	78	65- 97	40	27- 76
		1966		
June	188	163-222	70	53-102
July	139	117-171	87	67-124
August	133	109-170	61	41-117
September	74	58-100	55	37-107
		1967		
April	392	341-460	112	84-167
May	233	198-282	76	52-141
June	253	213-310	82	63-116
July	191	164-227	67	53- 91
August-September	210	170-274	57	43- 86
		1968		
June	278	234-343	94	68-154
July	231	199-274	84	64-123
August	176	149-215	95	75-130
September	174	140-230	100	65-221

*CI = Confidence Interval.

TABLE 12. Population Estimations for Peromyscus maniculatus Using the Schumacher-Eschemeyer Method for all Months June 1965 Through September 1968 for Both the Treated and Untreated Areas.

	Treated		Untreated	
	No.	CI*	No.	CI
		1965		
June	114	±12	66	±16
July	107	±13	60	± 6
August	82	± 6	43	± 4
September	80	± 9	40	± 9
		1966		
June	190	±19	75	±10
July	144	±19	88	±14
August	138	±22	63	±10
September	81	±13	65	±17
		1967		
April	395	±29	132	±25
May	235	±35	83	± 8
June	261	±33	83	± 5
July	192	±21	30	± 9
August-September	208	±45	59	±10
		1968		
June	273	±43	95	±29
July	243	±27	98	±23
August	195	±48	88	±26
September	172	±31	100	±47

*CI = Confidence Interval.

TABLE 13. Pesticidal Analyses Conducted on 166 Rodents. (D = dieldrin, HE = heptachlor epoxide.)

No.	Species*	Sex	Trapping Period Collected	Area where Collected	Results ppm
			1965		
1a	Mict. och.	F	June	Treated	0
2a	Mus	M	June	Treated	0
3a	P. flavus	M	June	Treated	0
4a	P. man.	M	June	Treated	0
5a	Mus	M	June	Untreated	0
6a	Sig. hisp.	F	June	Untreated	0
7a	Reith. meg.	M	June	Untreated	0
8a	Mict. och.	M	June	Untreated	0
9a	P. man.	F	June	Untreated	0
10a	Mict. och.	F	July	Untreated	0
11a	P. man.	M	July	Untreated	0
12a	P. man.	M	July	Untreated	0
13a	Sig. hisp.	M	July	Treated	0
14a	S. tridec.	F	July	Treated	0.24 D
15a	Mus	F	July	Treated	0
16a	Mus	M	July	Treated	0
17a	Mict. och.	F	July	Treated	0
18a	Mict. och.	F	July	Treated	0
19a	Mict. och.	M	August	Untreated	0
20a	P. man.	M	August	Untreated	0
21a	P. man.	M	August	Untreated	0
22a	P. man.	F	August	Treated	0
23a	Onych.	F	August	Treated	0
24a	P. man.	F	August	Treated	0
25a	Mict. och.	F	August	Treated	0
26a	P. flavesens	M	August	Treated	0
27a	Sig. hisp.	F	August	Treated	0
1	Mict. och.	M	September	Untreated	0
2	Mus	M	September	Untreated	0
3	Sig. hisp.	F	September	Treated	0
4	P. man.	M	September	Treated	0.01 D
5	P. man.	M	September	Untreated	0
6	Mus	M	September	Treated	0.01 D

*Species in order given above: *Microtus ochrogaster*, *Mus musculus*, *Perognathus flavus*, *Peromyscus maniculatus*, *Sigmodon hispidus*, *Reithrodontomys megalotis*, *Spermophilus tridecemlineatus*, *Onychomys leucogaster*, *Perognathus flavesens* and *Perognathus hispidus*.

Table 13. (cont.)

No.	Species	Sex	Trapping Period Collected	Area where Collected	Results ppm
			1966		
10	Sig. hisp.	F	June	Treated	0
11	P. man.	M	June	Treated	0
12	Mus	M	June	Treated	0
13	Reith. meg.	M	June	Treated	0
14	P. falvesens	M	June	Treated	0
15	Mict. och.	M	June	Treated	0
16	Mict. och.	M	June	Untreated	0
17	P. man.	F	June	Untreated	0
18	Reith. meg.	F	June	Untreated	0.03 D
19	Sig. hisp.	F	June	Untreated	0
20	Mict. och.	M	July	Treated	0
21	P. man.	M	July	Treated	0.01 D & 0.02 HE
22	Mus	M	July	Treated	0.13 D
23	Sig. hisp.	M	July	Treated	0
24	S. tridec.	M	July	Treated	0
25	Sig. hisp.	M	July	Untreated	0
26	Mus	M	July	Untreated	0
27	P. man.	M	July	Untreated	0
28	Onych.	M	July	Untreated	0
29	P. man.	M	August	Treated	0
30	Mict. och.	F	August	Treated	0
31	P. flavesens	M	August	Treated	0
32	P. man.	M	August	Treated	0
33	S. tridec.	M	August	Treated	0
34	Mus	M	August	Treated	0
35	Onych.	F	August	Treated	0.02 D
36	Sig. hisp.	M	August	Treated	0
37	P. man.	M	August	Untreated	0
38	Sig. hisp.	M	August	Untreated	0
39	Onych.	F	August	Untreated	0
40	P. flavesens	F	August	Untreated	0
41	Mus	M	August	Untreated	0
42	Mict. och.	F	August	Untreated	0
43	P. man.	F	September	Untreated	0
44	P. man.	F	September	Untreated	0.01 D
45	Mus	M	September	Untreated	0
46	P. flavesens	M	September	Untreated	0
47	P. man.	F	September	Treated	0
48	P. flavesens	F	September	Treated	0
49	P. man.	F	September	Treated	0
50	Mus	M	September	Treated	0.02 D

Table 13. (cont.)

No.	Species	Sex*	Trapping Period Collected	Area where Collected	Results ppm
			1967		
51	Sig. hisp.	F	April	Treated	0.01 HE
52	P. man.	M	April	Treated	0.01 HE
53	Onych.	M	April	Treated	0
54	P. man.	M	April	Treated	0
55	P. man.	F	April	Treated	0.01 D
56	Reith. meg.	F	April	Treated	0
57	P. man.	M	April	Untreated	0.01 D
58	P. man.	M	April	Untreated	0
59	Mus	F	April	Untreated	0
60	P. man.	M	May	Untreated	0
61	Mus	M	May	Untreated	0
62	Reith. meg.	M	May	Untreated	0
63	P. man.	F	May	Untreated	0
64	P. man.	M	May	Treated	0
65	P. man.	M	May	Treated	0.01 D
66	Reith. meg.	M	May	Treated	0
67	Reith. meg.	M	May	Treated	0
68	Mus	M	May	Treated	0.01 D
69	Sig. hisp.	M	May	Treated	0
70	Onych.	F	May	Treated	0
71	S. tridec.	*	June	Treated	0.01 D
72	Onych.	*	June	Treated	0.05 D
73	P. man.	*	June	Treated	0.01 D
74	P. hisp.	*	June	Treated	0
75	P. man.	*	June	Treated	0
76	Reith. meg.	*	June	Treated	0.02 D
77	P. man.	*	July	Treated	0.50 D
78	P. man.	*	July	Treated	0.02 D & 0.01 HE
79	Mus	*	July	Treated	0.01 D
80	Mus	*	July	Untreated	0
81	P. man.	*	July	Untreated	0
82	P. hisp.	*	July	Treated	0
83	S. tridec.	*	July	Treated	0.02 D & 0.01 HE
84	P. man.	*	Aug.-Sept.	Treated	0.03 D
85	P. man.	*	Aug.-Sept.	Treated	0.01 D
86	P. man.	*	Aug.-Sept.	Treated	0
87	P. hisp.	*	Aug.-Sept.	Untreated	0.01 D

*Information not available.

Table 13. (cont.)

No.	Species	Sex	Trapping Period Collected	Area where Collected	Results ppm
88	Onych.	*	Aug.-Sept.	Treated	0.02 D & 0.02 HE
89	P. man	*	Aug.-Sept.	Untreated	0
90	Sig. hisp.	*	Aug.-Sept.	Treated	0
91	Onych.	*	Aug.-Sept.	Untreated	0.01 D & 0.01 HE
92	Sig. hisp.	*	Aug.-Sept.	Treated	0
93	P. man.	*	Aug.-Sept.	Treated	0.01 HE
			<u>1968</u>		
94	P. hisp.	F	June	Untreated	0.28 D
95	P. hisp.	F	June	Treated	0
96	P. man.	M	June	Treated	0
97	Sig. hisp.	M	June	Treated	0
98	P. man.	M	June	Treated	0
99	S. tridec.	F	June	Treated	0
100	P. man.	F	June	Untreated	0.26 D
101	Sig. hisp.	F	June	Treated	0
102	Onych.	M	June	Untreated	0
103	Mus	F	June	Untreated	0
104	P. man.	M	June	Untreated	0
105	Reith. meg.	M	June	Untreated	0
106	Mus	F	June	Treated	0.01 D
107	Reith. meg.	F	July	Untreated	0
108	Sig. hisp.	F	July	Untreated	0
109	Sig. hisp.	M	July	Treated	0
110	Mus	M	July	Untreated	0.44 D
111	Mus	M	July	Treated	0
112	S. tridec.	F	July	Treated	0.02 D
113	Mict. och.	M	July	Treated	0
114	P. man.	M	July	Untreated	0.01 D
115	Onych.	F	July	Treated	0
116	P. man.	F	July	Treated	0
117	Onych.	F	July	Untreated	0
118	P. hisp.	M	July	Untreated	0
119	P. man.	M	July	Untreated	0.04 D
120	P. man.	F	July	Treated	0.04 D
121	Sig. hisp.	F	August	Untreated	0
122	Sig. hisp.	F	August	Treated	0
123	P. hisp.	F	August	Untreated	0
124	Mict. och.	F	August	Untreated	0
125	Onych.	M	August	Untreated	0
126	Mus	M	August	Untreated	0.15 D
127	P. man.	M	August	Untreated	0
128	Mus	M	August	Treated	0

Table 13 (concl.)

No.	Species	Sex	Trapping Period Collected	Area where Collected	Results ppm
129	P. man.	M	August	Treated	0
130	Onych.	M	August	Treated	0
131	P. man.	M	August	Treated	0
132	P. man.	F	August	Treated	0
133	Sig. hisp.	F	September	Treated	0
134	Mict. och.	M	September	Treated	0
135	Onych.	M	September	Treated	0
136	Onych.	F	September	Untreated	0
137	Mict. och.	M	September	Untreated	0
138	P. hisp.	M	September	Untreated	0
139	P. man.	F	September	Treated	0
140	Mus	M	September	Treated	0
141	Reith. meg.	F	September	Treated	0
142	P. man.	*	September	Untreated	0

TABLE 14. Summary of Pesticide Residue Analyses on the Carcasses of Small Mammals Collected During This Study.

Year	Treated Area			Untreated Area		
	Number Analyzed	Containing Pesticide Residues		Number Analyzed	Containing Pesticide Residues	
		Number*	Percent		Number*	Percent
1965	19	3	15.8	14	0	0.0
1966	23	4	17.4	18	2	11.1
1967	31	17	54.8	12	3	25.0
1968	26	3	11.5	23	6	26.1
Totals	99	27	27.3	67	11	16.4

*Body tissues containing 0.01 ppm or more residues.

TABLE 15. Days that a Significant Difference Between Total Number of Animals Captured to that Day and the Total on Day 10 Occurred.

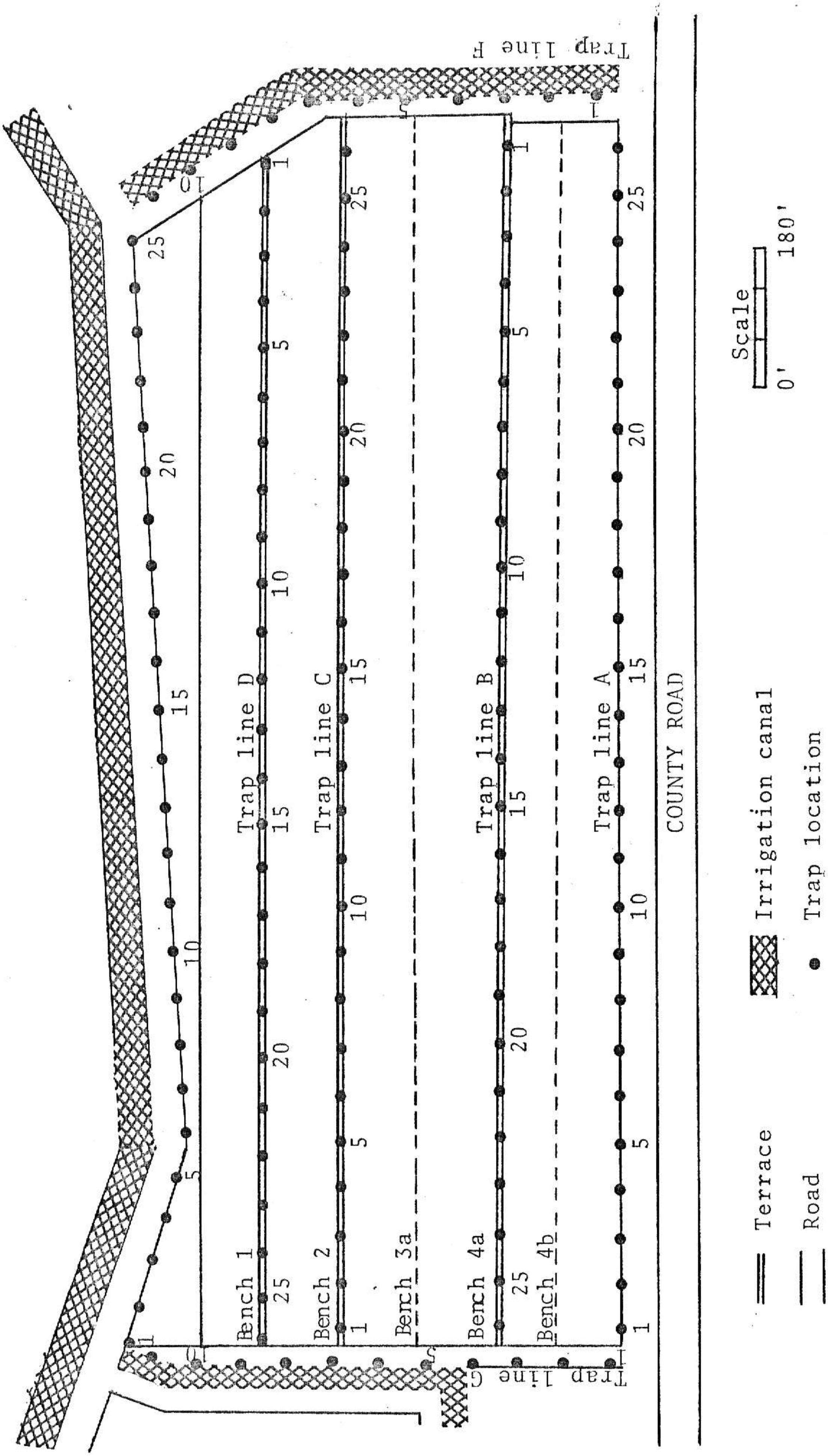
Level*	Days, Treated Area										Days, Untreated Area									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
							Total Capture													
0.990	x	x	x	x	x	x	x				x	x	x	x	x	x	x			
0.950	x	x	x	x	x	x	x				x	x	x	x	x	x	x			
0.900	x	x	x	x	x	x	x				x	x	x	x	x	x				
0.500	x	x	x	x	x						x	x	x	x						
							Peromyscus maniculatus Capture													
0.990	x	x	x	x	x	x	x				x	x	x	x	x	x	x			
0.950	x	x	x	x	x	x					x	x	x	x	x	x	x			
0.900	x	x	x	x	x	x					x	x	x	x	x					
0.500	x	x	x	x	x						x	x								

*Chi square values are: 1 = 34.57
2 = 28.12
3 = 17.98
4 = 16.75

TABLE 16. Carryover of Individuals on the Treated and Untreated Areas.

Year	Treated Area			Untreated Area		
	Total Capture	Carryover to Next Year	Percent	Total Capture	Carryover to Next Year	Percent
1965	498	16	3.2	234	4	1.7
1966	675	24	3.5	260	18	6.9
1967	883	21	2.4	320	15	4.7
Total	2056	61		814	37	
Average			3.0			4.5

Figure 1. Map of the treated area showing locations of trap lines and traps. (After Stalling, 1968.)



Trap line F
Trap line G
Trap line D
Trap line C
Trap line B
Trap line A
Bench 1
Bench 2
Bench 3a
Bench 4a
Bench 4b
COUNTY ROAD
Scale
0'
180'
Terrace
Road
Irrigation canal
Trap location

Figure 2. Map of the untreated area showing locations of trap lines and traps. (After Stalling, 1968.)

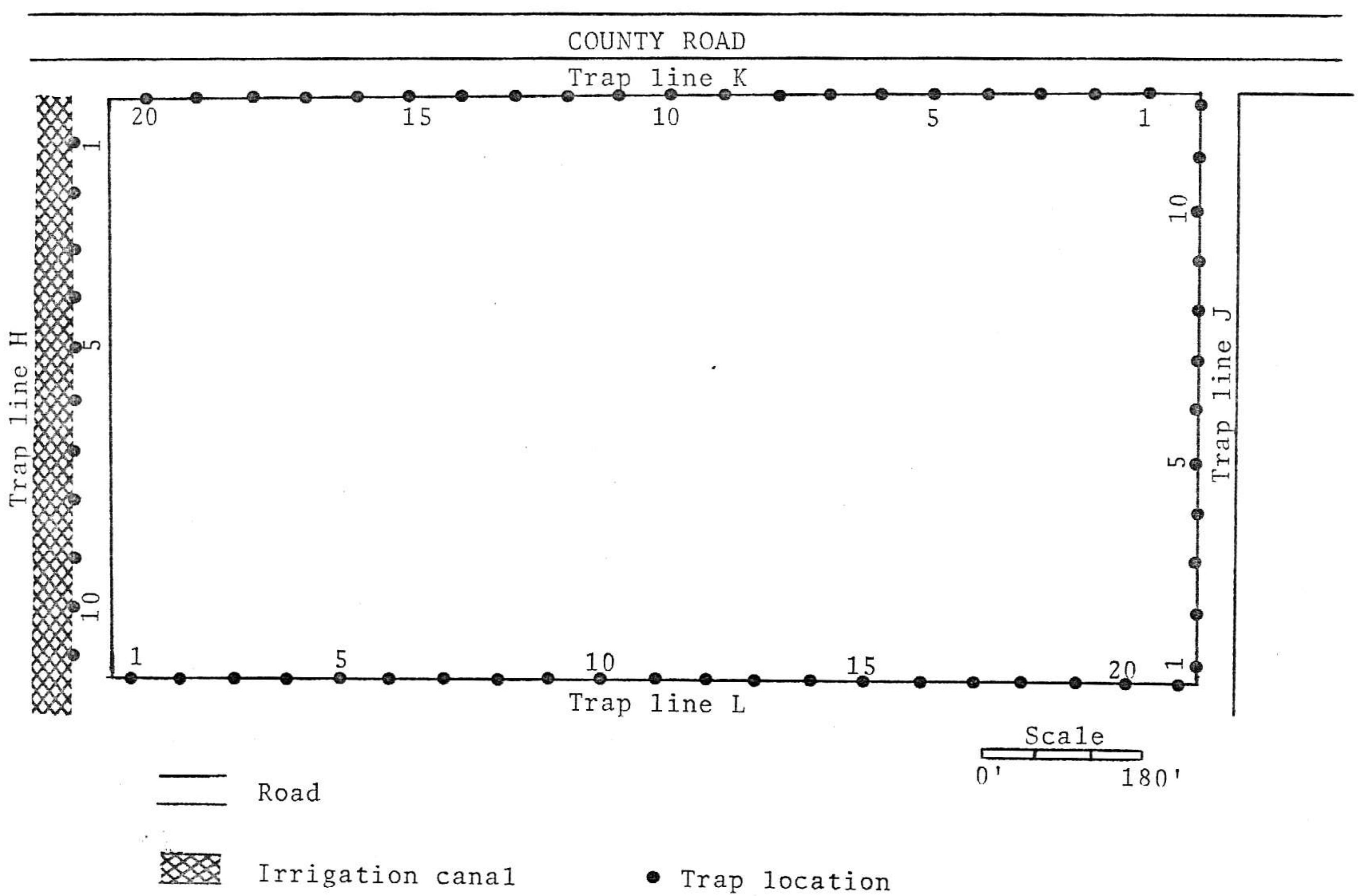

COUNTY ROAD
Trap line K
Trap line J
Trap line L
Trap line H
Scale
0'
180'
Road
Irrigation canal
Trap location

Figure 3. Periods during which trapping was conducted from 1965 through 1968. (Bars indicate days on which trapping occurred.)

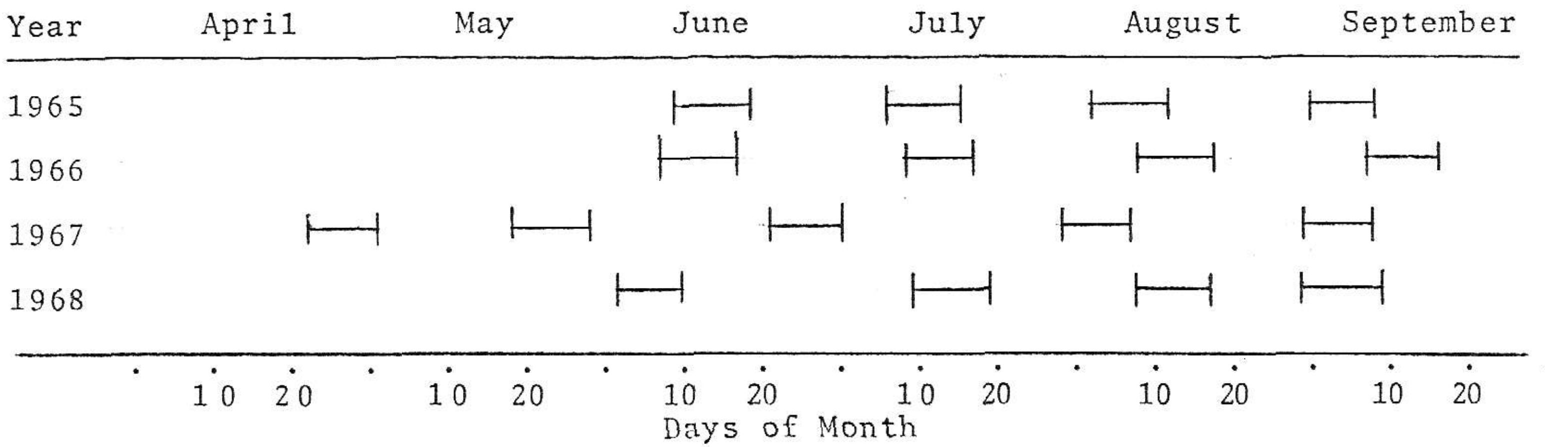

Year
April
May
June
July
August
September
1965
1966
1967
1968
10 20
10 20
10 20
10 20
10 20
10 20
Days of Month

Figure 4. Population estimation for Schnabel and Schumacher-Eschemeyer indices for all periods June 1965 through September 1968 on both the treated and untreated areas.

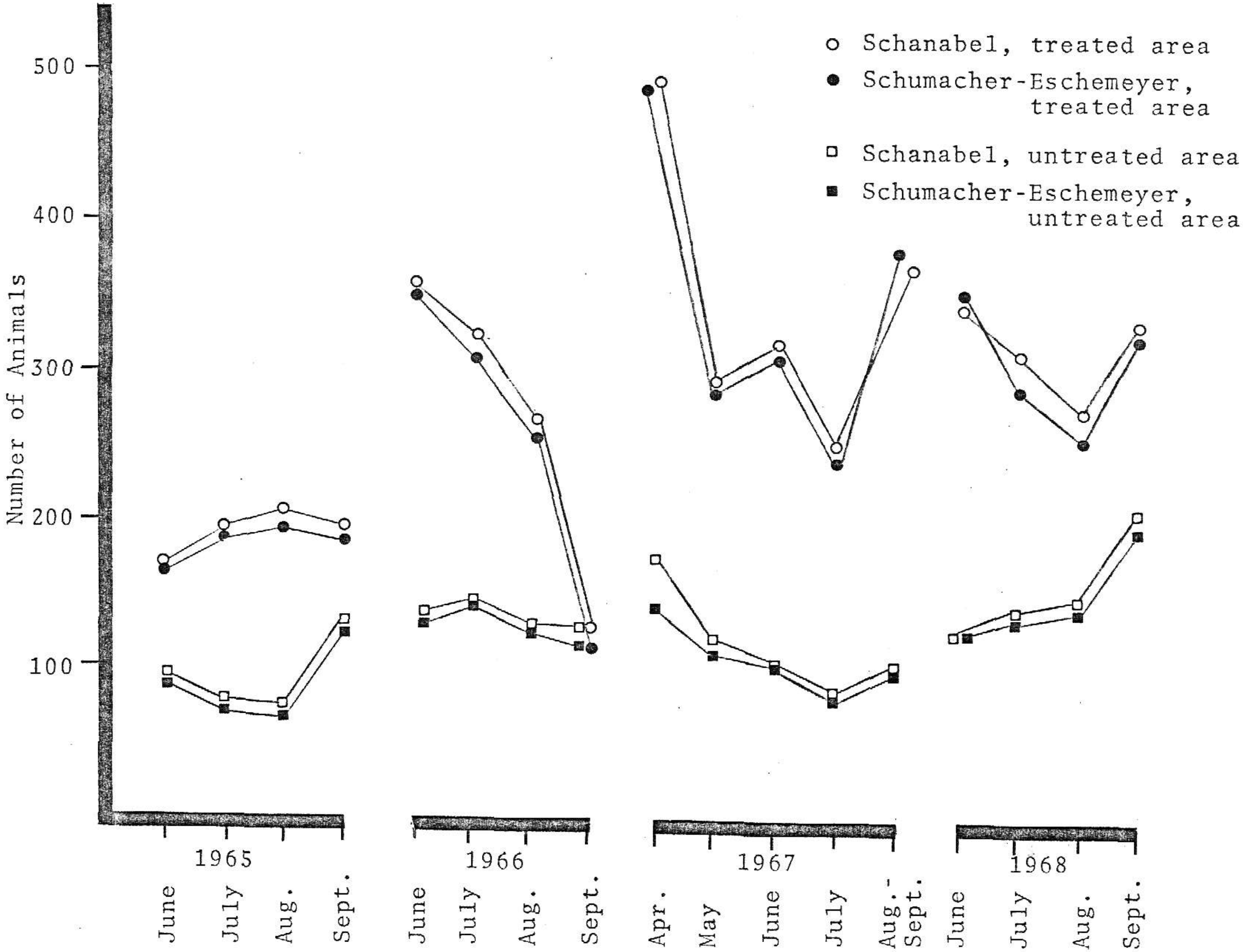

Schanabel, treated area
Schumacher-Eschemeyer, treated area
Schanabel, untreated area
Schumacher-Eschemeyer, untreated area
Number of Animals
500
400
300
200
100
1965
1966
1967
1968
June
July
Aug.
Sept.
Apr.
May
Aug.-Sept.

Figure 5. Total estimated population per 1000 feet of trap line by the Schnabel method on the treated and untreated areas.

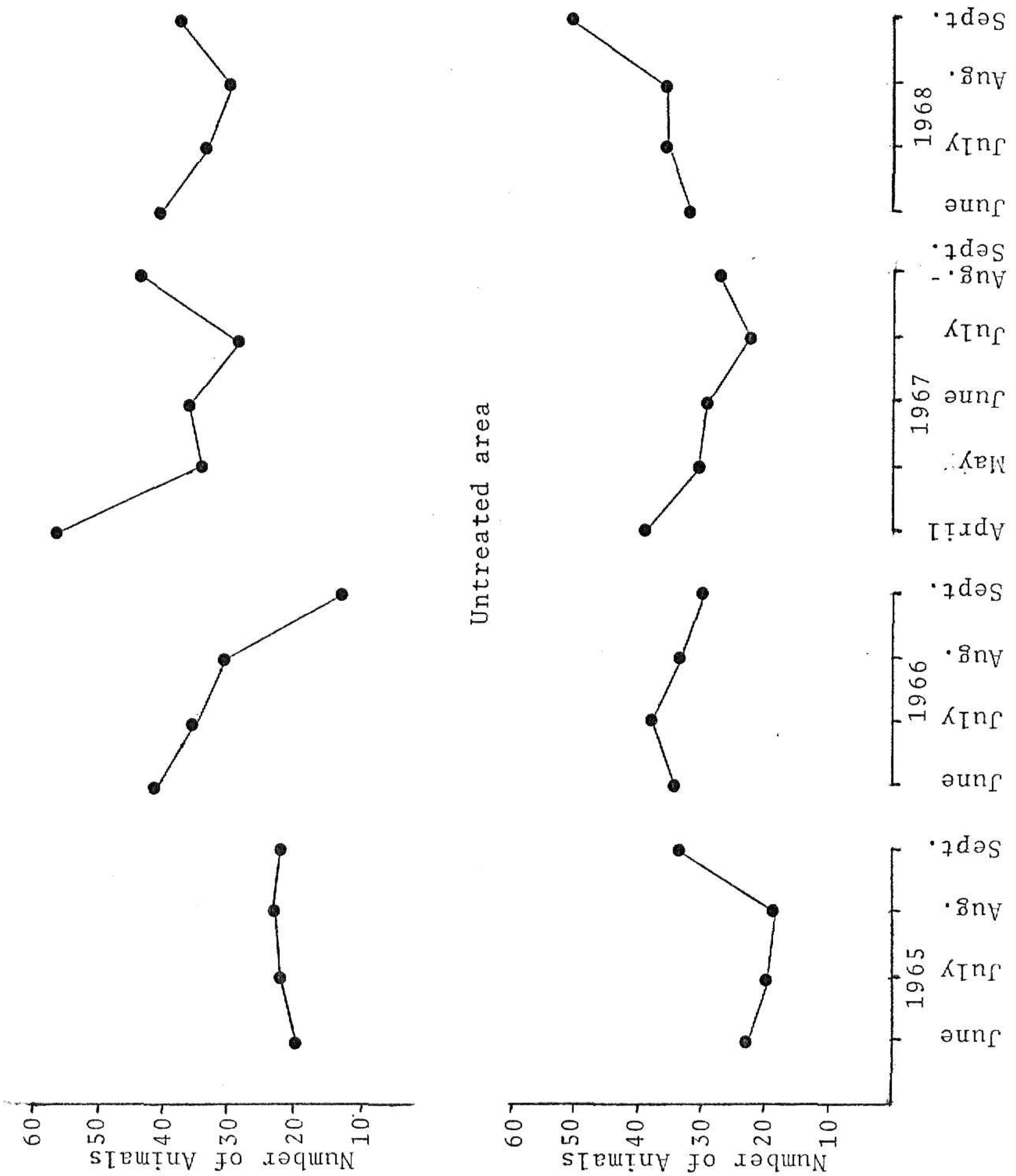
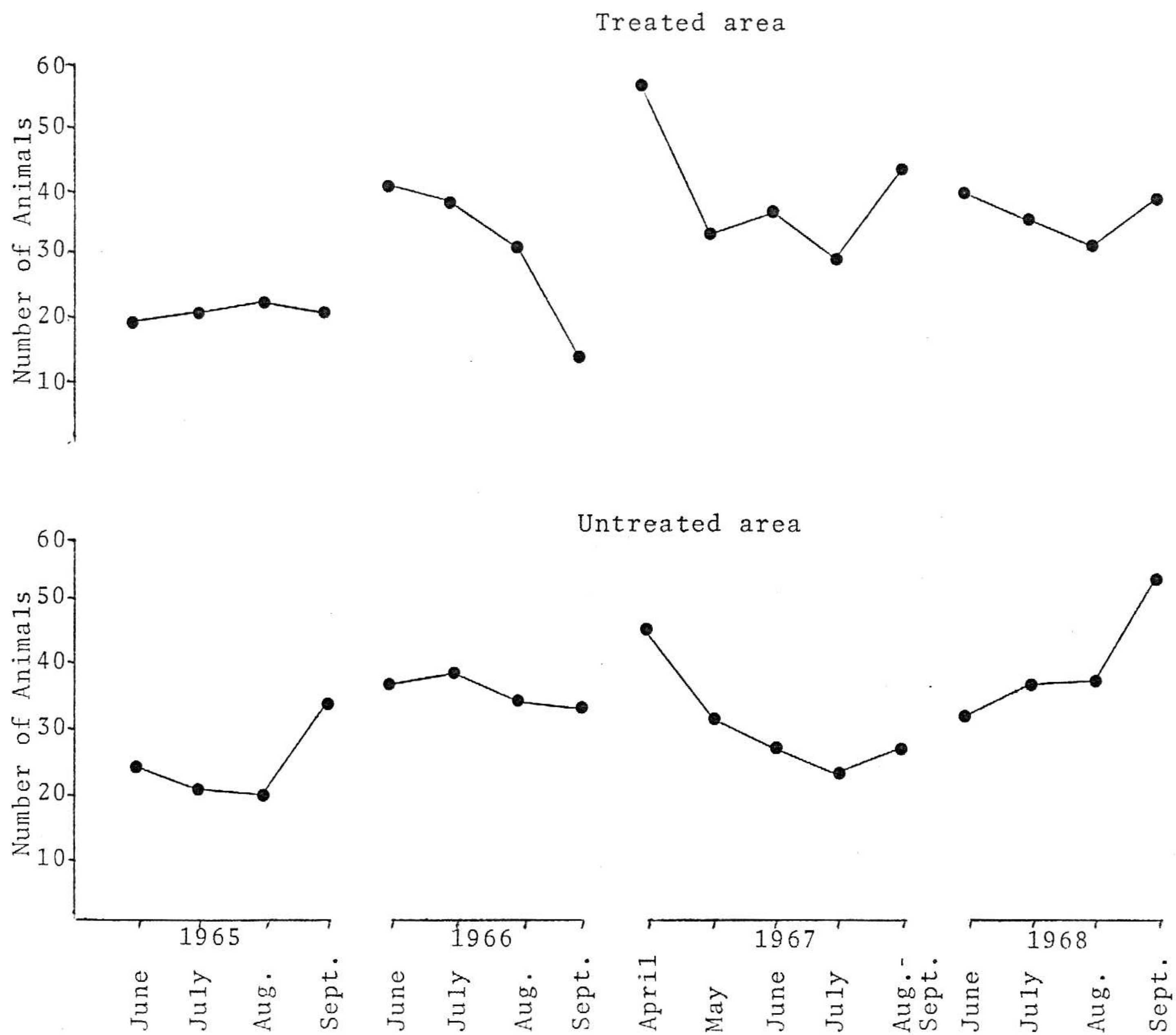

Treated area
Untreated area
Number of Animals
60
50
40
30
20
10
Number of Animals
60
50
40
30
20
10
June
July
Aug.
Sept.
1965
June
July
Aug.
Sept.
1966
April
May
June
July
Aug.-Sept.
1967
June
July
Aug.
Sept.
1968

Figure 6. Total estimated population per 1000 feet of trap line by the Schumacher-Eschemeyer method on the treated and untreated areas.


Treated area
Number of Animals
60
50
40
30
20
10
Untreated area
Number of Animals
60
50
40
30
20
10
1965
1966
1967
1968
June
July
Aug.
Sept.
June
July
Aug.
Sept.
April
May
June
July
Aug.-Sept.
June
July
Aug.
Sept.

EFFECTS OF PESTICIDES ON SMALL MAMMAL POPULATIONS
PHASE II

by

MAX EDGAR WESTFAHL

B.S., Colorado State University, 1967

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ABSTRACT

In an effort to determine the effect of commercial pesticides on small mammal populations, a study was initiated in 1965 on the Cedar Bluffs Irrigation District in Ellis County, Kansas. Two similar areas located one mile apart were used--one area received treatment with 11 commercially available pesticides at recommended rates, the second was untreated with these control chemicals.

Samples were taken each summer, April to September, in four or five 10-day trapping periods, with 215 live traps (151 on the treated area, 64 on the untreated) placed in a linear system. Traps were baited in late afternoon and checked in early morning.

Animals were marked for identification by toe clipping and ear notching. The species captured included *Peromyscus maniculatus*, *Microtus ochrogaster*, *Mus musculus*, *Sigmodon hispidus*, *Onychomys leucogaster*, *Reithrodontomys megalotis*, *R. montanus*, *Perognathus flavus*, *P. flavesens*, *P. hispidus*, *Spermophilus tridecemlineatus*, *Dipodomys ordii* and *Sylvilagus floridanus*.

During 17 trapping periods, 25,670 trap nights on the treated area and 10,880 on the untreated area resulted in 6,888 and 2,426 small mammal captures, respectively.

Peromyscus maniculatus was the most prominent species, comprising a combined total of 74.0 percent of the total captures during the 4-year study.

Population estimations made by the Schnabel and the Schumacher-Eschemeyer methods were in such close agreement that either used separately would have been sufficient.

The population on the treated area tended to be more stable than the population on the untreated area.

Pesticide-residue analyses were made on 166 small mammals during the study. Of these, 22.9 percent had detectable residues of 0.01 ppm or greater. All residues were either dieldrin or heptachlor epoxide; there were no residues of diazinon, parathion, methyl parathion, malathion, endrin, aldrin, DDE, DDT O,P or DDT P,P.

The same population results would have been obtained if the 10-day trapping periods had been reduced to 8 days.

Two primary conclusions were reached: No correlation of population fluxuation and pesticide application could be found; and less than one-fourth (22.9 percent) of the 166 animals sampled contained residues from 0.01 to 0.50 ppm dieldrin and heptachlor epoxide. No other residues were recorded.