USE OF A TRACE ELEMENT IN STUDYING THE MOVEMENTS OF SOME SMALL MAMMALS

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An Abstract of
A Thesis

Submitted to the Graduate School of Bowling Green State University in partial fulfillment of the requirements for the degree of

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DISCLAIMER

ABSTRACT

The workability of a new technique using the non-radioactive trace element rubidium to determine movement patterns of some small mammals (Rattus rattus and Rattus exulans) was tested. The study was conducted on the Eniwetok Atoll, Marshall Islands, United States Trust Territory of the Pacific. Two application methods were tried: a foliar spray and an impregnated bait. The rubidium concentrations acquired by the rodents were determined from subsequent tissue analyses by atomic absorption spectrophotometry.

The amount of rubidium absorbed by plants was dependent upon the hydration and evapotranspiration but the loss-rate was not. The half-loss time (time needed for initial concentration to decrease by half) was much shorter for dicots than for monocots. In plant and animal tissues, the average background rubidium concentrations (by weight) were 7.8 ppm for plants and 26.5 ppm for rats. The rodents which had injested the rubidium baits or treated vegetation were easily detected having concentrations ranging from 35.4 to 3420 ppm, by weight. No correlation was found between the acquired rubidium concentrations in rats and their capture distance for the rubidium source.

The technique which is workable has some disadvantages such as individual marking difficulties and identification upon death only. Some of the distinct advantages of the technique are the ease of handling, application and its definitive identification. Much more information concerning the physiological properties and reactions of rubidium in plants and animals is needed before this technique can be fully appreciated.

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INTRODUCTION

This study tests the workability of a new technique using a trace element to determine movements of small mammals. Involved is an environmental application of rubidium, a non-radioactive trace element, which serves as an index for movement and dispersion patterns.

Dispersion has been defined by Lack (1954) as a non-random type of distribution. Wynne-Edwards (1962) more specifically defined dispersion as comprising the placement of individuals and groups of individuals within habitats they occupy and the processes by which this is brought about.

The concept of home range is necessarily considered when studying movement and dispersion patterns. Burt (1940) states that home range is that area about the animal's established home which is traversed by the animal in its normal activities of food gathering, mating, and caring for young.

Several parameters of population density may lead to dispersion. While environmental factors, such as temperature and rainfall, may cause dispersion (Davis and Golley, 1963), food according to Lack (1954, 1966) is the predominant density dependent factor determining population stability. The rate of emigration (the movement out of an area) increases when a population reaches environmental capacity (Davis and Golley, 1963); Cagle (1944) reports that individuals forced from their homes may return to them when conditions are again suitable. Wynne-Edwards (1962) states that the population density appears to bear approximately a constant relation to the amount of food present.

In essence, before maximum population densities are reached, environmental requirements, such as food, are readily available; as competition for them is increased, weaker competitors are forced to disperse, thus the population remains at approximately the carrying capacity of the environment.

Barnett (1963) observed no hierarchy in wild rat colonies but has observed a pattern of dominance and recessiveness. He has found three types of rats: Alphas, Betas, and Omegas. The Alphas are dominant, while the Betas are subordinate and are tolerated by the Alpha rats. The Omegas, which are essentially on an equal basis with the Betas, are not tolerated and are continually attacked by the Alphas. Therefore, the Omega rats must either leave the colony or be killed directly by the Alpha rats or indirectly by starvation or secondary causes.

Population studies have involved a variety of data collecting techniques. Direct observations of animals marked with colored plastic ear tags (Manville, 1949) as well as examination of excretory products colored by characteristic dyes either added to food supplies (New, 1958) or injected subcutaneously (Brown, 1961; Gast, 1963) are some older techniques. Recently, the technique of tagging with radioactive materials either externally as leg bands (Godfrey, 1954; Gifford and Griffin, 1960; Griffin, 1952; Kaye, 1960 and 1961) or internally as radioactive impregnated foods (Jenkins, 1954) or as subcutaneous injections (Harvey, 1965; Karlstrom, 1957; Miller, 1957; Twigg, 1963) has proven itself to be workable.

A technique using non-radioactive elements as tracers has had some success. Lowman (1965) found the identification of non-radioactive

trace elements by atomic absorption spectrophotometry to be helpful in determining river influence on the surrounding sea. Similarly, trace element composition has aided geologists in identification of mineral samples (Angino, 1966; Capacho-Delgado and Manning, 1965; Olson, 1965; Simmons, 1965).

My study uses this non-radioactive tracer technique by adding rubidium to the natural environment to determine movement and dispersal patterns of rodents. This experiment consisted of two phases. First, a solution of rubidium chloride (RbCl) was applied to the foliage of plants; and second, RbCl was added to a supplementary food supply.

Atomic absorption spectrophotometry was employed in this study for the detection of the trace element concentration. This method is based on the atom's capacity to go from the ground state to the excited state by absorbing energy from its surroundings. A discharge lamp, emitting the same wavelength as the metal in the flame absorbs, is used to provide the background energy. The absorbance of this energy, while traveling through the low energy flame, is a measure of the concentration of the metal being analyzed (Prugger, 1966).

Rubidium (Rb) a rare, monovalent, alkali metal having atomic weight 85.48 and atomic number 37 was selected as the non-radioactive tracer to be used. Although no true mineral has yet been found (Rose, 1956), the oxides of Rb are widely dispersed, though not abundantly, throughout the Earth's crust (Whiteley, 1950). The average percentages of rubidium found in sea water, marine organisms, rivers, fresh water organisms, soils and grasses are 2×10^{-5}, 3.4×10^{-4}, 1.6×10^{-7}, 2.9×10^{-4}, 6×10^{-3}, and 6.4×10^{-4}, respectively (Mellor, 1963).

Rubidium chloride phytotoxicity, similar to that of the chloride salts of other alkali metals, causes stunting or death due to calcium depletion (Mellor, 1963), and is proportional to the acquired concentrations. While many plants are indifferent to small concentrations of rubidium, growth in several species may actually be stimulated (Mellor, 1963).

Rubidium has been found in humans by Yamagata (1962) and in many but not all marine and terrestrial organisms by Mellor (1963). Rubidium toxicity to animals is the lowest of the alkali metals (Rose, 1956) and appears to depend on its interference with potassium (Mellor, 1963). It is the only element that can be partially substituted without harm for potassium in several yeasts, mycobacteria, aerobic spore-forming organisms (Mellor, 1963), and in human blood (Rose, 1956).

Glending et al. (1956) found that rats fed diets containing 0.1 per cent Rb or more suffered a decrease in growth, reproductive performance, and survival time. In comparison, rats fed diets containing 0.02 per cent Rb or less were not affected. Rubidium was not concentrated in any particular tissue or organ, though bone contained less Rb than the soft tissue. Beyond some basic information, relatively little is known of rubidium's affect on animals (Mellor, 1963), except that it is not a nutritional requirement for white rats (Glending et al., 1956).

This study was conducted at Eniwetok Atoll, Marshall Islands, United States Trust Territory of the Pacific. The atoll, located 11° 21' North latitude and 162° 21' East longitude, has a mean annual rainfall of 57.60 inches and an average monthly temperature of 82.3 F (Connor, 1966). The atoll covers 388 square miles and consists of

40 islets having a dry land area of two and one-fourth square miles (Donaldson, 1959) and an elevation above sea level of 13 feet (Connor, 1966). The impact of the nuclear testing program between 1946 and 1958 on the physical and biotic aspects of the atoll have been summarized by Hines (1962) and Jackson (1967). Only four of the 40 islets were involved in this study: Runit, Japtan (Muti), Biijiri, and Engebi (Figure 1).

Runit, located on the eastern edge of the atoll, has primarily a grass hummock environment inhabited by the roof rat, Rattus rattus. The vegetation covering Runit, which has been repeatedly destroyed by nuclear testing, was relatively sparse (Figures 2 and 3). The selected study area had secondary scrub vegetation identified as: Frimbristylis atollensis (a grass), Ipomoea spp. (a vine), Messerschmidia argenta (a shrubby hardwood), Scaevola fructescens (a shrubby hardwood) and Triumfetta procumbens (a vine). Taxonomic usage follows St. John (1960).

Japtan, located on the southeastern edge of the atoll, has a dense Cocos nucifera (coconut) forest environment (Figure 4) inhabited by the Polynesian rat, Rattus exulans. The vegetation covering Japtan has been affected little by the nuclear testing; however, about 20 years ago, forest area was cleared of secondary vegetation but this has since regrown. More recently (about five years ago), construction pushed back the forest; this has since regrown into grassy fields. Sections of these regrown areas were included within the study area (Figure 5). The major vegetation of the study area was identified as: Cenchrus echinatus (a grass), Cocos nucifera, Frimbristylis atollensis, Lepturus repens (a grass), Tricachne insularis (a grass) and Triumfetta procumbens.

The vegetation covering Biijiri has not been seriously affected since it was leveled by the 1952 nuclear test. Biijiri, which is still nearly devoid of trees, is inhabited by the Polynesian rat, Rattus exulans. A vine covered field with a few shrubby hardwoods nearby was the selected study area (Figure 6), and the vegetation identified was: Frimbristylis atollensis, Ipomoea spp., Messerschmidia argenta, and Scaevola fructescens.

Engebi, completely denuded by construction and testing activities, now covered by a mixture of grassland and scrub forest, is inhabited by the roof rat (Rattus rattus) (Jackson, 1967). Within the study area, along the edge of an old airport runway (Figure 7), the principal vegetation was identified as: Frimbristylis atollensis, Ipomoea spp., Messerschmidia argenta, Pluchea odoratus, and Scaevola fructescens.

METHODS

This study was conducted on four of the atoll's 40 islets. The foliar application phase involved areas on Runit and Japtan; the supplementary food supply phase, Biijiri and Engebi.

The dimensions of the sprayed area on Runit were 13 meters by 10 meters. With a three-meter wide dirt road, having essentially no vegetation and not being sprayed, transecting the area, the net area sprayed was 100 square meters.

A four gallon aqueous solution of 0.1 molar (M) RbCl was applied with a Chapin, number 192, compressed air sprayer to the foliage within the 100 square meter area on 24 July, 1966. The spray had the consistancy of a coarse mist and was applied in a criss-cross pattern: first in a north-south direction, then in an east-west direction. Drift appeared slight despite the constant sea breeze, but no actual determination of rubidium levels immediately outside the treated area was made. Immediately following the spraying, the islet was subjected to approximately five minutes of heavy rainfall.

On 27 August, 1966, 34 days after the foliar application, the study area of 133,750 square feet, which included the sprayed area, was intensively trapped for one night. A total of 246 Victor rat traps, baited with coconut, were placed in a grid pattern at 25 foot (8 meters) intervals within the study area. With each capture, the point of capture within the grid was recorded. The liver and both kidneys were collected, weighed to the nearest 0.01 gram on a triple beam balance, oven dried at 65 C for approximately four days, individually wrapped

in foil, surrounded by gauze, and sealed in plastic bags for shipment to Bowling Green State University for further analysis.

In order to determine rubidium concentrations, representative plant parts (stems, leaves, and flowers when available) sprayed with RbCl were collected from the sprayed area on 25 July, 9 August, and 28 August, which were 24, 384, and 840 hours after application, respectively. Prior to spraying, plant parts were collected on 25 July from the unsprayed area to obtain normal background concentrations of rubidium. Similarly, the liver and kidneys of rats captured prior to the foliar application were collected from another area of Runit. Plant tissues were processed in the same manner as the animal tissues.

The Japtan sprayed area of 100 meters square was sprayed on 7 August, with a 0.1 M aqueous RbCl solution (Figure 5) in exactly the same manner as previously described for Runit. Because of the wind shielding action of the surrounding Cocos forest, the solution was applied in a fine mist with a minimum of drift. Representative portions of plants (except Cocos nucifera) were collected from the sprayed area on 8 August and 22 August, 24 and 360 hours after application, respectively; reference plant tissues, on 22 August from a different section of the forest. The Japtan study was terminated on 22 August, 14 days after the foliar application, by intensively trapping the area for one night with 249 Victor rat traps. Animal and plant tissues were processed in the same manner as those obtained from Runit.

The short term supplementary food supply phase was initiated on both Biijiri and Engebi on 30 August, 1966. The meat from three coconuts was grated, soaked for four days in aqueous 0.4 M RbCl solution,

then scattered over a one meter square area on each islet. Trapping on Biijiri and Engebi was accomplished on the fourth and second days, respectively, following the bait placement. Fifteen Victor rat traps, baited with coconut, were set in straight lines radiating from the baited area in each of the four cardinal directions, the initial trap in each line being within one meter of the bait, others at intervals of about eight meters (eight paces). On Biijiri, space limited the south and north lines to 10 and 11 traps, respectively, The tissue samples (the liver and both kidneys) taken from the captured rodents were processed as previously described.

The instruments necessary for tissue processing and analysis in the laboratory were housed in either the Chemistry or the Biology Departments of Bowling Green State University. The balance used was an Ohaus Cent-O-Gram, model CG311, and the hot plate used was a Lindberg Hevi-duty, model 53014. The Perkin-Elmer Atomic Absorption Spectrophotometer, model 303, was used for the tissue analysis. Standard conversion tables were used to convert the percent absorbance, which was read directly from the spectrophotometer, to absorbance.

All glassware prior to use was thoroughly washed. The washing procedure was as follows: (1) scour with alconox (a powerful wetting agent and detergent), (2) rinse three times with tap water, (3) rinse with 50 per cent nitric acid, (4) rinse three times with tap water, (5) rinse three times with distilled water, (6) rinse with 70 per cent isopropyl alcohol, and (7) rinse with acetone.

In the laboratory, the rat samples were unpackaged, weighed on a triple beam balance to the nearest 0.01 gram, and placed in 100 ml/

Kimax beakers on a hot plate for wet ashing (Urone and Anders, 1950).

From the resulting residue, a 10 ml solution was prepared for analysis in three steps during which each beaker was washed a total of ten times: once with 1 ml of 1:10 dilution of concentrated HCl; once with 1 ml of 1.0 per cent NaCl; eight times with 1 ml portions of distilled water. The washings were necessary for maximum transfer of rubidium.

Before and after each analysis sequence, a series of prepared rubidium standards (0.5, 1.0, 2.0, 3.5, 5.0, 10.0, 25.0, 50.0, 100.0, 150.0, 200.0 parts Rb/million, by weight) were analyzed. During the analyses of the samples, a known standard concentration of rubidium was tested after every 10 samples in order to check the sensitivity of the instrument. The unknown absorbance for each sample was then compared with the standard rubidium absorbances for that trial to determine the amount of rubidium present in the 10 ml sample solution. The rubidium concentration per gram dry weight (ppm, by weight) was calculated.

RESULTS

The samples from Japtan rats were analyzed on 24 February and rats sampled from Runit, Biijiri, and Engebi were analyzed on 24 March, 1967. The absorbances of rubidium standards were obtained before and after each analysis session. Data obtained from the rubidium standards appear in Table 1. One rubidium standard (2 ppm) was not analyzed on 24 March because of contamination. The instrumental variation is shown for each test session on all standard graphs by plotting the absorbance of the two trials of each session for the same standard (Figure 8). The absorbance of concentrations greater than 200 ppm, the greatest standard concentration used, was extrapolated. The rubidium concentration of the solution (ppm) was read directly from the appropriate standards graph; then concentration per gram dry weight of sample was calculated.

The data obtained from vegetation sampled on Runit and Japtan appear in Tables 2 and 3, respectively. Rubidium concentrations (ppm) found in the unsprayed vegetation were low, ranging from 27.4 for Cenchrus to 5.2 for Lepturus on Japtan and from 0.0 for Frimbristylis to 5.4 for Ipomoea on Runit. Unsprayed vegetation from Japtan had approximately twice as much rubidium as similar vegetation from Runit.

The sprayed vegetation from both study areas had considerably higher rubidium concentrations, initially about 100 times more, than the unsprayed vegetation (Tables 2 and 3). The first plant samplings (24 hours after application) showed slightly higher concentrations for plants on Japtan than for similar plants on Runit. These, however,

were only 1.4 per cent to 11.4 per cent of the total ppm applied.

The sampled plants had varying affinities and differential loss rates for rubidium. Of all plants sampled, Frimbristylis and Lepturus had the lowest initial affinity. Frimbristylis, Cenchrus, Tricachne, and Lepturus, all monocots of family Gramineae, had low rates of loss, whereas most dicots, Messerschmidia, Triumfetta, and Ipomoea, had much greater rates of loss. Of all plants tested, Messerschmidia had the greatest loss rate, losing 90.1 per cent of that absorbed in 360 hours. The average half-loss time for monocots could not be determined but was estimated at 170 hours for dicots.

Data obtained from Rattus rattus captured on Runit on 26 August (31 days after rubidium application) appear in Table 4. The points of capture, with respect to the sprayed area, of all rats collected on Runit are presented in Figure 11. A total of 20 roof rats, (11 ♂♂ and 9♀♀) were captured on 246 trap nights (trap success = 8.15 per cent). Although the traps were checked twice in one night, no trap captured more than a single rat.

The control rat (no. 1879) had a rubidium concentration of 25.8 ppm. A level of 35.0 ppm was selected as the minimum concentration for a positive test (a rat having fed from the sprayed area). On this basis, three of the 20 individuals captured (15 per cent) were positive, the concentration ranged from 37.2 ppm (no. 2060) to 161.0 ppm (no. 2046). The capture distance (distance between the capture point and the sprayed area) ranged from 100 feet (no. 2046) to 212 feet (no. 2060), the average being about 153 feet.

Data obtained from Rattus exulans captured on Japtan on 21 August (14 days after rubidium application) appear in Table 5. A summary of the points of capture of all rats collected on Japtan is presented in Figure 12. A total of 109 Polynesian rats (57♂♂ and 52♀♀) were captured on 249 trap nights (trap success = 43.8 per cent). The traps were checked twice in the night, and 25 traps caught two rats each.

The control rat (no. 1878) had a rubidium concentration of 507.8 ppm. This rat, as was later realized, was involved with pilot studies of the supplementary food supply phase of this study and therefore was not a valid control. Since the majority of the rats captured had concentrations near those found for Rattus rattus from Runit, 35.0 ppm was again selected as the minimum concentration for a positive test. Fourteen of the 109 rats captured (12.8 per cent) were positive, the concentration ranging from 35.4 ppm (no. 1914) to 565.0 ppm (no. 1982). The capture distance ranged from within the sprayed area (nos. 1956; 1957) to 175 feet away (nos. 2005; 1914). The positive tests are centered, generally, about the sprayed area, with the average capture distance being 41 feet.

Data obtained from Rattus exulans captured on Biijiri on 3 September (4 days after bait placement) appear in Table 6. The capture points of all rats are presented in Figure 13. A total of 15 Polynesian rats (6♂♂ and 9♀♀) were captured on 51 trap nights (trap success = 29.4 per cent.)

The control rat from Biijiri (no. 2128) had a concentration of 20.6 ppm. Four of the 15 rats captured (26.6 per cent) were positive,

the concentration ranging from 93.5 ppm (no. 2115) to 3420 ppm (no. 2126). The capture distance ranged from 125 feet (nos. 2113; 2115) to 250 feet (no. 2125), the average being 163 feet.

Data obtained from Rattus rattus captured on Engebi on 1 September (2 days after bait placement) appear in Table 7. A summary of the capture points of all rats captured is presented in Figure 14. A total of 21 roof rats (12♂♂ and 9♀♀) were captured on 60 trap nights (trap success = 35 per cent).

The control rat (no. 1744) had a concentration of 27.2 ppm which was near the concentrations found in most other animals. Six of the 21 rats captured (28.5 per cent) were positive, the concentration ranging from 50.4 ppm (no. 2095) to 3020.0 ppm (no. 2100). The capture distance ranged from within three feet (nos. 2100; 2103) to 375 feet (no. 2106) from the baited area, the average being 125 feet.

DISCUSSION AND CONCLUSIONS

The uptake of rubidium by various plant tissues is increased by plant auxins and is directly related to the hydration of the tissues (Mellor, 1963). Rose (1956) found that plants growing in water or in damp places contained three to seven times as much rubidium as other species of the same family growing in dry sites.

Testing operations destroyed the soil on Runit, and little has subsequently been rebuilt. The relatively undisturbed soil of Japtan, with 80 times more organic matter than Runit (Univ. of Wash., Laboratory of Radiation Biology, unpublished data), would retain greater quantities of capillary water. Also, the wind blown, shadeless Runit study area would have had a greater evapotranspiration rate and therefore would be more xeric than the wind protected, shady Japtan study area.

This study found, in accordance with Mellor (1963), that the control plants from the more mesic Japtan had two to four times greater rubidium concentrations than control plants of the same species from the xeric Runit (Tables 2 and 3). The mean background rubidium concentration in plants from "wet" and "dry" islets was 12.8 and 2.8 ppm, respectively, with the average of both being 7.8 ppm. That the sprayed vegetation, such as Frimbristylis, Ipomoea, and Triumfetta, always showed higher rubidium concentrations on Japtan than Runit (Figures 9 and 10) thus was not unexpected. The lower initial concentration found in the Runit vegetation may have been accentuated by washing resulting from the rain which fell on Runit immediately after spraying operations.

Although the 0.1 M RbCl solution was applied specifically to the aerial plant parts, the soil, especially on Runit after the rain, probably had relatively large concentrations of rubidium. Since no soil samples were taken, this hypothesis cannot be verified.

The pilot experiments of this study indicated rubidium was readily absorbed by the roots and transported to the aerial plant parts. Mellor (1963) found that rubidium uptake by the roots was inversely affected by the amount of available potassium. With the atoll soils being high in calcium (Kenady, 1962), about 369,000 ppm (LRB unpublished data), and low in potassium (Donaldson, 1959), about 70 ppm (LRB unpublished data), large amounts of rubidium were probably absorbed by the roots and transported, via the vascular tissue (Bukouae, 1957; Wittwer and Teubner, 1959), to the leaves and stems. Bukouae (1957) found the absorption half-time of rubidium to be about six hours. With the first vegetational sampling 24 hours after application, the rubidium concentrations found at this time were probably near their peak.

The spray solution contained 18,700 ppm (by weight), while an average of 1400 ppm (by weight) was found in the plants. Thus about eight per cent of the ppm applied chemical had been absorbed.

This study found rubidium concentrations within the plant decreased with time. This decrease was similar for both "wet" and "dry" islets and thus was not dependent upon hydration or evapotranspiration. Bukouae (1957) found no significant decrease in the leaves until after 192 hours. My study found the half-loss time (the time at which one-half the initial concentration was lost) for dicots to average 170 hours. Compared to the rubidium loss in dicots (1077 ppm/360 hours), the monocots

showed essentially no rubidium loss (Figures 9 and 10). In fact, most monocots, all of the family Gramineae, had increasing concentrations for the first 336 hours after application. The rise in concentration with time seen for monocots, resulting in a very long half-time, indicates a more constant rubidium uptake from the soil and a higher maintenance level for monocots as compared to dicots.

Theoretically, all the sampled plant parts should have contained the same rubidium concentrations. In practice, however, variations in spraying, uptake rates of tissues, sampling as well as instrumental and human errors, resulted in concentration differences within a single plant. These variations may explain the unpredictable rises in concentration with time as seen in Figure 9.

The valid control rats from all islets had an average rubidium concentration of 26.5 ppm, a value within the range (3 to 28 ppm) reported for all vertebrates by Mellor (1963).

With food being the ultimate factor determining population density (Wynne-Edwards, 1959), a small population of rats would be expected for the relatively barren Runit islet. A low trap success (8.1 per cent) and a low population estimate (24 rats / 100,000 square feet) confirmed this expectation.

That the average size of the home range appeared to decrease as the population increased has been claimed by Sanderson (1966), though Blair (1953) did not consider this a valid concept for all species. If Sanderson (1966) be correct, the average size of home range for Runit rats, because of a low population, should be larger than average.

Following Harrison (1958), the standard diameter, a measure of

home range, was calculated for Rattus rattus on Runit to be 162 feet for females and 262 feet for males. Jackson and Strecker (1962) reported that the standard diameter for the same species on Ponape averaged 195 feet for females and 250 feet for males, though the population densities in grasslands on Ponape were about half those in Cocos plantations (3.7 vs 7.9 rats/100,000 square feet) (Jackson, unpublished). That the standard diameter found in this study was similar and not smaller than found on Ponape supported Blair (1953) rather than Sanderson (1966).

All positive rodents on Runit were captured within a distance equal to their standard diameter from the sprayed area and thus were considered to have been moving within their home range. Data presented here support Tomich (MS) who found Rattus rattus rarely moved from its home range and found no evidence of dispersing roof rats.

Tomich (MS) states that a remarkable feature of Rattus rattus behavior is its tendency to maintain a restricted home area. The positive animals of this study, with two exceptions, were captured within 75 feet (one-half the standard diameter) of the sprayed area (Figure 12). The exceptions, both adult females (nos. 1914, 2005), were captured 140 feet from the sprayed area, a distance equal to their standard diameter (Figure 12); therefore they were considered to be within their home range.

Since food apparently was plentiful on Japtan, according to Sanderson (1966) and Wynne-Edwards (1959), a dense population of rats with a relatively small home range was expected. A trap success of 44 per cent and a population estimate of 58 rats/100,000 square feet

confirmed the former. The standard diameter for Rattus exulans on Japtan was calculated as 140 feet for females and 155 feet for males. Jackson and Strecker (1962) report populations of 40 rats/ 100,000 square feet in similar habitats on Ponape to have a standard diameter of 85 feet for females and, as usual, a larger standard diameter of 92 feet for males. Summarizing, Rattus exulans in this study had both higher population densities and larger home ranges than normally expected. My data supported Blair (1953).

Japtan had twice the rat population density of Runit, but the percentage of positive rats captured was nearly the same (12.8 per cent for Japtan; 15 per cent for Runit). Although the percentages were similar, the average capture distance from the sprayed area (153 feet for Rattus rattus and 41 feet for Rattus exulans) varied considerably. This difference reflects the observation that the standard diameter of Rattus rattus was larger in all cases than Rattus exulans (Jackson and Strecker, 1962).

RUBIDIUM-IMPREGNATED BAIT

In the grassy, vine-covered study area of Biijiri, four of the 15 rats (27 per cent) captured were positive; the capture distance ranged from 125 to 250 feet (Figure 13). Three of these four positive rats were captured within the standard diameter calculated for the same species on Japtan and that reported by Jackson and Strecker (1962) for Rattus exulans in grasslands on Ponape (137 feet for males; 100 feet for females, Jackson and Strecker, 1962). Tomich (MS) reported the average diameters of Rattus exulans were larger in the cane fields, which corresponds with

the findings of Jackson and Strecker (1962). Since the Biijiri study area was a grass field, the home range of these rats should be generally larger than the forest rats on Japtan, however the small number of captures of this study indicate just the opposite.

For Engebi, one-third of the positive rats (Rattus rattus) were captured beyond a distance equal to the standard diameter calculated for the same species on Runit. The trap success (35 per cent) was four times that of Runit and indicates a much higher population density on Engebi. According to Wynne-Edwards (1959), who contends that food is the primary density controlling factor, this higher rat population was not unexpected for an islet of more vegetational cover as Engebi. This study finds Rattus rattus to have similar home ranges with differing population densities, which directly opposes Sanderson's (1966) concept of decreasing home ranges with increasing population densities. Perhaps the small number of Scaevola and Messerschmidia bushes (the prime food stuff of the rats), may account for the larger home ranges in the highly populated areas.

Rodents with activity centers near the rubidium source might be expected to consume greater concentrations than other rodents; therefore a correlation between capture distance and rubidium concentrations should be found. However, no such correlation was found in either phase of this study.

In conclusion, the application of this non-radioactive tracer technique to animal movements seems to be feasible, but is not without drawbacks. For instance, animals cannot be individually marked and

must be killed for positive identification. This technique does have several advantages, such as the ease in handling and applying the tracer to the environment. The ability to mark animals without capture and the accuracy of tracer identification is also to its credit. Before this technique can be used most effectively much information concerning the physiological properties of rubidium with respect to plants and animals is needed.

SUMMARY

This study tested the workability of using a trace element to determine movements of some small mammals (Rattus rattus and Rattus exulans). Rubidium, a non-radioactive tracer, was added to the environment by a foliar spray and by a rubidium-impregnated bait.

For plants, the uptake rate seemed dependent upon hydration and evapotranspiration. The rate of rubidium loss in dicots appeared unaffected by hydration and evapotranspiration. Monocots tended to retain absorbed rubidium concentrations considerably longer than dicots.

In both phases of this study, all rodents were captured either within or near the distance calculated for their standard diameter. Although lack of recapture data made it extremely difficult to distinguish between dispersion and normal movements, all positive rodents were thought to have been within their home range.

No correlation between capture distance from the source and rubidium concentrations were found in either phase of this study.

With respect to previously established marking techniques, this non-radioactive tracer technique had several distinct advantages: its ease of handling, application, and its definitive identification. Some shortcomings, such as the impossibility of individual marking and identification only upon the animals death, were also recognized. Several related studies involving the characteristic affects of rubidium on plants and animals are needed before this technique can be used effectively.

LITERATURE CITED

Angino, Ernest E. 1966. Distribution of iron in the various components of recent carbonate sediments. Kansas Geol. Survey Bull. 180:3.

Barnett, S. A. 1963. The rat: a study in behavior. Aldine Publishing Company. 288pp.

Blair, W. Frank. 1953. Population dynamics of rodents and other small mammals. Advances in Genetics 5:1 - 41.

Brown, L. N., and C. H. Conaway. 1961. Dye excretion as a method for determination of small mammal home ranges. American Midland Nat. 66(1):128 - 137.

Bukouae, M. J., and S. H. Wittwer. 1957. Absorption and mobility of foliar applied nutrients. Plant Physiol. 32:428 - 435.

Burt, William Henry. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Misc. Pub. Mus. Zool., Univ. of Mich. 45:1 - 58.

Cagle, Fred R. 1944. Home range, homing behavior and migration in turtles. Misc. Pub. Mus. Zool., Univ. of Mich. 61:1 - 34.

Capacho-Delgado, Luis, and David C. Manning. 1965. Determination of tin by atomic absorption. Atomic Absorption Newsletter 4(7):317 - 318.

Connor, John T. 1966. Local climatological data. Annual summary with comparative data, 1966: Eniwetok, Marshall Islands, Pacific. U. S. Dept. of Commerce. 6pp.

Davis, David E., and Frank B. Golley. 1963. Principles in mammalogy. Reinhold Publishing Corp., New York. 335pp.

Donaldson, Lauren R. 1959. Radiobiological studies at the Eniwetok test site and adjacent areas of the western Pacific. In. Transactions of the second seminar on biological problems in water pollution, April 20 - 24, 1959. U. S. Public Health Service. 7pp.

Gast, James A. 1963. Rhodamine-B dye for studying movements of animals. Ecol. 44(3):611 - 612.

Gifford, C. E., and D. R. Griffin. 1960. Notes on homing and migratory behavior of bats. Ecol. 41(2):378 - 381.

Glendering, B. L., W. G. Schrenk, and D. B. Parrish. 1956. Effects of rubidium in purified diets fed white rats. Jour. of Nutrition 60:563 - 579.

Godfrey, G. K. 1954. Tracing field voles (Microtus agrestis) with a Geiger-Müller counter. Ecol. 35(1):5 - 10.

Griffin, Donald R. 1952. Radioactive tagging of animals under natural conditions. Ecol. 33(3):329 - 335.

Harrison, John L. 1958. Range of movement of some Malayan rats. Jour. of Mamm. 39(2):190 - 206.

Harvey, Michael J., and Roger W. Barbour. 1965. Home range of Microtus ochrogaster as determined by a modified minimum area method. Jour. of Mamm. 46(3):398 - 402.

Hines, Neal O. 1962. Proving ground. Univ. of Wash. Press, Seattle. 366pp.

Jackson, William B. 1967. The Engebi rats- another chapter. The Second National Symposium on Radioecology. Ann Arbor, Mich. 15 - 17 May.

Jackson, William B., and Robert L. Strecker. 1962. Home range studies. In. Pacific island rat ecology: Report of a study made on Ponape and adjacent islands 1955 - 1958. Bernice P. Bishop Museum, Bulletin 225. 274pp.

Jenkins, D. W. 1954. Advances in medical entomology using radioisotopes. Exptl. Parasitology 3(5):474 - 490.

Karlstrom, E. L. 1957. The use of Co^{60} as a tag for recovering amphibians in the field. Ecol. 38(1):187 - 195.

Kaye, S. V. 1960. Gold-198 wires to study movements of small mammals. Sci. 131(3404):824.

Kaye, S. V. 1961. Movements of harvest mice tagged with gold-198. Jour. of Mamm. 42(3):323 - 337.

Kenady, Reid M., Jr. 1962. The soils of Rongelap Atoll, Marshall Islands. (Master of Forestry Thesis) Univ. of Wash. 76pp.

Lack, David. 1954. The natural regulation of animal numbers. Oxford at the Clarendon Press. 343pp.

Lack, David. 1966. Population studies of birds. Oxford at the Clarendon Press. 341pp.

Lowman, Frank G. 1965. River analysis p. 51 - 53. In. Progress report: Marine biology program FY1965. Puerto Rico Nuclear Center. no. 60.

Manville, Richard H. 1949. Techniques for capture and marking of mammals. Jour. of Mamm. 30(1):27 - 33.

Mellor, J. W. 1963. Inorganic and theoretical chemistry. John Wiley and Sons Inc., New York. vol. II. 894pp.

Miller, Lotus Simon. 1957. Tracing vole movement by radioactive excretory products. Ecol. 38(1):132 - 136.

New, John G. 1958. Dyes for studying the movements of small mammals. Jour. of Mamm. 39(3):416 - 429.

Olson, Alvin M. 1965. Gold assay by atomic absorption spectrophotometry: A preliminary report. Atomic Absorption Newsletter 4(5):278 - 280.

Prugger, Hans. 1966. The development of absorption flame photometry to a chemical laboratory technique. Zeiss Information Mag. 56:54 - 59.

Rose, Arthur and Elizebeth. 1956. The condensed chemical dictionary. Reinhold Publishing Corp., New York. 992pp.

Sanderson, Glen C. 1966. The study of mammal movements. Jour. of Wildlife Manag. 30(1):215 - 235.

Simmons, E. C. 1965. Gold assay by atomic absorption spectrophotometry Atomic Absorption Newslettle 4(5):281 - 287.

St. John, Harold. 1960. Flora of Eniwetok Atoll. Pacific Science 14(4):313 - 336.

Tomich, P. Quentin. MS. Research report on movement patterns of field rodents in Hawaii.

Twigg, G. I., and H. Miller. 1963. The use of calcium^{45} as an agent for labeling rat populations. Jour. of Mamm. 44(3):335 - 337.

Urone, Paul F., and Hanns K. Anders. 1950. Determination of small amounts of chromium in human blood, tissues, and urine. Analytical Chemistry 22:1317.

Whiteley, M. A. 1950. Thorpe's dictionary of applied chemistry. Longmans, Green and Company, London. vol. X, 4th. ed. 913pp.

Wittwer, S. H., and F. G. Teubner. 1959. Foliar absorption of mineral nutrients. Annual Review of Plant Physiol. 10:13 - 32.

Wynne-Edwards, V. C. 1962. Animal dispersion in relation to social behavior. Hafner Publishing Company, New York. 653pp.

Yamagata, Noboru. 1962. The concentration of common cesium and rubidium in the human body. Jour. of Radiation Research 3:9 - 30.

TABLE 1A

DATA OBTAINED ON 24 FEBRUARY, 1967
FROM ANALYSIS OF RUBIDIUM STANDARDS

Conc. of standard (ppm, by weight)	Per cent absorbance		Absorbance	
	Trial I	II	Trial I	II
0.5	0.42	0.22	0.0018	0.0010
1.0	0.52	0.55	0.0022	0.0024
2.0	1.30	1.16	0.0057	0.0050
3.5	2.64	2.34	0.0116	0.0103
5.0	3.08	2.86	0.0136	0.0125
10.0	5.36	5.20	0.0239	0.0232
25.0	10.98	10.76	0.0505	0.0493
50.0	17.78	17.94	0.0850	0.0859
100.0	27.96	27.78	0.1424	0.1414
150.0	33.50	33.00	0.1772	0.1759
200.0	38.60	38.80	0.2118	0.2132

TABLE 1B

DATA OBTAINED ON 24 MARCH, 1967
FROM ANALYSIS OF RUBIDIUM STANDARDS

Conc. of standard (ppm, by weight)	Per cent absorbance		Absorbance	
	Trial I	II	Trial I	II
0.5	0.32	0.38	0.0014	0.0016
1.0	0.52	0.62	0.0023	0.0026
2.0	-	-	-	-
3.5	2.10	2.20	0.0092	0.0097
5.0	2.76	2.78	0.0121	0.0122
10.0	4.92	5.04	0.0219	0.0225
25.0	10.10	10.24	0.0462	0.0470
50.0	17.10	17.44	0.0814	0.0833
100.0	26.50	25.98	0.1337	0.1307
150.0	33.00	32.66	0.1739	0.1717
200.0	37.98	37.90	0.2075	0.2069

TABLE 2

DATA OBTAINED FROM THE VEGETATION ON RUNIT
(ANALYZED ON 24 FEBRUARY 1967)

Vegetation	Weight (grams) wet	Weight (grams) dry	Per cent absorb.	Absorb.	Ppm, by weight. µg Rb/g dry weight
Unsprayed vegetation Collected on 25 July, 1966.					
Frimbristylis	3.16	1.80	0.00	0.0000	0.0
Ipomoea	20.00	3.50	1.14	0.0050	5.4
Messerschmidia	20.00	3.53	0.28	0.0012	1.3
Scaevola	20.00	3.49	0.70	0.0031	3.4
Triumfetta	20.00	4.37	0.72	0.0032	3.8
Sprayed vegetation Collected on 25 July, 1966 (24 hours after spraying operations)					
Frimbristylis	6.32	2.28	43.13	0.2451	815.0
Ipomoea	20.00	3.36	63.28	0.4350	1560.0
Messerschmidia	20.00	3.17	67.70	0.4776	1930.0
Scaevola	30.00	3.44	62.04	0.4202	1420.0
Triumfetta	20.00	4.62	60.20	0.4001	1020.0
Sprayed vegetation Collected on 9 August, 1966 (384 hours after spraying operations)					
Frimbristylis	14.38	3.82	50.20	0.3028	820.0
Ipomoea	20.00	3.42	31.52	0.1644	360.0
Messerschmidia	20.00	2.94	19.42	0.0938	191.0
Scaevola	20.00	3.60	45.44	0.2631	695.0
Triumfetta	20.00	3.75	23.76	0.1177	178.0
Sprayed vegetation Collected on 28 August, 1966 (840 hours after spraying operations)					
Frimbristylis	9.32	3.31	43.10	0.2449	700.0
Ipomoea	8.77	3.31	31.44	0.1639	374.0
Messerschmidia	22.65	3.65	21.02	0.0970	164.0
Scaevola	17.61	3.25	49.92	0.3003	955.0
Triumfetta	10.67	2.65	21.08	0.1027	242.0

TABLE 3

DATA OBTAINED FROM VEGETATION ON JAPTAN
(ANALYZED ON 24 FEBRUARY 1967)

Vegetation	Weight (grams) wet	Weight (grams) dry	Per cent absorb.	Absorb.	Ppm, by weight. µg Rb/g dry weight
Unsprayed vegetation Collected on 22 August, 1966					
Cenchrus	10.19	3.84	6.30	0.0283	27.4
Frimbristylis	5.72	2.18	1.82	0.0080	13.8
Ipomoea	20.35	3.74	2.08	0.0091	9.4
Lepturus	9.07	4.46	1.40	0.0061	5.2
Tricachne	7.27	2.45	1.94	0.0084	13.3
Triumfetta	3.97	3.48	1.70	0.0074	8.1
Sprayed vegetation Collected on 8 August, 1966 (24 hours after spraying operations)					
Cenchrus	5.00	3.29	65.10	0.4572	1720.0
Frimbristylis	10.00	3.13	49.38	0.2957	960.0
Ipomoea	17.58	3.50	69.52	0.5159	1930.0
Lepturus	9.08	4.42	31.32	0.1631	277.0
Tricachne	7.32	3.64	65.46	0.4616	1570.0
Triumfetta	15.01	2.93	67.62	0.4897	2140.0
Sprayed vegetation Collected on 22 August, 1966 (360 hours after spraying operations)					
Cenchrus	7.84	3.47	69.90	0.5214	1980.0
Frimbristylis	10.12	3.17	52.74	0.3255	1112.0
Ipomoea	16.90	1.90	49.70	0.2984	1630.0
Lepturus	6.11	3.12	38.64	0.2120	596.0
Tricachne	16.98	3.67	61.48	0.4142	1342.0
Triumfetta	14.04	2.38	29.70	0.1530	484.0

TABLE 4

DATA OBTAINED FROM RATTUS RATTUS CAPTURED ON RUNIT
31 DAYS AFTER RUBIDIUM APPLICATION
(ANALYZED ON 24 MARCH 1967)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight µg Rb/g dry weight
2043	4.03	1.26	♀	1.00	0.0044	B1 8.5	13.5
2044	6.36	1.70	♀	1.34	0.0059	F1 0.5	12.9
2045	10.61	2.78	♀	1.92	0.0040	E 3.0	5.4
2046	9.66	2.68	♀	15.80	0.0747	A 6.5	161.0
2047	8.82	2.38	♀	3.70	0.0164	F1 9.0	26.4
2048	5.92	1.72	♀	1.40	0.0061	D 10.5	13.3
2049	3.73	0.91	♀	1.12	0.0049	C1 9.0	20.8
2050	7.22	1.89	♀	1.82	0.0080	D1 10.5	16.5
2051	9.17	2.31	♂	2.26	0.0115	F1 1.5	18.9
2052	6.45	1.74	♂	2.28	0.0100	D 0.5	21.8
2053	9.53	2.41	♂	2.68	0.0118	D1 1.0	18.7
2054	5.35	1.50	♂	1.42	0.0062	E 2.0	16.0
2055	6.49	2.03	♀	1.98	0.0087	B1 2.0	16.2
2056	8.04	2.04	♂	1.34	0.0059	F 0.5	10.8
2057	7.89	2.21	♂	5.04	0.0225	B 0.5	42.6
2058	6.95	1.81	♂	2.92	0.0129	A1 1.5	27.0
2059	8.36	2.47	♂	1.54	0.0068	A1 9.0	10.5
2060	6.85	1.83	♂	3.98	0.0176	B1 9.0	37.2
2061	6.47	1.71	♂	1.72	0.0075	B 9.0	16.9
2062	4.50	1.21	♂	1.20	0.0052	A 4.0	15.7
1879	4.10	1.56	♂	2.38	0.0105	Control	25.8

TABLE 5

DATA OBTAINED FROM RATTUS EXULANS CAPTURED ON JAPTAN
14 DAYS AFTER RUBIDIUM APPLICATION
(ANALYZED ON 24 FEBRUARY 1967)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight ug Rb/g dry weight
1912	3.48	1.07	♀	1.86	0.0080	A1 1.0	28.2
1913	4.38	1.31	♂	1.94	0.0085	A1 5.5	24.4
1914	1.69	0.54	♀	1.20	0.0051	A1 9.0	35.4
1915	4.17	1.20	♀	2.36	0.0103	A1 9.5	31.7
1916	4.47	1.31	♀	2.12	0.0092	A1 9.0	26.7
1917	1.09	0.38	♀	0.36	0.0015	A1 9.5	15.8
1918	1.52	0.49	♂	0.30	0.0012	A1 10.5	8.1
1919	1.16	0.36	♀	0.34	0.0014	A1 10.5	16.7
1920	2.96	0.91	♀	1.04	0.0046	A 2.5	18.7
1921	4.41	1.28	♂	2.46	0.0107	A 5.0	32.0
1922	3.77	1.10	♂	1.00	0.0045	A 5.5	16.7
1923	1.37	0.43	♂	0.38	0.0015	A 6.0	13.9
1924	3.22	1.03	♀	1.50	0.0067	A 6.0	24.2
1925	1.25	0.42	♀	0.20	0.0010	A 8.0	7.2
1926	4.04	1.15	♂	1.06	0.0047	A 8.0	14.8
1927	4.53	1.40	♀	1.26	0.0052	A 8.5	14.2
1928	3.42	0.81	♀	0.20	0.0010	A 9.5	3.7
1929	3.60	1.07	♀	0.46	0.0021	A 9.5	6.5
1930	3.76	1.17	♂	1.00	0.0045	A 10.0	14.6
1931	3.90	1.48	♀	0.82	0.0037	A 10.5	11.3
1932	2.62	0.77	♀	0.32	0.0014	A 10.5	6.5
1933	3.57	0.99	♀	0.28	0.0014	B1 3.5	5.1
1934	3.79	1.15	♂	1.04	0.0047	B1 8.5	14.8
1935	1.22	0.37	♂	0.01	0.0004	B1 10.5	5.4
1936	3.28	0.90	♀	0.62	0.0030	B 0.5	13.3
1937	4.14	1.28	♀	1.00	0.0049	B 4.5	14.8
1938	1.45	0.47	♂	1.80	0.0084	B 6.5	68.5
1939	4.95	1.44	♀	4.94	0.0222	B 6.0	63.0
1940	4.42	1.17	♀	1.14	0.0058	B 7.0	18.8
1941	6.10	1.62	♂	1.96	0.0090	B 7.0	21.0

TABLE 5

DATA OBTAINED FROM RATTUS EXULANS CAPTURED ON JAPTAN
14 DAYS AFTER RUBIDIUM APPLICATION
-(ANALYZED ON 24 FEBRUARY 1967) (CON'T)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture		Ppm, by weight µg Rb/g dry weight
1942	1.67	0.53	♀	0.70	0.0033	B	7.5	24.8
1943	4.15	0.37	♂	0.36	0.0017	B	8.5	16.2
1944	4.23	1.30	♀	1.30	0.0056	B	9.5	16.1
1945	3.30	0.89	♂	0.82	0.0038	B	10.5	16.8
1946	2.93	0.85	♀	1.04	0.0046	B	10.5	19.9
1947	4.05	1.18	♀	0.66	0.0031	C1	0.5	10.2
1948	4.73	1.41	♂	1.50	0.0071	C1	2.5	19.2
1949	2.67	0.79	♂	0.72	0.0033	C1	6.5	15.3
1950	0.66	0.25	♀	2.52	0.0116	C1	6.5	179.0
1951	4.47	1.15	♀	20.64	0.1004	C1	7.0	548.0
1952	3.66	1.05	♀	1.96	0.0086	C1	8.0	32.4
1953	3.93	1.24	♀	1.22	0.0055	C1	9.5	16.9
1954	1.58	0.48	♂	0.66	0.0030	C1	10.5	23.2
1955	1.48	0.44	♂	0.56	0.0025	C1	10.5	20.6
1956	0.79	0.26	♂	3.02	0.0133	C	6.5	194.0
1957	2.06	0.60	♂	10.14	0.0465	C	7.0	398.0
1958	2.32	0.71	♂	4.46	0.0199	C	7.5	111.0
1959	1.67	0.50	♀	0.34	0.0014	C1	7.5	9.9
1960	3.12	0.87	♂	0.62	0.0030	C	8.0	13.8
1961	2.77	0.79	♂	0.46	0.0021	C	8.0	10.1
1962	1.92	0.56	♂	1.50	0.0061	C	8.5	42.7
1963	4.09	1.16	♂	1.00	0.0045	C	9.0	14.7
1964	3.25	1.03	♂	0.76	0.0035	C	9.5	12.6
1965	4.33	1.21	♂	1.24	0.0053	C	9.5	16.5
1966	3.53	1.03	♂	0.64	0.0029	C	10.0	10.7
1967	4.26	1.38	♂	0.88	0.0039	D1	3.5	10.9
1968	1.61	0.51	♂	3.82	0.0171	D1	5.5	129.0
1969	4.04	1.12	♂	2.40	0.0113	D1	7.0	38.6
1970	3.61	1.08	♂	1.54	0.0064	D1	8.0	22.2
1971	4.00	1.21	♀	1.60	0.0070	D1	8.5	22.4

TABLE 5

DATA OBTAINED FROM RATTUS EXULANS CAPTURED ON JAPTAN
14 DAYS AFTER RUBIDIUM APPLICATION
(ANALYZED ON 24 FEBRUARY 1967) (CON'T)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight ug Rb/g dry weight
1972	4.33	1.26	♂	1.86	0.0082	D1 9.0	24.6
1973	4.62	1.20	♀	1.58	0.0068	D1 10.0	20.0
1974	2.97	0.88	♂	1.40	0.0063	D1 10.0	27.4
1975	1.47	0.43	♂	0.32	0.0013	D1 10.5	11.6
1976	3.58	0.98	♀	1.04	0.0045	D 2.0	17.4
1977	3.69	1.04	♂	1.00	0.0043	D 2.0	15.4
1978	5.01	1.47	♀	0.98	0.0043	D 3.0	10.9
1979	3.75	1.00	♀	7.60	0.0343	D 5.0	150.0
1980	5.59	1.53	♂	1.90	0.0083	D 6.0	21.0
1981	3.39	1.04	♂	1.70	0.0073	D 6.0	27.0
1982	2.57	0.81	♂	16.46	0.0796	D 6.5	565.0
1983	4.08	0.99	♀	1.80	0.0081	D 7.5	31.3
1984	2.09	0.64	♂	0.44	0.0019	D 7.5	12.5
1985	1.25	0.38	♀	0.22	0.0011	D 8.0	10.6
1986	4.42	1.33	♀	1.00	0.0039	D 8.0	11.3
1987	5.94	1.55	♀	1.72	0.0043	D 9.5	11.0
1988	3.64	1.04	♀	0.82	0.0039	D 9.5	14.5
1989	2.62	0.80	♂	0.90	0.0038	D 10.0	18.7
1990	5.64	1.43	♀	2.02	0.0090	D 10.5	23.8
1991	1.04	0.32	♂	0.32	0.0016	D 10.5	18.8
1992	4.61	1.07	♀	1.10	0.0054	E1 4.0	19.6
1993	2.25	0.61	♂	0.32	0.0014	E1 5.0	8.2
1994	3.79	1.03	♂	0.56	0.0026	E1 5.5	9.8
1995	2.77	0.85	♀	0.36	0.0017	E1 6.5	7.1
1996	2.69	0.79	♀	0.34	0.0015	E1 7.0	7.6
1997	3.36	1.09	♀	0.40	0.0018	E1 7.0	6.4
1998	3.89	1.10	♂	1.48	0.0064	E1 9.5	21.8
1999	1.89	0.61	♀	0.50	0.0023	E1 9.5	13.1
2000	3.02	0.79	♀	0.58	0.0027	E1 10.0	11.3
2001	3.75	1.07	♂	1.00	0.0047	E 6.0	16.8

TABLE 5

DATA OBTAINED FROM RATTUS EXULANS CAPTURED ON JAPTAN
14 DAYS AFTER RUBIDIUM APPLICATION
(ANALYZED ON 24 FEBRUARY 1967) (CON'T)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight ug Rb/g dry weight
2002	3.12	0.90	♀	0.56	0.0024	E 7.5	10.0
2003	1.22	0.39	♀	0.20	0.0010	E 8.0	10.3
2004	3.49	0.94	♀	0.92	0.0046	E 9.5	18.2
2005	4.36	1.25	♀	18.20	0.0879	E 9.5	425.0
2006	2.64	0.77	♀	0.01	0.0005	E 10.0	2.6
2007	4.70	1.28	♂	1.42	0.0066	E 10.0	19.5
2008	0.96	0.29	♂	0.20	0.0011	F1 3.5	13.8
2009	3.77	0.08	♂	0.92	0.0042	F1 5.5	14.8
2010	3.33	1.01	♀	1.50	0.0067	F1 6.0	25.0
2011	1.07	0.35	♂	0.30	0.0013	F1 8.0	14.3
2012	1.26	0.40	♂	0.36	0.0017	F1 8.5	14.9
2013	1.49	0.46	♂	0.44	0.0022	F1 9.0	17.3
2014	3.97	1.11	♂	1.80	0.0072	F1 9.5	25.2
2015	3.76	1.10	♂	1.34	0.0054	F1 9.5	19.2
2016	3.77	1.07	♂	1.22	0.0050	F1 10.0	17.7
2017	3.80	1.12	♂	0.78	0.0033	F1 0.5	11.6
2018	3.68	1.04	♂	0.74	0.0030	F 3.5	10.6
2019	3.33	0.92	♂	0.76	0.0032	F 4.5	13.1
2033	1.31	0.40	♂	0.42	0.0019	C 5.5	19.8
1878	4.44	1.88	♂	25.44	0.1370	Control	507.8

TABLE 6

DATA OBTAINED FROM *RATTUS EXULANS* CAPTURED ON BIIJIRI
4 DAYS AFTER BAIT PLACEMENT
(ANALYZED ON 24 MARCH 1967)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight µg Rb/g dry weight
2113	3.66	0.99	♂	48.46	0.2878	6 N	2930.0
2114	4.39	1.12	♀	0.86	0.0037	10 N	12.5
2115	3.58	1.18	♂	5.92	0.0265	6 W	93.5
2116	4.20	1.01	♂	0.78	0.0034	5 W	12.0
2117	3.33	0.88	♂	0.74	0.0032	10 W	13.6
2118	5.03	1.39	♂	1.60	0.0070	9 W	18.7
2119	4.86	1.36	♀	0.90	0.0039	8 W	11.0
2120	4.26	1.17	♀	1.98	0.0087	7 W	29.2
2121	7.29	2.08	♀	1.88	0.0082	8 S	14.9
2122	3.26	0.87	♀	1.50	0.0066	10 S	28.9
2123	3.56	0.94	♀	0.72	0.0032	5 S	12.7
2124	3.30	0.87	♀	1.18	0.0051	4 E	21.9
2125	2.42	0.63	♀	6.28	0.0282	11 E	191.0
2126	4.34	1.19	♂	53.68	0.3342	7 E	3420.0
2127	5.51	1.58	♀	1.22	0.0053	8 E	12.6
2128	2.75	0.63	♂	0.82	0.0036	Control	20.6

TABLE 7

DATA OBTAINED FROM RATTUS RATTUS CAPTURED ON ENGEBI
2 DAYS AFTER BAIT PLACEMENT
(ANALYZED ON 24 MARCH 1967)

Autopsy no.	Weight (grams) wet	dry	Sex	Per cent absorb.	Absorb.	Point of capture	Ppm, by weight µg Rb/g dry weight
2086	7.10	1.94	♂	1.32	0.0058	13 N	11.3
2087	4.91	1.37	♂	2.32	0.0102	5 N	28.4
2088	5.19	1.48	♂	2.46	0.0108	2 N	27.8
2089	4.23	1.24	♂	2.32	0.0102	6 W	31.5
2090	7.35	2.42	♂	53.30	0.3307	11 W	1490.0
2091	5.88	1.87	♂	2.00	0.0088	3 S	18.1
2092	6.29	1.64	♂	2.30	0.0101	9 S	23.8
2093	7.98	2.27	♂	2.50	0.0110	13 S	18.5
2094	6.50	1.87	♂	2.54	0.0112	14 S	23.5
2095	1.18	0.34	♂	1.00	0.0044	5 E	50.4
2096	8.85	2.41	♂	2.40	0.0106	6 E	17.0
2097	4.68	1.25	♂	2.00	0.0088	10 E	27.0
2098	6.05	1.59	♀	2.00	0.0088	11 E	21.4
2099	4.86	1.32	♀	1.36	0.0059	14 N	18.3
2100	5.50	1.76	♀	63.56	0.4384	1 W	3020.0
2101	5.72	1.98	♀	53.74	0.3388	3 W	1840.0
2102	8.00	1.97	♀	2.98	0.0131	10 W	25.4
2103	5.11	1.44	♀	6.94	0.0313	1 S	97.5
2104	8.44	2.13	♀	2.00	0.0088	8 S	15.9
2105	5.72	1.54	♀	1.64	0.0072	11 S	17.5
2106	6.64	2.00	♀	10.40	0.0477	15 S	130.0
1744	5.12	1.40	♂	2.50	0.0110	Control	27.2

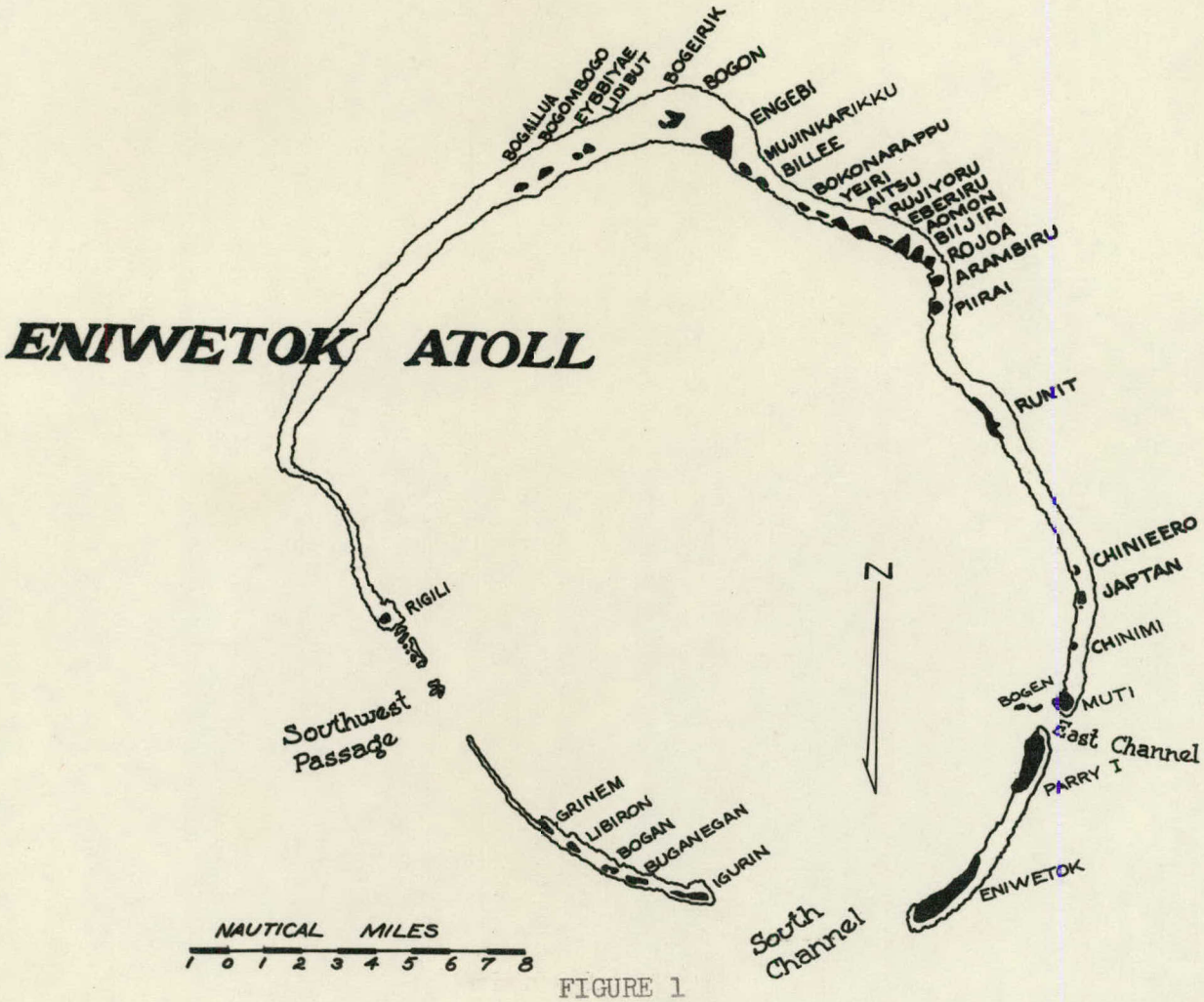

FIGURE 1

MAP OF ENIWETOK ATOLL

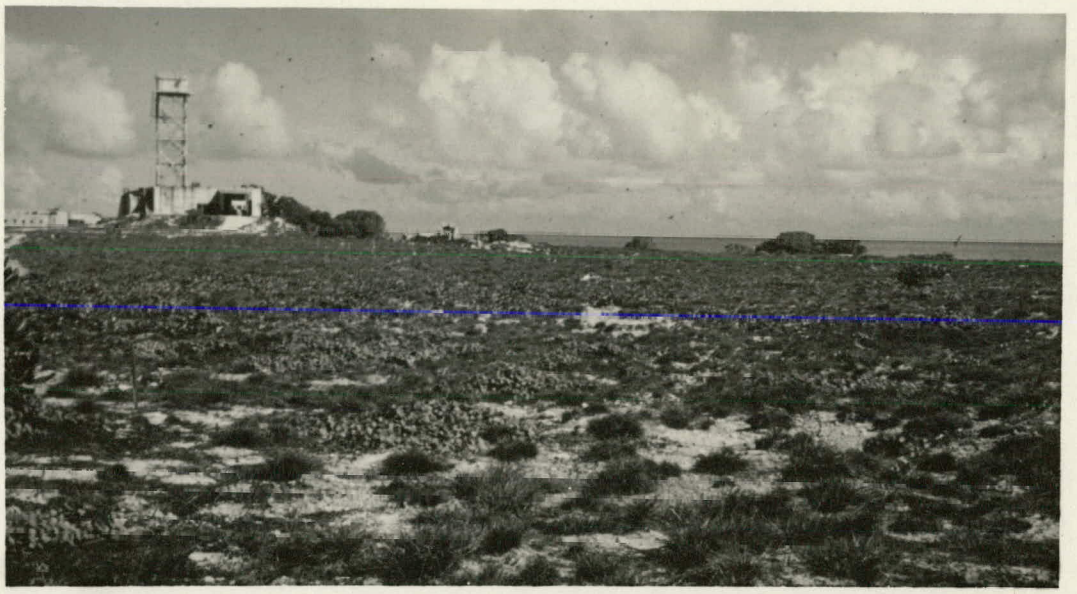

FIGURE 3

A VIEW OVERLOOKING THE RUNIT STUDY AREA SHOWING THE GROUND COVER OF FRIMBRISTYLIS ATOLLENSIS WITH PATCHES OF IPOMOEA SPP. AND TRIUMFETTA PROCUMBENS

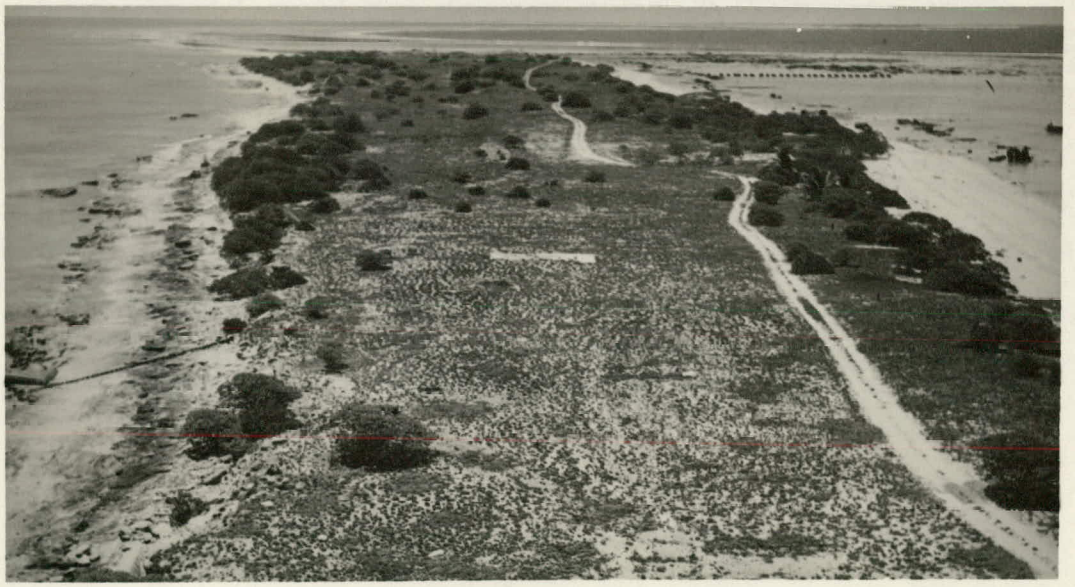

FIGURE 2

AN AERIAL VIEW OF RUNIT ISLET SHOWING THE GENERAL COVER VEGETATION WITH SCATTERED MESSERSCHMIDIA ARGENTA AND SCAEVOLA FRUCTESCENS

FIGURE 5

A SECTION OF THE LUSH FOREST VEGETATION WITHIN THE JAPTAN STUDY AREA SHOWING THE SPRAYING OPERATION

FIGURE 4

A DISTANT VIEW OF MESSERSCHMIDIA ARGENTA AND SCAEVOLA FRUCTESCENS ADJACENT TO THE COCOS NUCIFERA FOREST OF THE JAPTAN ISLET WITH SCAEVOLA FRUCTESCENS IN THE FOREGROUND

FIGURE 6

A VIEW OF BIIJIRI ISLET OVERLOOKING THE SITE OF BAIT PLACEMENT SHOWING IPOMOEA SPP. WITH SCAEVOLA FRUCTESCENS AND MESSERSCHMIDIA ARGENTA IN THE BACKGROUND

FIGURE 7

A VIEW OF ENGEBI ISLET OVERLOOKING THE SITE OF BAIT PLACEMENT SHOWING IPOMOEA SPP. AND PLUCHEA ODORATUS WITH SCAEVOLA FRUCTESCENS AND MESSERSCHMIDIA ARGENTA IN THE BACKGROUND

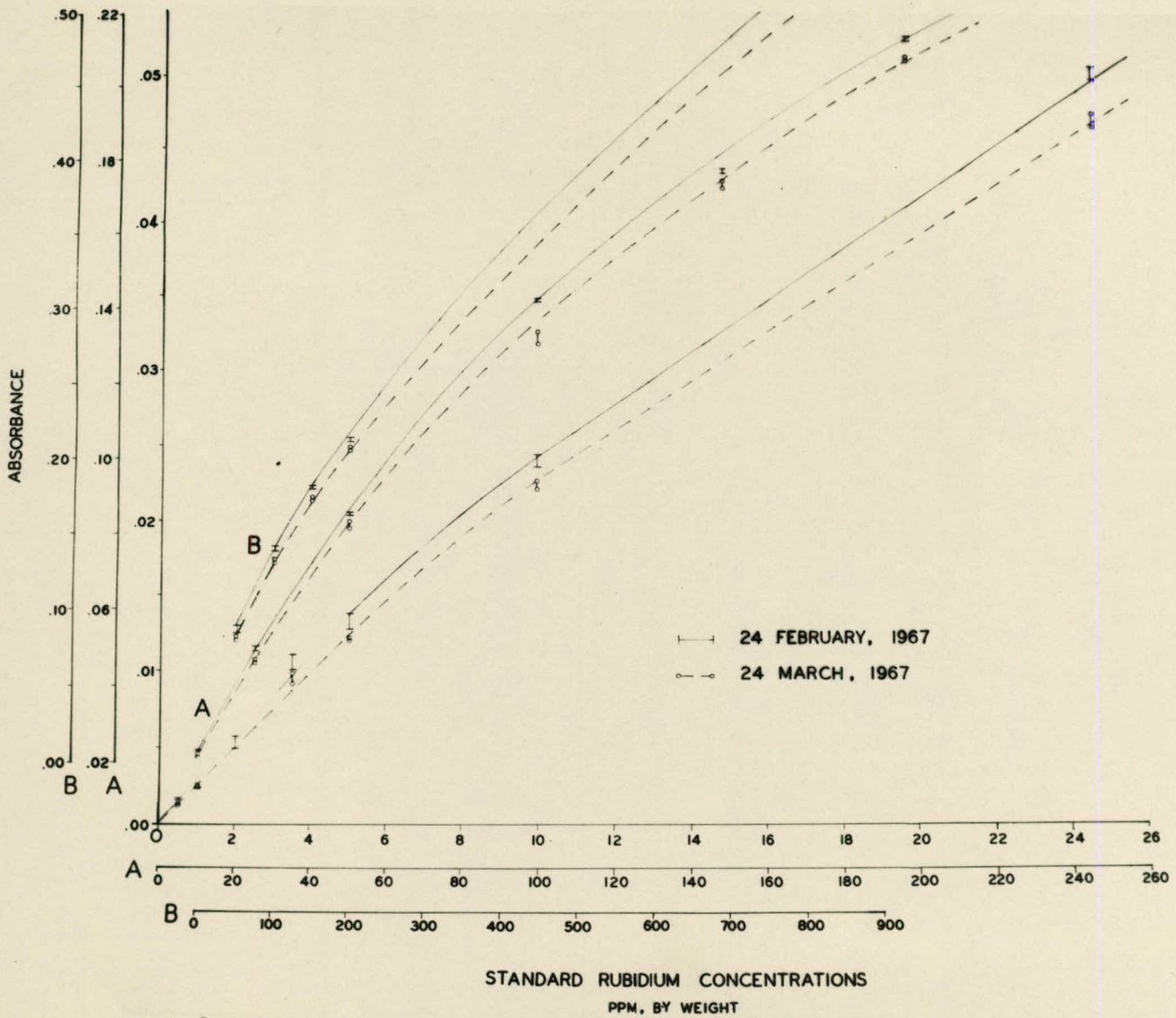

FIGURE 8. THE ABSORBANCES OF THE RUBIDIUM STANDARDS CONTAINING 0.1% NaCl.

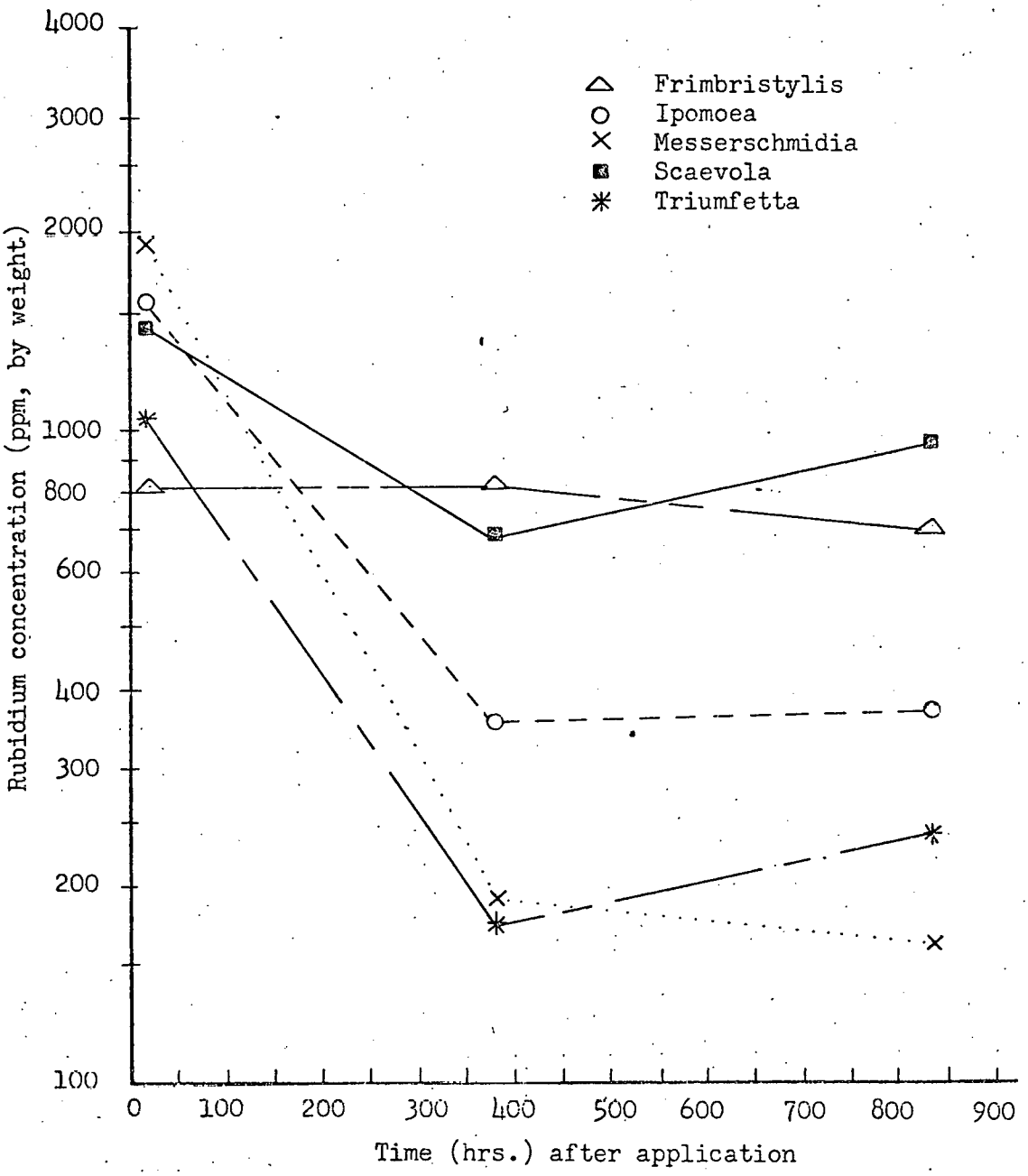

FIGURE 9

RUBIDIUM CONCENTRATIONS (PPM) OF THE SPRAYED PLANTS COLLECTED FROM THE RUNIT STUDY AREA

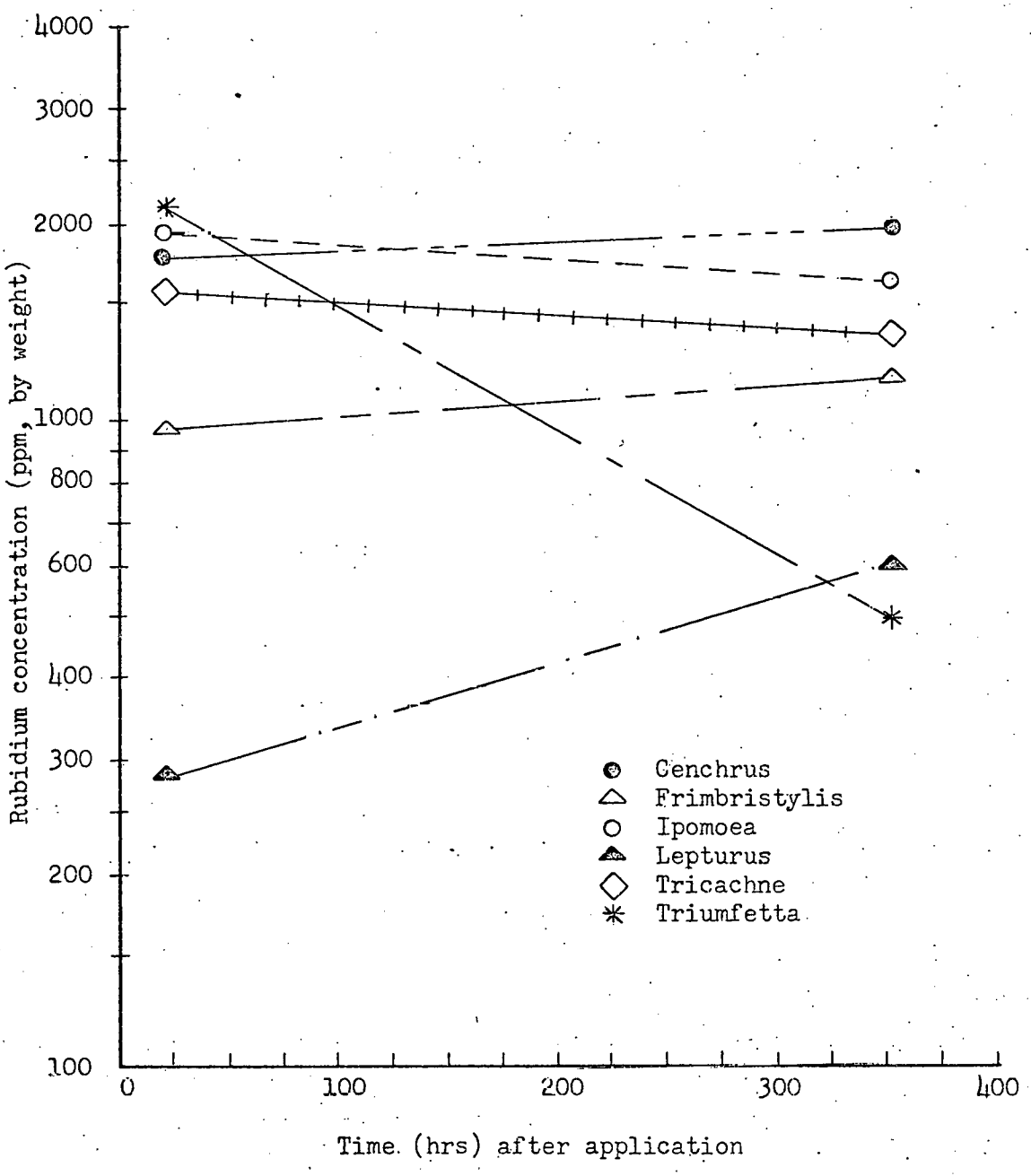

FIGURE 10

RUBIDIUM CONCENTRATIONS (PPM) OF THE SPRAYED PLANTS COLLECTED FROM THE JAPTAN STUDY AREA

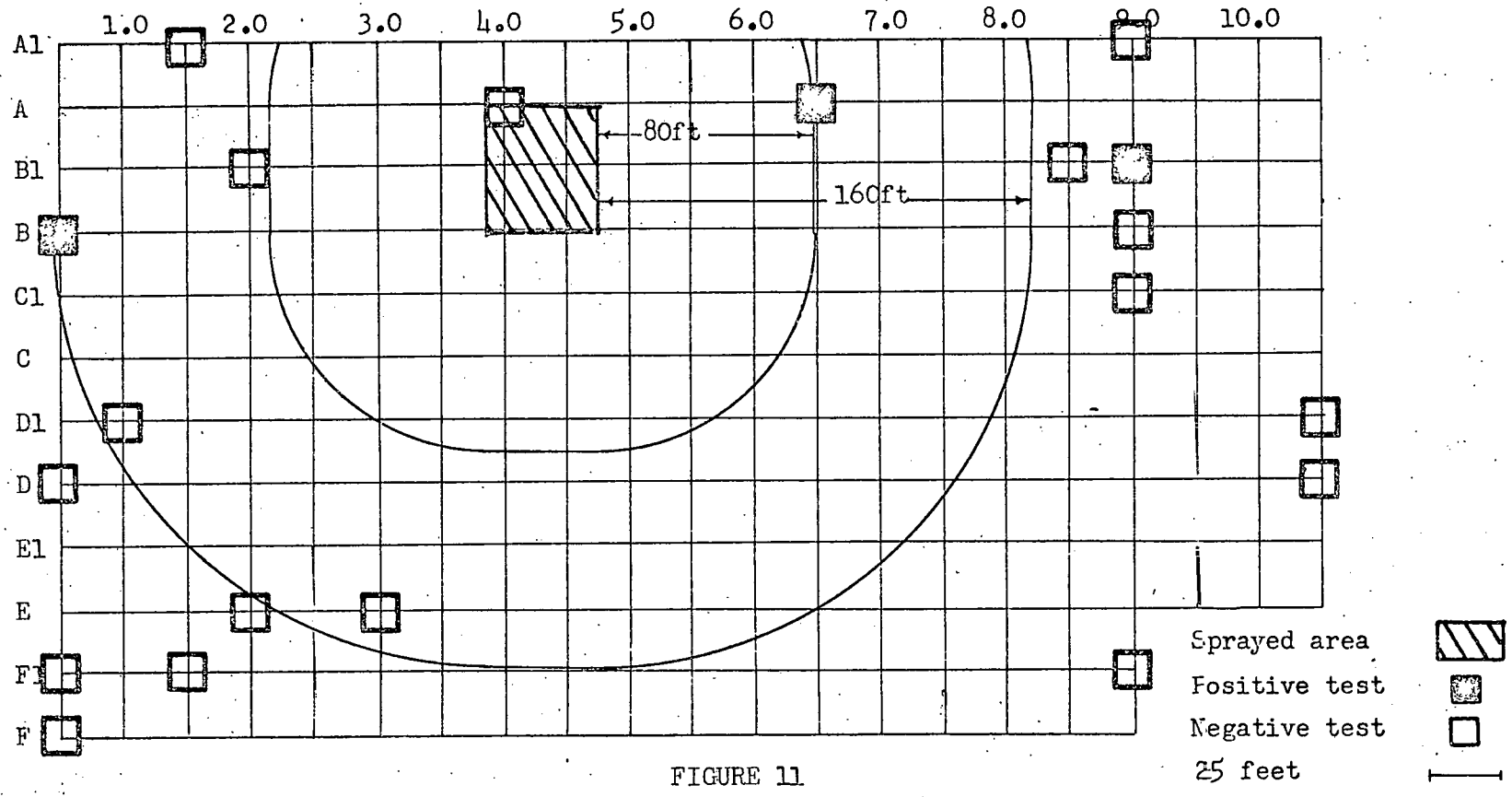

FIGURE 11

SUMMARY OF CAPTURE POINTS WITH RESPECT TO STANDARD DIAMETER OF RATTUS RATTUS COLLECTED FROM RUNIT ISLET, 31 DAYS AFTER FOLIAR APPLICATION, SHOWING POSITIVE AND NEGATIVE TESTS FOR RUBIDIUM

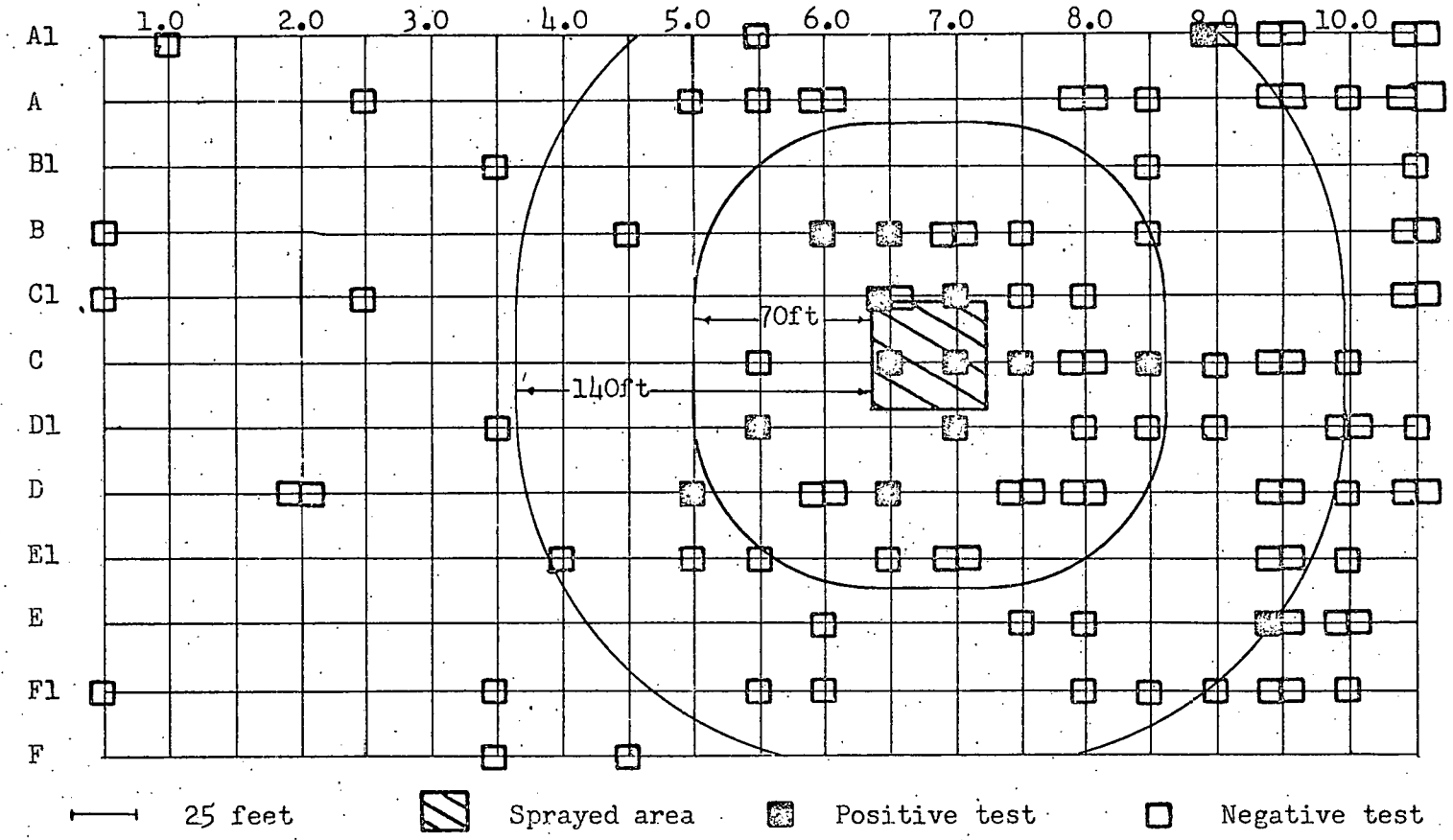

FIGURE 12

SUMMARY OF CAPTURE POINTS WITH RESPECT TO STANDARD DIAMETER OF RATTUS EXULANS COLLECTED FROM JAPTAN ISLET, 14 DAYS AFTER FOLIAR APPLICATION, SHOWING POSITIVE AND NEGATIVE TESTS FOR RUBIDIUM

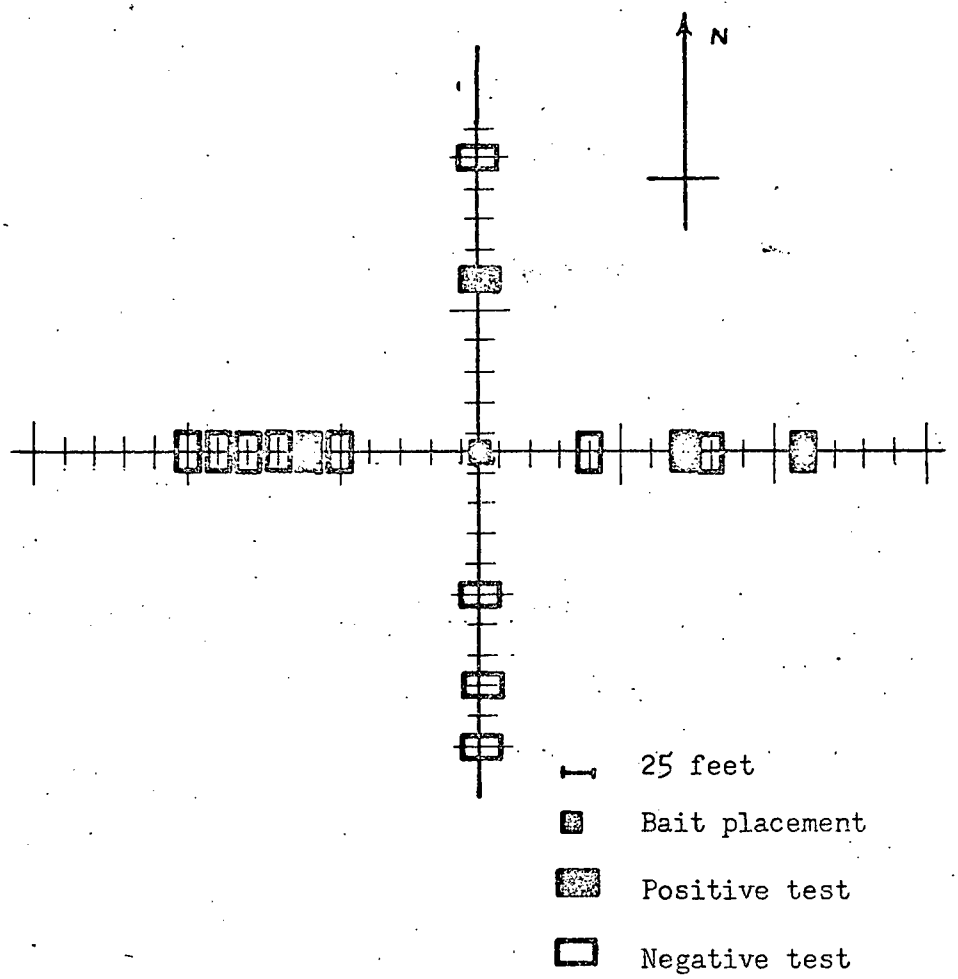

FIGURE 13

SUMMARY OF CAPTURE POINTS OF RATTUS EXULANS COLLECTED FROM BIIJIRI ISLET, FOUR DAYS AFTER BAIT PLACEMENT, SHOWING POSITIVE AND NEGATIVE TESTS FOR RUBIDIUM

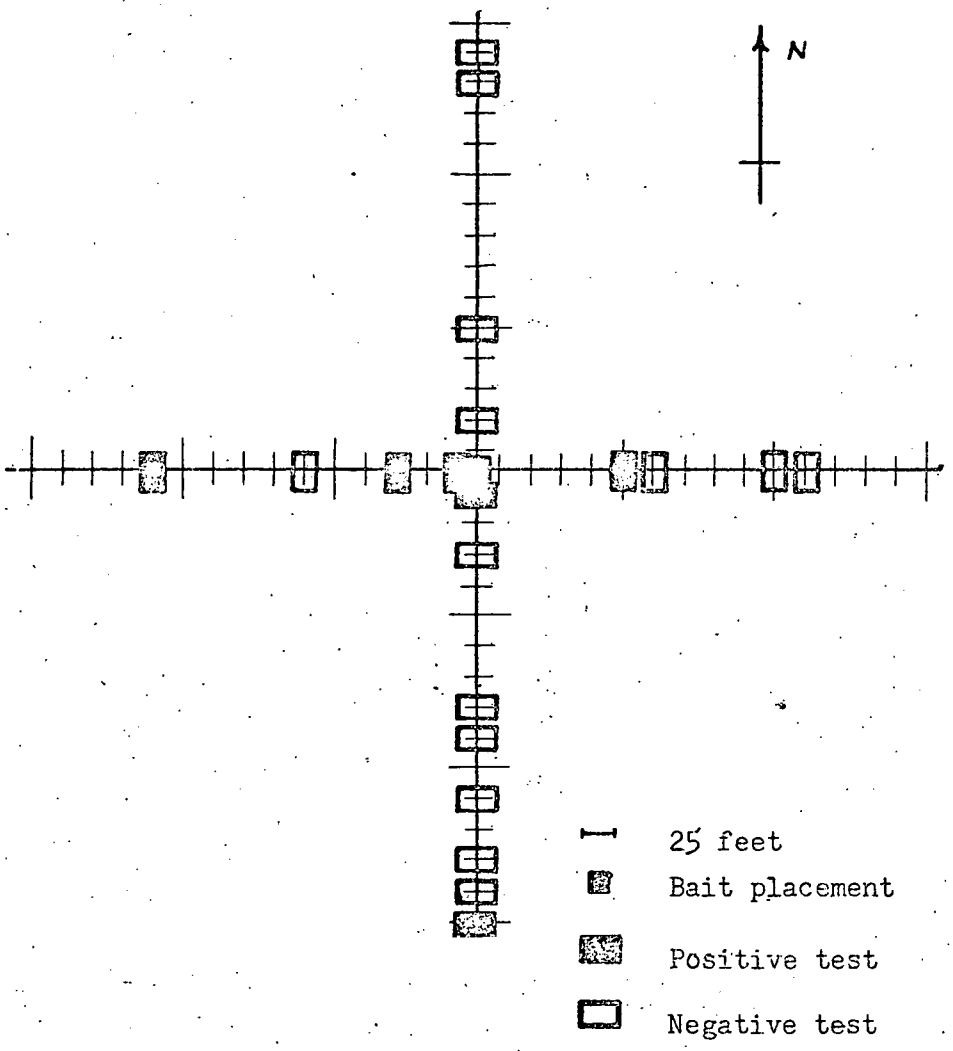

FIGURE 14

SUMMARY OF CAPTURE POINTS OF RATTUS RATTUS COLLECTED FROM ENGEBI ISLET, TWO DAYS AFTER BAIT PLACEMENT, SHOWING POSITIVE AND NEGATIVE TESTS FOR RUBIDIUM