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SEASONAL FOOD HABITS OF RATTUS RATTUS MINDANENSIS (The Philippine Ricefield Rat) in Central Luzon

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REPUBLIC OF THE PHILIPPINES
- National Economic Council
- Bureau of Plant Industry
- University of the Philippines, College of Agriculture

UNITED STATES
- Agency for International Development
- Denver Wildlife Research Center
- Bureau of Sport Fisheries & Wildlife

SEASONAL FOOD HABITS OF

RATTUS RATTUS MINDANENSIS (THE PHILIPPINE RICEFIELD RAT)

IN CENTRAL LUZON

by

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B.S., Colorado State University, 1958

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A thesis submitted to the Faculty of the Graduate School of the University of Colorado in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Department of Biology

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Seasonal Food Habits of *Rattus rattus mindanensis* (the Philippine Ricefield Rat) in Central Luzon

Thesis directed by Professor Olwen Williams

Food habits of the Philippine ricefield rat (*Rattus rattus mindanensis*) were studied for 12 months, June, 1970, through May, 1971. This investigation was part of a rat damage control program of the U. S. Agency for International Development and its contractor, the U. S. Bureau of Sport Fisheries and Wildlife. The damage ricefield rats cause to rice, while somewhat poorly quantified, is substantial, with estimates of 10 to 23 percent of the standing crop.

Rat control methods now used in the Philippines are not effective. Integrated control, involving cultural manipulation of vegetation, is probably the best approach to rat damage control. However, it was first necessary to determine the food preference of *R. r. mindanensis*. Plant and animal reference material and rat stomachs were collected each month by personnel of the Rodent Research Center, College Laguna, Republic of the Philippines, and shipped to the Denver Wildlife Research Center for preparation and examination. Twenty-five stomachs were examined microscopically every month (except October when only 14 were available) to determine the quality and quantity of the contents. Contents of additional stomachs were pooled each month and chemically analyzed for nutritional components and gross energy.

Although 34 food items were consumed by the rats, only eleven contributed 1 percent or more to the total year-long diet. Of the eleven materials, five were present in most months and contributed

the greatest percent volume. *Oryza sativa* (rice), insect matter, *Digitaria* sp., *Ipomoea aquatica*, and *Echinochloa colonum* were the food items most commonly eaten. Non-diagnostic parts of plants, thus unidentified, comprised 42.5 percent of the total year-long volume. Rice seed and unidentified plant parts occurred in inverse proportion. When rice seed was available, it comprised about 75 percent of the diet. The only rice seed available from late December through February was that portion left in the paddies after harvest. During the dry season, December through June, there is little growth of plants and the rats took a higher percentage of unidentifiable plant parts. Stomachs from June and September contained large amounts of insect matter; high protein, fat and gross energy levels reflected this increased ingestion of animal tissue. In the months of November, December, January, and February large amounts of rice seed were found in the stomachs; these stomachs also had the highest levels of nitrogen-free extract. Stomachs collected in February contained the least protein.

It was thought that perhaps rat weights would reflect the quality of the food the animals were eating. However, mean animal weights fluctuated throughout the year with the adults being heaviest in spring and fall. Even through the dry season, the rats were able to maintain relatively consistent weights. Numerical levels of the rat population at this time were unknown, however. Sex ratios of the animals trapped favored females, particularly in the dry season. Juvenile animals were most common in December and least common in September and October.

That cultural control of rats can be accomplished by clean harvesting methods and natural vegetation control is speculative. A field investigation to test this hypothesis was recommended.

This abstract is approved as to form and content. I recommend its publication.

Signed Olwen Williams
Olwen Williams

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In conclusion, without the help of my wife, Judy, who assisted in the preparation of microscope slides, typed draft upon draft of this manuscript, and continued to give moral support, I could not have completed this dissertation by Spring, 1972. I am most appreciative.

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SEASONAL FOOD HABITS (

RATTUS RATTUS MINDANENSIS (THE PHILIPPINE RICEFIELD RAT)

IN CENTRAL LUZON

INTRODUCTION

Rodents of the genus Rattus, notably the Norway rat, (R. norvegicus), the roof rat, (R. rattus), the Polynesian rat or kiore (R. exulans), and various subspecies thereof are found throughout the Pacific Basin, and while the damage they cause to agriculture is not well quantified, the animals have been a source of concern for many years. Clark (1958) reported that in the Philippines little was known of the relation of rats to agriculture until an outbreak occurred in Cotabato in 1953, followed by another on Mindanao in 1955.

Rat damage occurs in many agricultural situations. Up to 50% damage by rats to copra on a New Hebrides plantation and rat damage at a maximum of 73% in the Gilbert and Ellice Islands has been reported. Average copra loss in South Tarawa was 23% and in French Polynesia between 25 and 30%. In one 1930 report on the Colony of Fiji there was a 6.9% loss, but in 1934 on the Fijian Island of Taveuni the damage was 28%; the first calculation was considered too low (Wilson, 1968). However, these estimates are, if anything, conservative since they do not take into account depredation of stages other than the "half-grown nut" stage. Strecker (1962) noted that coconuts from the size of oranges to the "drinking-nut" stage are damaged by R. rattus and the outer husk poses no obstacle to

the animals' gnawing. Other biases may enter because damage estimates may be made more often in heavily damaged areas. Since complete destruction of coconut crops is rarely seen, 40 to 50% damage may be the upper limit which is imposed on the rat populations by the environment.

A variety of other crops are eaten by the various species of Rattus. Rat damage as high as 70% has been reported for cocoa, a crop gaining importance in the Pacific. One Samoan planter considers that he loses about 25% of his total annual yield (Wilson, 1968). Hood (1967) said that in Hawaii rat losses are estimated at 4.5 million dollars annually (plus $387,000 for rodent control programs, Teshima, 1968), and that in addition there is damage to nut, vegetable, and fruit crops. Throughout the Pacific Basin cash crops affected by rats include peanuts, pineapples, curcurbits, macadamia nuts, and corn, while subsistence crops such as taros, yams, sweet potatoes and manioc (cassova) are also eaten by rats (Wilson, 1968). Eight hundred thousand hectares of rice in Indonesia sustain an average damage of 40%. Further, in Java, 14,000 hectares of sugarcane suffered 30 to 100% rat damage (Soekarna, 1968). Finally, it should be pointed out that rat damage to cocoa, as well as other crops, notably sugarcane, may be indirect as well as direct since a rat-caused injury is an open invitation to plant disease (Wilson, 1968).

Thus, we have a brief summary of man's conflict with R. rattus in the Pacific Basin Islands, but the problem precipitating this present study concerns the Philippine Islands. Alfonso (1968) stated that rice is the most important agricultural crop in the Philippines and that the 7½ million acres devoted to rice culture produce 49

million dollars worth of rice annually. The ricefield rat is considered its major pest, for it attacks germinating seeds, growing seedlings, panicle-bearing plants and stored grains. LaVoie *et al.* (1970) stated that although destruction during early vegetative periods was light, there was a marked increase in rat damage in the reproductive growth period--up to 23% of the tillers (the fruit-bearing stems of the rice plant) sampled. LaVoie's data were not available when Alfonso (1968) stated that a loss of 10% exceeded the value of rice imported annually by the Philippines to cover its rice shortage. It is then possible, although not proven, that the actual loss in reality may be closer to 20%.

Recognizing that an immense problem exists in the Philippine man-rat conflict, the Denver Wildlife Research Center of the U. S. Bureau of Sport Fisheries and Wildlife was contracted by the U. S. Agency for International Development to study the Philippine ricefield rat (*Rattus rattus mindanensis*) problem and develop methods to curb the economic losses. One facet of this program is the study herein reported. It had two objectives:

1. To determine the seasonal (12 month) food habits of the ricefield rat in a cultivated, nonirrigated area in central Luzon, in terms of plant species and other material.

2. To determine the proximate analysis (ash, protein, fat, crude fiber, nitrogen-free extract, and carbohydrate) of stomach contents and their gross energy value for each of 12 months.

The information gained from this study will be related to *R. r. mindanensis* populations management.

BIOLOGY OF *RATTUS RATTUS* IN THE PACIFIC

Taxonomy

Variability of *Rattus rattus* in the Pacific is illustrated by the number of named subspecies; it is estimated that there are 125. Although originally described by Mearns as a distinct species, the ricefield rat is now designated *Rattus rattus mindanensis* (Barbehenn, 1969; Johnson, 1962; Sanborn, 1952). It is a medium-sized rat; adults weigh about 180 g (Barbehenn, 1969). The tail in *R. r. mindanensis* is somewhat longer than the head and body combined and it is uniformly black or dark-brown throughout; scalation is variable. The hind foot averages 38 mm in length, but the range of 34 to 42 mm overlaps that of many other species of rats. Plantar pods are well developed. Ears, measured from the notch, average 21 mm (range 19 to 23 mm). Pelage color is quite variable, light gray to somewhat melanistic (Barbehenn, 1969). On Ponape, and perhaps other islands, other subspecies also show varying degrees of melanism. This melanism occurs in three grades: 1) black above and slate below, 2) black above and normal below, and 3) normal above and slate below (Marshall, 1962). The ricefield rat typically has two pairs of pectoral and three pairs of inguinal mammae, with the anterior pair actually being abdominal and more distinct from the middle pair than the posterior pair (Barbehenn, 1969). To the non-taxonomist the various subspecies are very similar and where ranges overlap it is extremely difficult to separate them.

Distribution

Rattus rattus occurs almost worldwide, although it is not found

far inland in the northern latitudes. It has been reported as far north as Urbana, Illinois in the United States (Burt and Grossenheider, 1964). On the other hand, R. exulans (the Polynesian rat) occurs only in the Pacific Basin (Southwick, 1966). Johnson (1962) stated that all rodents of Micronesia seemed to have arrived in the company of man. Tomich (1969) added that although both R. rattus and R. exulans occur in the Philippines (and many other islands as well*), R. exulans has not ventured far into the Asian continent. Barbehenn (1969) considered R. r. mindanensis to be an endemic subspecies in the Philippines since it is presumed to occur on virtually every island. The animals are found from the seacoast to over 6,000 feet in Luzon and Mindanao, although they are less common at the higher altitudes.

Reproduction and Ontogeny

Considerable variation occurs in the birth and development of Rattus within the Pacific basin and elsewhere. Speaking of both R. rattus and R. exulans Jackson and Barbehenn (1962) stated that the young are naked and helpless at birth and that their eyes open in about two weeks. They soon accept solid foods and may be force-weaned at three weeks. Southwick (1966) said that the gestation period is from 21 to 23 days and the average litter size is five to eight. He further stated that time to maturity for R. rattus is 40 days and for R. exulans, 45 days. In contrast, Jackson and Barbehenn (1962) said that both R. rattus and R. exulans, although testes descended in about seven weeks, required ten weeks to reach sexual maturity. To further confuse the issue, in Indonesia,

*author's note

Soekarna (1968) said that R. r. brevicaudatus matures in five weeks and mates. He further stated that the gestation period is four weeks and the average litter contains 11 young.

Number of young produced per female per year varies considerably in R. rattus. For example on Ponape the figure is 12.2, in Malaya 16.0, Honolulu 40.3, and on ships in London harbor 56.2 (Southwick, 1966). Infant mortality in Rattus is high; the average length of life from birth for R. rattus is six weeks. However, older individuals have greater life expectancy. Average life after weaning is about six months (Davis, 1969). Work done by Jackson (1962a) agreed with Southwick's (1966) statement that production is low on Ponape. Jackson said that the reproductive rates of both R. rattus and R. exulans on Ponape were strikingly different from most populations studied elsewhere. Both prevalence of pregnancy and average litter size were as much as 50% less. Only figures on intra-uterine loss of embryos corresponded to those percentages reported for similar losses among populations of other regions. On Ponape, breeding continued through the year in both species, but in R. rattus there seemed to be a correlation of breeding peaks with the drier season. Also, there were more male rats present than females. Depending on the habitat, up to 60% of the population consisted of males, although usually the male-female ratio was little more than 50%.

Home Range and Travel

In Hawaii R. rattus is common in gulches and grasslands. It rarely moves from its home area although a movement of 686 feet was

once recorded (Tomich, 1960). Tomich used the adjusted range length to define R. rattus movements. The adjusted range length is defined as: "the straight-line distance between the most widely separated sites of capture of an individual rodent, with the correction factor of half the distance to the nearest trap added to each end". In Hawaii the adjusted range length for male R. rattus was 62 m (range 13 to 144 m) and for females 54 m (range 13 to 145 m).

R. rattus leaves little evidence of its presence in the field. Droppings are hard to find and they disentegrate rapidly. Runways are rarely found; direct observation shows wandering, exploratory movements. The home range extends up to 0.5 ha, with the standard diameter for males, 66 m, and for females, 52 m. Fourteen out of 28 males moved farther than 79 m (Strecker and Jackson, 1962). Although R. r. mindanensis may travel as far as 100 m from their nests, most movements are estimated to be 20 to 40 m (Alfonso et al., 1967).

On Ponape R. rattus is most common in grassland and least common in ferns, lowland woods and rainforest. There, as probably elsewhere, R. rattus is more adaptable than R. exulans, especially to human-disturbed conditions. R. rattus is also found in human villages (Jackson and Strecker, 1962). Rattus exulans can reach a density of 40 to 50 per hectare on Ponape, while on Guam there may be only 10 to 23 per hectare (Jackson, 1966). Rattus is an efficient digger, but the burrow may not be extensive. One burrow excavated by Strecker and Jackson (1962) was only 36 inches long. In the Philippines, the average number of R. r. mindanensis burrows per 100 m of paddy dike was 0.5, and 2.8 per 100 m of water transport dike (Rodent Research Center, 1970).

Inter-Intraspecific Relationships

Rodent populations may be naturally restricted in numbers by competition within or among species for the environmental necessities that are in limited supply. Although Davis (1969) stated that rat populations are limited by social behavior rather than food deficit, Southwick (1966) did not entirely agree. He said that most field studies indicated that other factors such as food supply, predation, or direct behavioral strife (agression, aberrant parental behavior, cannibalism) come into operation before the more classical symptoms of the general adaptive syndrome (reduced fertility and increased mortality) are evident.

Barbehenn and Strecker (1962) found little indication of strife between R. rattus and R. exulans. Where habitat is diversified the roof rat may make more use of its climbing proclivities whereas the Polynesian rat forages at ground level. Where the habitat is uniform grassland, R. exulans may avoid competing with the larger roof rat by being more active in the daytime. In contrast, Jackson (1966, p. 10) in a later report believed that interspecific competition in island populations may be very intense: "This characteristic has profound effects on the population dynamics of the species. Our data on rats suggest very stable populations with low reproductive rates, long life span, and high survival--all in direct contrast to rat populations elsewhere in the world."

Foods and Feeding

Rats are usually considered generalists in their food habits, being able to utilize a wide variety of food. Their feeding patterns

vary. Alfonso et al. (1967) said Philippine ricefield rats usually feed at night. Barnett (1969) added that some members of Rattus tend to have a four-hour rhythm of activity. The animals particularly like rice plants, rice grains, and green corn. Shelled corn, cassova, and fruit serve as secondary foods. They are great gnawers and nibblers and seldom eat their food at one sitting. Ricefield rats converge in areas where the best food is available and where shelter is adequate. The rat is omnivorous, feeding on insects and snails as well as vegetation (Alfonso et al., 1967). Half the diet of rats in some areas may be insects (Barnett, 1969). Further, food is often carried away and eaten under cover. Piles of snail shells are found in Philippine ricefields (LaVoie, personal communication).

Rat food varies also because of availability. On Ponape, Strecker and Jackson (1962) reported rats feeding on bananas, sugarcane, tapioca, tomatoes, beans, pineapple, papayas, soursap, durien (Pangium edule), cacao, and coconut. In grasslands the passion flower (Passiflora foetida), a shrub (Melastoma marianaum), and seeds of Bermuda grass (Cynodon dactylon) were eaten. In the rain-forests, fruits of Parinarium glaberrimum, Elaeocarpus carolinensis, and Campnosperma brevipetiolata were utilized. A large land snail (Achatina fulica) may serve as a food item, but was not preferred, and a slug (Sarasinuda plebeja) was eaten. However, the slug can be injurious as it may serve as a source of lungworms (Angiostrongylus cantonensis). Plant material composed 94% of the volume of the stomachs examined by Strecker and Jackson (1962). Water seems not to be a limiting factor because of the succulent vegetation available.

Parasites and Disease

Not a great deal is known about the diseases afflicting Rattus in the Pacific Basin except where human health is involved. However, Leptospira australis and L. icterohaemorrhagiae are suspected to occur (Jackson, 1962b).

In Java, Indonesia, Kardarsan (1968) reported that the infective agent of rat-anemia, Bartonella muris, has been found in the blood of R. norvegicus and R. r. brevicaudatus. Also spontaneous poly-arthritis was observed in R. norvegicus but the bacterium was not definitely identified. However, a similar disease in laboratory rats was determined to be caused by a symbiotic relationship between Streptobacillus moniliformis and a very small pleuropneumonia-like organism. Plague, caused by Pasteurella pestis, and typhus, caused by Rickettsia typhy and R. tsutsugamushi, were isolated from ecto-parasites on Rattus and are of public health concern.

Parasites are perhaps easier to study since apparently healthy animals may be found which are severely infested. In contrast, rats dying from bacterial or viral disease are rarely found. Ford-Robertson and Bull (1966) in a study on Little Barrier and Hen Islands near New Zealand listed a trypanosome, Trypanosoma lewisi; a cestode, Hymenolepis diminuta; a mite, Mesopsylla australiensis; a louse, Hoplopleura pacifica; four fleas, Xenopsylla vexabilia, Pygiopsylla hoplia, Parapsyllus longicornis, and Nosopsyllus fasciatus; and a nemotode, Mastophorus muxis, as occurring in or on the kiore (R. exulans).

To this list Jackson (1962b) added, for the Rattus on Ponape and nearby islands, the ectoparasites Hoplopleura oenomydis (a

louse) and Laelaps echidninus and L. nuttalli (mites). He also reports three endoparasites: Capillaria hepatica, a round worm; Taenia taeniaeformes, a liver tapeworm; and Angiostrongylus cantonsis a lung nemotode. Kadarsan's (1968) paper on parasites and disease of wild rats in Java expanded the list of parasites, and increased the list of rat hosts. Kadarsan spoke of R. norvegicus, R. r. diardi, R. r. brevicaudatus, R. whiteheadi, R. lepturus and "wild rat".

The effects of these parasites on populations of Rattus in the Pacific is unknown, but Ford-Robertson and Bull (1966) did not consider the high incidence of Trypanosoma lewisi in the R. exulans on Little Barrier Island to be important in controlling rat populations. Other persons, however, (Barbehenn, personal communication) considered that Angiostrongylus spp. may be a limiting factor in Rattus populations.

METHODS AND MATERIALS

Study Area

The rat collecting area was chosen by the U. S. Agency for International Development/Bureau of Sport Fisheries and Wildlife, Rodent Research Center personnel at College Laguna, Republic of the Philippines. Because the food habits study was part of a larger investigation of population dynamics, only a limited number of the rats collected were used in this determination of the food habits. We chose a non-irrigated area as more representative of the overall rice culture in the Philippines. A site near Barrio Bentigan in the province of Nueva Ecija, Luzon, was selected (Plate 1). The area from which the animals and plants were taken was a 2 x 3 km plot divided into six quadrats of 1 km^2 each.

Collection of Reference Material

A Filipino botanist (Danilio Sanchez) collected the plant and animal reference material. One hundred and four plants were collected, dried and pressed, and sent to Denver. The first collection, arriving in March, 1971, consisted of two specimens of the 55 most common species; these were identified. The second shipment of rarer plants arrived in November of 1971 and about 40% of the plants still remain unidentified. Fortunately, none of the unidentified plants appeared in the rat stomachs.

The limited number of animal species in the reference collection consisted of insects, snakes, frogs, crabs, snails, and mammals. Some of the higher animals were identified to species, but most of the insects were identified only to order. Specific identification

Plate 1. Rice paddies early in the rainy season (June or July) near Barrio Bentigan, Luzon. Photograph by Rodent Research Center personnel.

was unimportant as no attempt was made to identify this material beyond "insect" or "animal tissue". The animals were preserved in either alcohol or formalin until reference slides could be prepared.

Collection of Rats

Rice planting in Bentigan and thus availability of rice to the rats is dependent upon the onset of rains. In 1970 transplantings were made in July and August and harvested in late November and December. The dry season usually begins in December and lasts through May (Rodent Research Center, 1970 annual report). The rat stomachs used in this study were collected from June, 1970, through May, 1971.

The rats were collected within the 6 km^2 paddy system. Each of the six 1 km^2 quadrats was randomly assigned a number, which thereafter designated the sequence of trapping. After all quadrats had been trapped, the sequence was repeated. Two hundred snap-traps, baited with roasted coconut, were set in each area in four lines of 50 each. The space between the traps was 10 m. Since the traps were set along dikes, the distance between lines varied, but generally was about 100 m. The trapping was usually done in the middle of each month and the lines were checked for three nights or until sufficient specimens were trapped. Twenty-five animals were considered sufficient, but usually 40 to 50 rat stomachs were sent to the Denver Wildlife Research Center each month. In October, 1970, however, because of trap theft and probably poisoning, only 14 animals were caught in two separate attempts. This was the only month in which fewer than 25 stomachs were analyzed for food habits, and no stomachs were available for the proximate analysis.

Rat stomachs were removed as soon as practical after the animals were collected, and placed in small vials containing 75% ethanol or methanol and 25% glycerol. Each bottle was labeled with a reference number and a tag with the same number was placed in the bottle. Data collected were 1) sex, 2) age, and 3) weight of each animal, along with any pertinent observations.

Preparation of Reference Slides

Most literature on the techniques of food habits refers to the work of Baumgartner and Martin (1939) and Dusi (1949 and 1952) with the various modifications such as those of Williams (1959a and 1962), Keith et al. (1959), Ward (1960), Ward and Keith (1962), Hayden (1966), Myers and Vaughan (1964), and Vaughan (1967). In addition, the good compilation of methods used in food habits research by Korschgen (1969) was utilized. A later reference (Hansson, 1970) was not obtained in time to be of much value in this study. For the most part, the methods given by Dusi (1949) and Williams (1959a) were used in this study.

The plants were pressed and stored for several months prior to examination. Subsequently they were segregated as to leaf, stem, root, and flower, cut into small fragments, soaked for about two weeks in a solution of equal parts of water, glycerol, and 95% ethanol; they were then ground in a high-speed blender. The ground plant material was first placed on a funnel covered with fine bolting silk or similar fabric and thoroughly washed with tap water. The material was then treated with an iron alum mordant, stained with 1% hematoxylin, and rinsed in tap water to remove the excess stain. Finally, a small amount of the stained material was mounted

on a slide in a non-resinous mounting medium (Williams, 1959a) under a 22 x 40 mm cover glass. The slide was labeled appropriately.

At the suggestion of Keith LaVoie two additional steps of preparation were used for the stomach-content slides and the second shipment of plants. Between the first washing with tap water and the application of the mordant, the finely divided material was treated with 1% sodium hypochlorite for about one minute, washed, neutralized with 2% acetic acid, and washed again. These steps helped clarify the tissue, and the epidermal patterns by which materials were recognized were generally easier to see. Animal tissue was prepared in the same manner.

For each plant species sent in March, 1971, separate slides were prepared for the leaf, stem, root, and flower. However, the stem and root portions proved so non-diagnostic that they were omitted when the second collection of plant specimens was prepared. Photomicrographs in black and white were taken of each species. Photomicrograph prints were put in sheets of clear plastic and stored for easy reference in large loose-leaf notebooks.

Preparation of Stomach Sample Slides

The whole stomachs were stored in the preservative until the reference slides made from the first shipment of plants were completed and photographed. Finally, the stomach contents were carefully removed, with an effort to exclude the mucosa and the macroparasites. Only nematodes (unidentified) were found. The stomach contents were then weighed while still wet and their volumes determined by water displacement (Fichter *et al.*, 1955). These data had little value, however, as they merely indicated how much the animal had eaten prior

to being trapped. The contents were then transferred to a filter funnel and the slides prepared in the same manner as the second shipment of plants, i.e., including the clarifying step. Two slides were made of each stomach.

Preparation of Stomach Contents for Proximate Analysis

The stomach contents not used for the food habits determination were pooled by month and stored in jars until analyzed. About 10 g dry weight were needed for these analyses.

Identification of Stomach Contents

Two slides of each stomach (25 per month) were examined using a Leitz Ortholux Microscope, and plant and animal fragments indentified. Vegetative material in the slide was compared with the photomicrographs and verified with the original reference slide, until such level of skill was acquired that verification was not always necessary. Plants were identified to species when possible. Several instances occurred when species within a genus were so similar that genus alone was recorded. Epidermal patterns, stomata and trichomes were used to identify the plants. I tried to use at least two of these features in each identification. Plates 2, 3, 4, 5, and 6 are photomicrographs of reference materials and corresponding food items found in the stomachs, and they illustrate the diagnostic features. Animal matter was tentatively identified as animal tissue or insect. It later developed that only insect remains could be conclusively identified. Sometimes it was necessary to use chemical tests (cellulose, lignin, and chitin analyses) to determine whether the subject material was plant or animal.

Plate 2. Photomicrographs of Ipomoea aquatica. Upper plate was taken from a microscope slide in the reference collection. The lower plate is the plant as it appeared in the stomach contents of a Rattus rattus mindanensis. (X100)

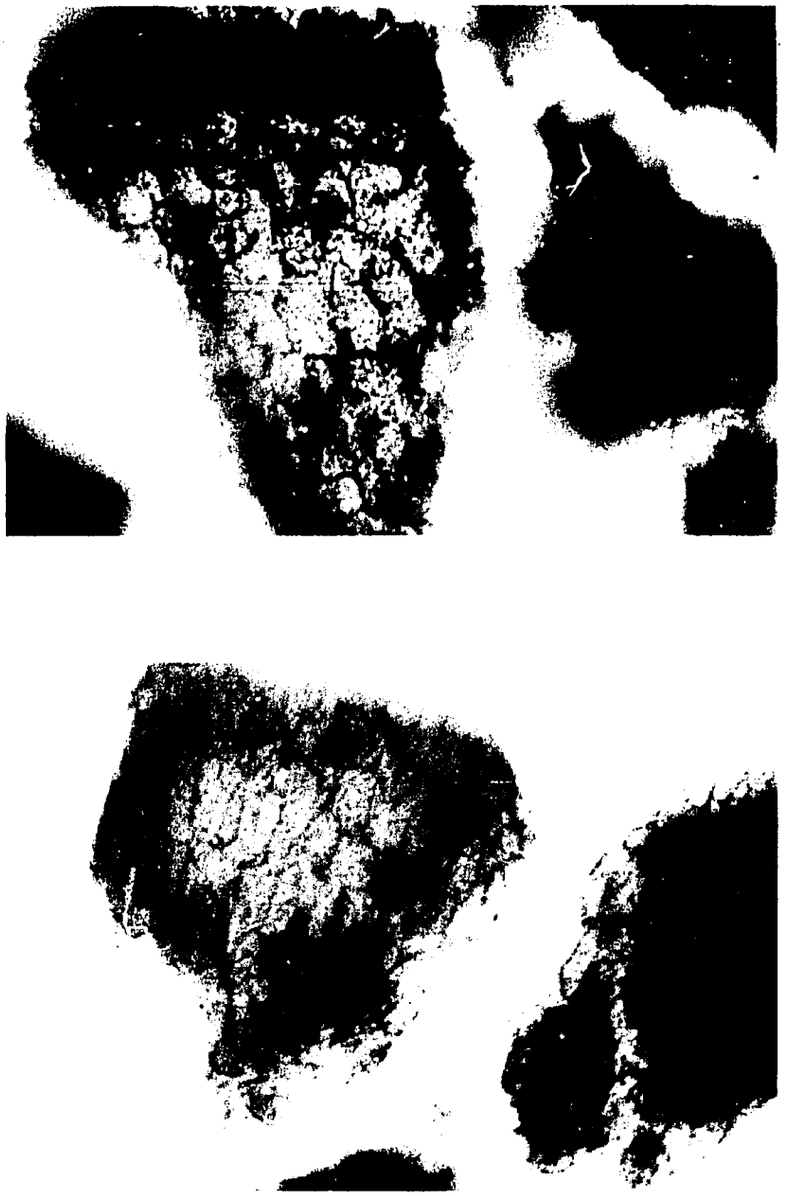

Plate 3. Photomicrographs of rice seed (Oryza sativa). Upper plate was taken from a microscope slide in the reference collection. The lower plate is rice seed as it appeared in the stomach contents of a Rattus rattus mindanensis. (X100)

Plate 4. Photomicrographs of Echinochloa colonum. Upper plate was taken from a microscope slide in the reference collection. The lower plate is the same plant as it appeared in the stomach contents of a Rattus rattus mindanensis. (X100)

Plate 5. Photomicrographs of insect parts found in the stomach contents of Rattus rattus mindanensis. Upper plate is the integument of a larval insect. Lower plate shows unidentified insect eggs. (X100)

Plate 6. Non-diagnostic parts of plants found in stomach contents of Rattus rattus mindanensis. (X100)

Since it was necessary to quantify the food items appearing in the stomachs, ten spots (field of the microscope) were examined per stomach (five spots on each slide--one in each quadrant and in the center) at low (about 100X) magnification (Keith et al., 1959; and Ueckert, 1968). No attempt was made to select any particular spot on the slide. The only criterion for selection was that there be food items within the field of view.

The percent of the field occupied by each food item (used interchangeably with percent volume in this study) was recorded, together with frequency of occurrence. The percent of the field was an actual count of the number of squares in a 10 x 10 (area = 1 mm^2 at 100X) grid that a particular food item occupied. The percent volume of the stomach contents indicated which food materials were preferred and were the major energy source for the rats. The frequency of occurrence, on the other hand, indicated how many times a specific food material was sampled and, alone, does not suggest food preference. However, when frequency of occurrence and percent volume are examined together, preference and need for a food item may be inferred; in addition, the availability of the material may be suggested.

Bait material (coconut) was recorded, but eliminated before data analysis since coconut palms are very rare in the collection area, and the possibility of the rats obtaining wild coconut was almost nil. After completion of the 12-month identification, spot samples were taken of several slides each month and species presence verified. Special emphasis was placed on the June collection, since this was the first analysis and thus a learning period.

Proximate Analysis and Gross Energy of Stomach Contents

The quality (species identity) and quantity of the stomach contents give only part of the dietetic story of the rat. The nutritional composition may indicate whether an animal utilizes a diet high in protein or carbohydrate, or whether some other component is important. Therefore, a proximate analysis, performed by The Industrial Laboratories Company of Denver, Colorado, was utilized to determine the percent weight of ash, protein, fat, crude fiber, nitrogen-free extract, and total carbohydrate. In addition, the company determined the gross energy of the stomach contents. All analyses were performed using the Association of Official Agricultural Chemists methods (Horwitz, 1965).

Since glycerol was a component of the preserving solution, the amount of glycerol in each sample was quantified and subtracted from the nitrogen-free extract component and the gross energy of each sample. The presence of glycerol made analysis difficult and caused some imprecision, thereby contributing to wide variation in the gross energy determinations.

Statistical Analyses of Data

The following data were compared among months: 1) frequency of occurrence of food items, 2) percent volume, 3) proximate analysis values and gross energy, 4) sex and age ratios and weights of all animals used in the study.

Numbers of males and females were compared using Chi-square (Snedecor, 1956). Adult-juvenile percentages, being incomplete and somewhat subjective, were not analyzed statistically. The remaining

data were analyzed by analysis of variance (Snedecor, 1956). Where the analysis of variance showed significant differences to exist, the means were separated by Duncan's New Multiple Range Test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Rat Food Items

Of the 104 plants collected in the study area and prepared as references, only 33 were identified in the rat stomachs (Table 1). Of these, when unidentified matter (almost totally plant, this material was essentially all non-diagnostic parenchyma, collenchyma and sclerenchyma.) was not included, only ten species contributed 1% or more to the year-long diet. When insect matter was included with the ten species of plants, these 11 items composed almost 96% of the identified material. However, when unidentified or non-diagnostic plant parts are included, the 11 items contributed only 55% of the total. Non-diagnostic plant parts constituted 42.5% of the volume.

Since not all 11 food items appeared in all 12 months (June, 1970 through May, 1971), Table 2 illustrates the percent volume of the five occurring throughout most of the year, Oryza sativa, insec Digitaria sp., Ipomoea aquatica, and Echinochloa colonum. Note in Table 1 that these plants, except for Oryza sativa (rice) were present in the Bentigan area all year and are abundant. Figure 1 illustrates the utilization by rats of these five food items and the unidentified or non-diagnostic material, calculated on 100% stomach volume. With the addition of the unidentified material, the percentage of the five food item dropped proportionately. These features of the figure appear noteworthy: 1) insect use is highest in June and September (protein and fat are also highest then--Table 11 and 12); 2) rice use appears inversely proportional to unidentified matter; and 3) the other three plant species do not

Table 1. Plants utilized by *Rattus rattus mindanensis* in the Bentigan area of Central Luzon.

Family	Species	Seasonal Occurrence	Abundance	Distribution
Convolvulaceae	*Ipomoea aquatica* Forsk.	all year	very abundant	pure stands to mats
Malvaceae	*Malacra capitata* L.	all year	common	singly or small patches
"	*M. fasciata* Gurtz.	all year	common	singly
"	*Sida rhombifolia* (L.) Borss.	all year	common	singly
Palmaceae	**Cocos nucifera* L.	all year	rare	singly
Tiliaceae	*Corchorus capsularis* L.	all year	common	singly
Gramineae	**Echinochloa colonum* (L.) Link.	all year	abundant	large colonies
"	**Brachiaria mutica* Forsk.	all year	very abundant	large colonies or pure stands
"	*B. distachya* (L.) Stapf.	all year	rare	small patches
"	**Paspalidium flavidum* (Retz.) A. Camus	all year	rare	small patches
"	**Panicum repens* L.	wet season	very abundant	pure stands or mats
"	**Oryza sativa* L.	wet season	very abundant	pure stands or mats
"	**Digitaria* sp.	all year	common	small patches to pure stands
"	*Paspalum longifolium* Rxb.	dry season	common	small patches

Table 1. Continued

Gramineae	P. punctatum (Burm.) A. Chase	wet season	rare	singly or small patches
"	Pennisetum polystachyon (L.) Schult.	wet season	common	small patches to large colonies
"	Ischaemum rugosum (Cav.) Merr.	wet season	abundant	small patches
"	Cynodon dactylon (L.) Pers.	all year	rare	small patches and pure stands
Amaranthaceae	Alternanthera sessilis (L.) R. Br.	all year	common	small patches
Leguminosae	Crotalaria quinquifolia L.	?	rare	singly
"	Alysicarpus vaginalis (L.) DC.	all year	abundant	small patches to pure mats
"	Desmodium capitatum (Burm.) DC.	all year	common	small patches
Rubiaceae	Hedyotis corymbosa (L.) Lam.	?	common	small patches
Sterculiaceae	Melochia conchorifolia L.	all year	rare	singly
Commelinaceae	Commelina diffusa Burm.	all year	common	small patches
"	C. benghalensis L.	all year	common	small patches
"	Aneilema malabaricum (L.) Merr.	wet season	rare	small patches
Pontederiaceae	*Monochoria vaginalis (Burm.) Presl.	all year in water	common	small patches to large colonies
Capparidaceae	Cleome ciliata Schmn. and Thorn.	all year	very rare	singly

Table 1. Continued

Onagraceae (Oenotheraceae)	*Ludwigia perennis* L.	all year	common	singly
Verbenaceae	**Lippia nodifolia* (L.) Rich.	all year	common	small patches to pure mats
Compositae	*Blumea* sp.	dry season	common to very abundant	small patches to large colonies
"	*Eclipta zippeliana* B.	all year	common	small patches
Solanaceae	*Physalis angulata* L.	?	very rare	singly

* Contributing 1% or more to the year-long diet of *R. r. mindanensis*.

**Used as trap bait. Discarded from calculations.

Table 2. Percent volume of the five most utilized food items found in *Rattus rattus mindanensis* stomachs each month. Calculated as percent of the identified material.

Months--June, 1970, through May, 1971	Percent Volume				
	Oryza sativa	Insect	*Digitaria* sp.	*Ipomoea aquatica*	*Echinochloa colonum*
June	0	29.2	0.1	17.9	25.1
July	10.7	40.3	0	10.2	10.6
August	4.0	12.9	23.4	15.3	2.6
September	0.9	69.6	5.4	0.1	3.2
October	78.9	9.4	0	0	0
November	72.9	12.5	1.7	0	0
December	78.2	8.0	5.2	0	0
January	72.4	8.0	0.9	0	0
February	79.8	9.2	0.5	0	0
March	41.2	11.8	41.2	0	0
April	15.8	24.4	54.1	0	0
May	0	3.6	29.6	39.7	0

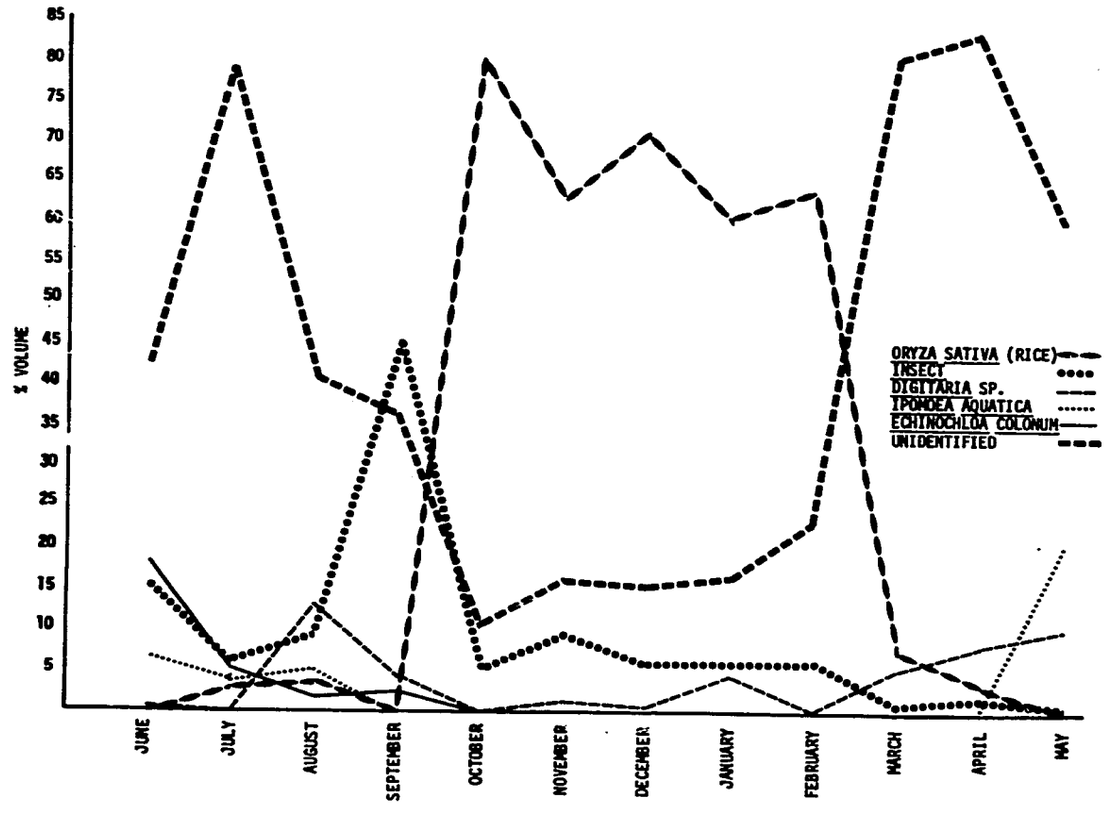

Figure 1. Percent of total volume of the five most common food items and the unidentified matter found in Rattus rattus mindanensis stomachs. Non-diagnostic parts of plants make up the unidentified portion.

contribute much to the food supply. Insects are available to the animals throughout the year, but apparently are used more in the rainy season. Vegetative parts of the rice plant were rarely identified; the rice usage as graphed in Figure 1 was essentially rice seed. The rice becomes available sometime in October, depending on the onset of the rainy season and thus on how early it was planted. Rice seed utilization remained high until a precipitous drop occurred between February and March. This drop may coincide with the burning of the rice paddies and the removal by various secondary consumers and reducers of the rice grains left on the ground in the paddies after harvest. The Denver Wildlife Research Center 1970 narrative report stated that in one study, 182 kg of rice/ha were left in the paddies after harvest. During this period when rice seed utilization by rats was high, the percentage of unidentified matter, or non-diagnostic plant parts, drops. The percentage of this non-diagnostic material was high when rice seed was unavailable, and since the crude fiber level (Table 13) was highest in March, may indicate that the rats were eating a poorer quality food. Furthermore, the rats may have been taking parts of the plant not utilized when there was ample food.

Frequency of occurrence of food items in the rat diets indicated close agreement with the percent volumes (Table 3). Of the five items in Table 2, only Echinocholoa colonum did not appear in the high-five frequency of occurrence; it was number six (Table 5). These results contrast with those of Hansson (1970) who did not find close agreement between frequency of occurrence and percent volume. The analysis of variance for frequency of occurrence showed

Table 3. Frequency of occurrence for 12 months of the five most important food items found in 284 *Rattus rattus mindanensis* stomachs.

Food Items	Frequency of Occurrence	Percent of Total Stomachs
Oryza sativa	136	48
Insect	192	68
Digitaria sp.	91	32
Ipomoea aquatica	33	12
Echinochloa colonum	22	8

significant difference among the means (Table 4). The separation of the mean frequencies of the food items is shown in Table 5. When the five items contributing the greatest percent volume were considered, only two, insect and Oryza sativa, differed significantly from all others in frequency of occurrence. However, comparison of the percent volumes on the basis of identified-only and total food items present, did show significant differences. There were fewer species and thus fewer degrees of freedom available when unidentified material was included (Tables 6 and 7).

Tables 8 and 9 illustrate the mean separation as calculated by Duncan's New Multiple Range Test. (This test is used where the analysis of variance shows a significant difference among means. The Duncan's Test provides a method of determining which means differ significantly.) Oryza sativa (rice) and unidentified, or non-diagnostic matter, were the only means significantly different from the other six food items (Table 8). Likewise, Table 9 shows rice to be different from all other food items in terms of percent volume in the rat diets. That there is no difference between means of 19.92 (insect) and 3.46 (Echinochloa colonum) indicated the great variation within the data. Percent volumes varied from a high of 79.8 to 0.

Coconut was used for trap bait and therefore not included in the analyses. Its effect on normal food habits is unknown, but in several instances it composed 100% of the volume of a stomach. Unfortunately, this bias could not be accounted for and subtracted from the proximate and gross energy analyses.

Table 4. Analysis of variance of the frequency of occurrence of 12 most commonly used food items found in *Rattus rattus mindanensis* stomachs.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	143	8233.16		
Food Items	11	5304.58	485.51	22.16**
Residual	132	2892.58	21.91	

**Highly significant difference, tabular $F\alpha = 0.01$ is 2.4.

Table 5. Mean separation of frequency of occurrence of food items found in *Rattus rattus mindanensis* stomachs.*

	Brachiaria mutica	*Monocharia vaginalis*	*Panicum repens*	*Lippia nodifolia*	*Paspalidium flavidum*	*Echinochloa colonum*	*Malacra capitata*	*Ipomoea aquatica*	*Digitaria* sp.	*Oryza sativa*	Insect	Unidentified matter
$\bar{X}$	0.50	0.67	0.67	1.33	1.58	1.83	2.58	2.75	7.58	11.33	16	18.25

*No significant difference among means connected by line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 6. Analysis of variance of all food items found in *Rattus rattus mindanensis* stomachs.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	95	43534		
Food Items	7	20315	2902	11**
Residual	88	23217	263	

**Highly significant difference, tabular F α = 0.01 is 2.85.

Table 7. Analysis of variance of identified-only items found in *Rattus rattus mindanensis* stomachs.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	131	90		
Food Items	10	15756	1575	7.6**
Residual	121	25232	208	

**Highly significant difference, tabular F α = 0.01 is 2.47.

Table 8. Mean percentage separation of total food items found in *Rattus rattus mindanensis* stomachs. Means are for the entire year.*

	Paspalidium flavidum	*Malacra capitata*	*Echinochloa colonum*	*Ipomoea aquatica*	*Digitaria* sp.	Insect	*Oryza sativa*	Unidentified matter
$\bar{X}$	1.38	1.78	2.31	3.18	4.49	9.63	29.62	42.5

* No significant difference exists among those connected by the line $\alpha = 0.01$. Mean separation by Duncan's New Multiple Range Test.

Table 9. Percent volume mean separation of identified-only food items found in *Rattus rattus mindanensis* stomachs.*

	Panicum repens	*Lippia nodifolia*	*Brachiaria mutica*	*Monochoria vaginalis*	*Paspalidium flavidum*	*Echinochloa colonum*	*Malacra capitola*	*Ipomoea aquatica*	*Digitaria* sp.	Insect	*Oryza sativa*
$\bar{X}$	0.98	1.35	1.66	2.04	2.28	3.46	3.87	6.93	14.34	19.92	37.90

*No significant difference exists among those connected by the line $\alpha = 0.01$. Mean separation by Duncan's New Multiple Range Test.

Proximate Analysis of Stomach Contents

Pooled stomach contents were analyzed each month for ash, fat, protein, crude fiber, nitrogen-free extract, total carbohydrate and gross energy; no stomach contents were available for October. The analyses were replicated 12 times each month. The mean weight percentages are shown in Tables 10 and the analysis of variance for nutritional components occupies Table 11; significant differences existed among the means. The glycerol used in the preservative was subtracted before the data were calculated.

There seems to be little information of significance in the percentages of ash found in the rat stomachs except that it was highest in August (Table 12). Results for February and July differed from those of other months also, but there was no seasonal pattern.

The data shown in Tables 13 through 17 are more informative. These tables indicate that the fat and protein contents and the nitrogen-free extract were inversely related by months. Stomach contents from June and September samples were highest in fat and protein and lowest in nitrogen-free extract. Stomachs from the June and September collections were also highest in insect matter (Figure 1). Samples from the months of greatest rice utilization, November, December, January, and February (Figure 1) were highest in nitrogen-free extract and lowest in fat. Conversely, in February, stomach contents showed the lowest percent protein. Stomach contents from the post-harvest months of December, January, and February were lowest in fat and occurred among those showing the highest nitrogen-free extract.

Table 10. Mean percentages of weights in grams for ash, protein, fat, crude fiber, nitrogen-free extract, and total carbohydrate for 12 months found in Rattus rattus mindanensis stomach contents.

Month	Proximate Analysis						
	Ash	Protein	Fat	Crude Fiber	Nitrogen-Free Extract	Carbohydrate	No. Stomachs Analyzed
June	7.95	26.48	7.42	12.46	47.70	58.04	23
July	8.88	18.96	4.46	10.44	57.26	67.70	19
Aug.	13.42	18.21	4.88	9.85	53.64	63.49	24
Sept.	4.95	30.80	10.97	14.69	38.59	53.28	20
*							
Nov.	5.76	20.58	3.35	6.39	63.92	70.31	11
Dec.	6.85	18.35	3.46	7.29	64.05	71.34	37
Jan.	5.68	19.32	3.16	9.62	62.22	71.84	20
Feb.	8.15	13.92	3.12	11.27	63.54	74.81	25
March	6.56	16.30	4.79	16.98	55.36	72.33	25
April	6.39	17.13	6.36	8.57	61.52	70.08	25
May	7.08	15.92	5.00	13.67	58.33	72.00	25

*No stomachs available in October.

Table 11. Analysis of variance for ash, protein, fat, crude fiber, nitrogen-free extract, and total carbohydrate from *Rattus rattus mindanensis* stomach contents analyzed monthly from June, 1970, through May, 1971.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	131	707.22		
Ash	10	636.03	63.60	108.17**
Residual	121	71.19	0.59	
Total	131	2956.89		
Protein	10	2884.59	288.46	483.18**
Residual	121	72.30	0.60	
Total	131	746.00		
Fat	10	664.86	66.49	99.23**
Residual	121	81.14	0.67	
Total	131	1308.71		
Crude Fiber	10	1237.09	123.71	209.32**
Residual	121	71.62	0.59	
Total	131	8386.08		
Nitrogen-Free Extract	10	8035.97	803.60	277.77**
Residual	121	350.10	2.89	
Total	131	5661.01		
Carbohydrate	10	5426.31	542.63	279.71**
Residual	121	234.78	1.94	

**Highly significant difference, tabular Fα= 0.01 is 2.47.

Table 12. Percent weight mean separation for ash found in *Rattus rattus mindanensis* stomach contents.*

	Sept.	Jan.	Nov.	April	March	Dec.	May	June	Feb.	July	Aug.
$\bar{X}$	4.95	5.68	5.76	6.39	6.56	6.85	7.08	7.95	8.15	8.88	13.42

*No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 13. Percent weight mean separation for protein found in *Rattus rattus mindanensis* stomachs.*

	Feb.	May	March	April	Aug.	Dec.	July	Jan.	Nov.	June	Sept.
$\bar{X}$	13.92	15.92	16.30	17.13	18.21	18.35	18.96	19.32	20.58	26.48	30.80

*No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 14. Percent weight mean separation for fat found in *Rattus rattus lindanensis* stomachs.*

	Feb.	Jan.	Nov.	Dec.	July	March	Aug.	May	April	June	Sept.
$\bar{X}$	3.12	3.16	3.35	3.46	4.46	4.79	4.88	5.00	6.39	7.42	10.97

* No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 15. Percent weight mean separation for crude fiber found in *Rattus rattus mindanensis* stomachs.*

	Nov.	Dec.	April	Jan.	Aug.	July	Feb.	June	May	Sept.	March
$\bar{X}$	6.39	7.29	8.57	9.62	9.85	10.44	11.27	12.46	13.67	14.69	16.98

*No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 16. Percent weight mean separation for nitrogen-free extract found in *Rattus rattus mindanensis* stomachs.*

	Sept.	June	Aug.	March	July	May	April	Jan.	Feb.	Nov.	Dec.
$\bar{X}$	38.59	45.70	53.64	55.36	57.26	58.33	61.52	62.22	63.54	63.92	64.05

*No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

Table 17. Percent weight mean separation for total carbohydrate found in *Rattus rattus mindanensis* stomachs.*

	Sept.	June	Aug.	July	April	Nov.	Dec.	Jan.	May	March	Feb.
$\bar{X}$	53.28	58.04	63.49	67.70	70.08	70.31	71.34	71.84	72.00	72.33	74.81

*No significant difference among those months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

That the animals were eating poorer quality food during the dry season after the waste rice seed was gone is indicated in Table 15. Crude fiber was high in the stomachs from March, May and June, but it was also high in September, a rainy season month. The abrupt change from rice seed in February to non-diagnostic plant parts in March (Figure 1) may have accounted for the increase in crude fiber, since rice contains less than 1% crude fiber (Altman and Dittmer, 1968). Table 17 shows the mean separation for total carbohydrate. Combination of the two components provided a less clear picture of the rat diets than the separate analyses.

These chemical analyses can be somewhat misleading. Without a bioenergetics study of the rat itself, there was no way of determining what percentage of the components in the proximate analysis was usable. Gross energy figures were thus biased also. In other words, the protein or carbohydrate may not be usable to the same degree in different species. Ruminants, such as cattle, for example, utilize crude fiber much better than a non-ruminant rat. We have no knowledge of assimilation efficiencies in *R. r. mindanensis*.

Gross Energy of Stomach Contents

As was done in preparation for the proximate analysis, the stomach contents were pooled each month before being analyzed for gross energy. The analysis was replicated 12 times each month; energy due to glycerol used in the preservative was subtracted from the total energy. Gross energy was reported as calories/gram of dry stomach contents. The monthly means are shown in Tables 18 and the analysis of variance is given in Table 19. Significant differences existed among means.

Table 18. Monthly means of gross energy found in *Rattus rattus mindanensis* stomach contents.

Month	Gross Energy (cal/g dry weight)
June	4550
July	5059
August	4392
September	4985
*	
November	4884
December	5197
January	4615
February	4986
March	4472
April	4777
May	4600

*No stomachs available for October.

Table 19. Analysis of variance of mean gross energy per month of *Rattus rattus mindanensis* stomach contents.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	131	21,252,353		
Months	10	8,471,527	847,152	8**
Residual	121	12,780,826	105,626	

**Highly significant difference, tabular $F_{\alpha=0.01}$ is 2.47.

Table 20 shows the mean separation of the gross energy for each month. July, September, November, December and February were the months in which the stomach contents contained the most gross energy. They were not significantly different from one another, but did differ from those values occurring during the rest of the year. Of these five months, only July stomach contents were low in rice (Figure 1); the stomach contents of the July sample contained a high percentage of unidentifiable material. I suspected that perhaps the stomach contents from the months of June and September would be high in energy because they were high in protein and fat. September's gross energy was predictably high, but the insect matter in the June stomach contents was evidently too low to produce gross energy levels comparable to the monthly samples high in nitrogen-free extract. There was a 805 cal/g difference between the highest and lowest values. Between these two extremes, the animals were apparently able to maintain a reasonably consistent level of energy. However, as was the case with usable amounts of protein and crude fiber, the amount of usable energy could not be determined by these data, either.

The overall gross energy analysis was hard to determine because glycerol was used in the preservative solution. After the alcohol had been evaporated, the remaining material appeared as a thick gel, which made sampling difficult and results more erratic than expected.

Other Biological Data on *Rattus rattus mindanensis*

Weights for all animals used in the study were available for 13 months, June, 1970, through June, 1971. These data were included because they offered additional information on the physiological adaptations of the animal to its diet, i.e., its ability to maintain

Table 20. Mean separation for gross energy in gram-calories from *Rattus rattus mindanensis* stomach contents.*

	Aug.	March	June	May	Jan.	April	Nov.	Sept.	Feb.	July	Dec.
$\bar{X}$	4392	4472	4550	4600	4615	4777	4884	4985	4986	5059	5197

*No significant difference among months connected by the line, $\alpha = 0.01$. Separation by Duncan's New Multiple Range Test.

consistent weight in different seasons. Numbers of animals caught in the study and monthly mean weights are shown in Table 21. Table 22 shows the analysis of variance for the weights of all animals captured. There was a significant difference among months. The mean separations are shown in Table 23. The animals trapped in May, September, and October were significantly heavier than those trapped in the other months. The weights of those animals caught in October and September, though not significantly different from rats trapped in May, could have reflected the weights of gravid females. The lowest mean weight occurred in December and reflected young animals being caught. Yearly habitat conditions may also have contributed greatly to animal weight since June, 1971, had significantly heavier animals than June, 1970, $\bar{X}$ 142 g vs. 119 g.

When weights of subadult rats were included in the analysis, the weight range was wide, and the weight change which could have been correlated with food availability became obscure. Therefore, the juvenile animal weights (less than 105 g) were omitted and the data reanalyzed. The average weight of adult rats was 145 g. The analysis of variance in Table 24 indicates that there were significant differences among the monthly weights. Table 25 shows which monthly weights are significantly different. Animals caught in March, May, September, October, and November were the heaviest and were significantly heavier than those trapped in the other months. Since these five months included both wet and dry seasons, it appeared that the animals were capable of maintaining normal weight under varying habitat conditions. However, there was no information on numbers of animals. Perhaps during the dry, stressful season there were fewer

Table 21. Numbers and mean weights of male and female *Rattus rattus mindanensis* trapped for this study in Central Luzon, June, 1970 through June, 1971.

Month	Numbers of Males	Numbers of Females	$\bar{X}$ Weight in g of All Animals
June, 1970	26	22	142
July	18	19	113
August	24	24	127
September	23	22	159
October	4	10	154
November	12	24	125
December	23	36	102
January, 1971	32	26	111
February	19	31	107
March	14	34	133
April	17	31	113
May	19	31	147
June	30	20	142
$\bar{X}$			127
Total	261	330	

Table 22. Analysis of variance for monthly weights of all *Rattus rattus mindanensis* captured for this study in Central Luzon, June 1970, through June, 1971.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	599	903837		
Months	12	183005	15250	12.41**
Residual	587	720832	1228	

**Highly significant difference, tabular $F_{\alpha} = 0.01$ is 2.22.

Table 23. Mean weight separation for all Rattus rattus mindanensis captured for this study in Central Luzon, June, 1970, through June, 1971.*

	Dec.	Feb.	Jan.	July	April	June 1970	Nov.	Aug.	March	June 1971	May	Oct.	Sept.
$\bar{X}$ (g)	102	107	111	113	113	119	125	127	133	142	147	154	159

*No significant difference among months connected by the line $\alpha = 0.01$.
Separation by Duncan's New Multiple Range Test.

Table 24. Analysis of variance for monthly mean weights of adult *Rattus rattus mindanensis* captured for this study in Central Luzon, June, 1970, through June, 1971

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F
Total	414	302967		
Months	12	53808	4484	7.24**
Residual	404	249159	619	

**Highly significant difference, tabular $F_{\alpha} = 0.01$ is 2.23.

Table 25. Mean monthly weight separation for adult *Rattus rattus mindanensis* captured for this study in Central Luzon, June, 1970 through June, 1971.*

	July	April	Feb.	Aug.	June 1970	Dec.	Jan.	June 1971	May	March	Sept.	Oct.	Nov.
$\bar{X}$ (g)	129	130	132	135	139	139	140	142	152	157	161	162	163

*No significant difference among months connected by the line $\alpha = 0.01$.
Dashed line indicates January mean was significantly different from May mean.
Separation by Duncan's New Multiple Range Test.

animals in the population and therefore the remaining rats were able to maintain normal weights. There seemed to be no pattern to the lighter weights; they were spread throughout the year.

Sex ratios deviated from 1:1 throughout the 13 months (Table 21). Chi-square analysis showed the differences to be significant at the $\alpha = 0.05$ level, but mean separation was not possible. However, inspection of the data showed the deviation beginning in November, 1970, with February through May consistently low in males. Thirteen months of trapping yielded 591 animals, 56% female and 44% males. Whether these sex ratios actually occurred in the population or were due to other factors such as selective trapping or seasonal behavioral differences, was beyond the scope of these data.

When total weights were compared, the animals trapped in December had the lowest mean weight, 102 g (Table 23). The December rat population appeared to have an adult-juvenile ratio which was different from the other months (Table 26). Furthermore, there were more animals trapped in December, 1970, (62) than in any other month; there were more juveniles (36) and a higher percentage of juveniles (58%). In addition, Table 26 shows differences in trapping data among the months and years. While it is logical that there would be more adults prior to the period of parturition (roughly the month of November) as indicated by the September-October percentages of juveniles, there was considerable discrepancy among other months. Data from the Rodent Research Center Annual Report (1969) illustrate some of these discrepancies. For example, while juvenile percentages were quite high in June and July, 1970, (42 and 36%) the percentages in June, 1971, (4%) and July, 1969, (10%) were low. Furthermore,

Table 26. Percent juveniles for rats trapped from June, 1970, through June, 1971, and comparable periods in 1968-1969.

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Numbers of Animals Trapped 1970-1971	48	44	43	45	14	36	62	60	50	50	48	50	50
Percent Juveniles 1970-1971	42	36	14	4	7	44	58	35	50	34	40	8	4
Numbers of Animals Trapped 1968-1969*		47	106	99	34	19	48	99		401	195	200	
Percent Juveniles 1968-1969		10	12	7	3	47	23	38		27	33	20	

*Rodent Research Center Annual Report, 1969.

when the two trapping periods in December, 1968 and 1970 were compared, the percent of juveniles was quite different; December, 1970, had 58% juveniles while 1968 had 23%. Variances also occurred throughout the other comparable periods; but since complete data were lacking in 1968-69, no statistical analysis could be performed. Whether yearly environmental differences or trapping technique produced these results is speculative.

Management Implications

It appears that if cultural methods of rat population control are to be utilized, then recovery or destruction of the waste rice is the first step. December had the highest percentage of juvenile animals (perhaps the overall rat population was at a peak then also). This population of rats must be sustained through the dry, stressful period of January through June. If waste rice were removed, many of the young might not survive and the breeding population in August and September would be proportionately smaller. Field trials would be necessary, however, to determine whether the induced juvenile mortality would constitute an addition to or replacement of normal mortality. If the mortality were additive, then a direct control method prior to rat parturition, perhaps in September or October, coupled with rice removal, should substantially reduce the overall rat population.

SUMMARY

While it is widely assumed that species of Rattus are generalists in their food habits and feed on a variety of material, the complete story may be somewhat different. Rattus rattus mindanensis certainly eats a wide variety of food materials, but only a few items, Oryza sativa, insect matter, Digitaria sp., Ipomoea aquatica and Echinochloa colonum, were identified as contributing the major nutrition. A significant fraction of material was composed of non-diagnostic parts of plants which defied identification. Of the identified matter, rice seed (Oryza sativa) and insect matter were most utilized; rice is high in carbohydrate and insect matter is high in fat and protein. The proximate and gross energy analyses and the percent volume and frequency of occurrence data were mutually supporting. Where high frequency of occurrence and percent volume of rice occurred in the stomachs, the carbohydrate levels were high. Conversely where insect matter was high in frequency of occurrence and percent volume, the fat and protein levels were high. When it was available, the animals chose high energy foods such as rice seed. The rice eaten was mostly seed, not vegetative matter. This study substantiated LaVoie's et al. (1970) findings. He discovered that cutting of rice stems prior to flowering was insignificant. After flowering, however, the percentage of fruit-bearing stems cut was 23%. Vegetative parts of the rice plant were rarely utilized; they were left uneaten in the paddy.

In the absence of rice, the rats ate greater amounts of insect matter, but they also ate more of the non-diagnostic parts of the plant. I believe that use of the internal parts of the plant, stem,

and roots may indicate a more difficult season of food procurement. The level of crude fiber in the stomach contents rose in March when rice seed became scarce. The dry season, usually December through May or June, was probably the most stressful period for the rats since no new food was being produced. However, at least through February there was adequate rice seed left in the paddies to sustain the animals; it occurred in the stomachs in levels approaching 70 to 80% volume.

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