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CHAPTER 3

RODENT ECOLOGY, POPULATION DYNAMICS AND BEHAVIOR

P.J. Alfonso, L.A. Fiedler and J.P. Sumangil

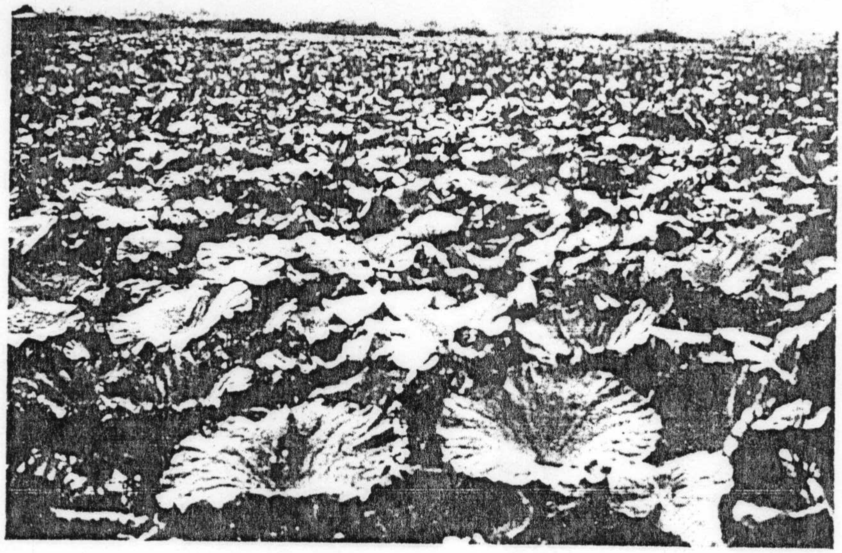
How Infestations Occur

A tropical ecosystem is characterized by having a great number of interacting plant and animal populations forming a relatively stable biotic community. The many complex interactions within and between these populations lead to an equilibrium that constantly shifts with the seasons. A rodent population in a given forest stand or grassland habitat influences and in turn is influenced by other populations in the biotic community. These different populations interact, serving as check and balance mechanism resulting in a relative stability in the living community. Laymen call this the balance of nature.

Man in his attempt to maximize land productivity, as through forest clearing, monocropping and irrigation, unwittingly disturbs the natural relationships among the plant and animal populations, thereby destroying the environmental stability or the "balance of nature." Populations favored by the change erupt in numbers and displace less favored populations. Thus, rodent populations rapidly increase and become important pests of farm crops and food stores. Forest areas in Mindoro which used to have a rat density of about two per hectare eventually experienced eruptive rat build-ups when converted into croplands. Cotabato similarly realized unmanageable rat outbreaks in newly-opened farm tracks extracted from the rain forests. Wide-ranging and unabated rodent infestations of the current years point to the need for effective rodent pest management.

Rodent Populations

Rat population estimates in Philippine rice areas differ widely from very few to thousands per hectare. A limited study in Luzon indicated an average rat population of 20 to 200 per hectare in mature rice. However, in an extensive sampling effort in Davao, Sumangil (1963) found that in late vegetative, booting and maturing rice, there were 516, 664, and 984 rats per hectare respectively. In a marshland habitat in Laguna de Bay, Libay and Fall (1976) observed an exceptionally high density of more than one adult R. r. mindanensis per m^2 (10,000 per hectare). This indicates that marshes have a high carrying capacity providing a reservoir rodent population for invading nearby ricefields. In fact many historical rat "outbreaks" in the Philippines have occurred in areas adjacent to wide marshlands (Crucillo, et al. 1954 and Villadolid, 1956). Sporadically heavy rat infestation has also been



Many rodent outbreaks in the Philippines have been associated with the marshland habitats.

reported in areas bordering the Liguasan and Libungan marshes in Mindanao, in agricultural areas bordering the Candaba swamp and Chico river in Luzon, and in the area bordering Lake Naujan in Mindoro (Libay and Fall, 1976). The marsh is one interesting ecosystem for studying rodent ecology in relation to outbreaks.

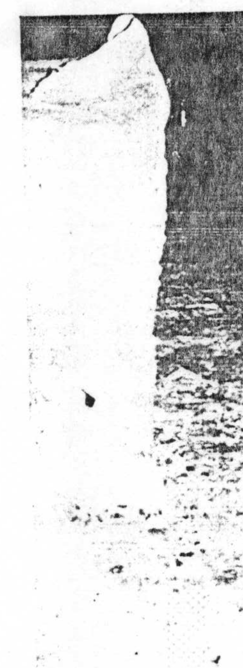
Population Dynamics

An initial rodent population grows slowly at first, later increases at an accelerating rate, and eventually levels off upon reaching the carrying capacity of its particular environment.

Under agricultural field conditions, however, the carrying capacity is seldom reached as conditions change rapidly in relation to the cropping cycle, land preparation, planting, crop maturity and harvesting.

Rodent populations when given favorable conditions (as good crop stand) may effect eruptive population growth. The momentum of population increases may result in rodent densities exceeding the carrying capacity of the environment for a limited time (an outbreak).

Rat nest



Droppings

RAT SIGNS

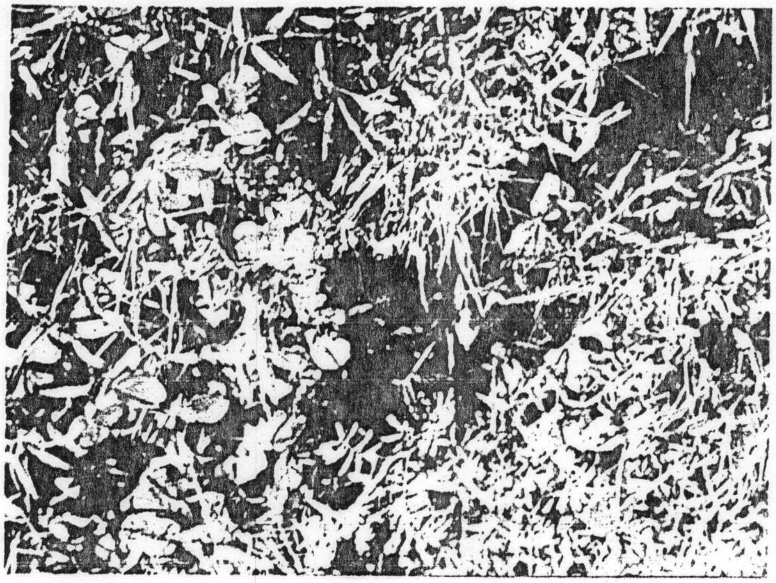
Rat nest

Young rats

Droppings

Damaged plants

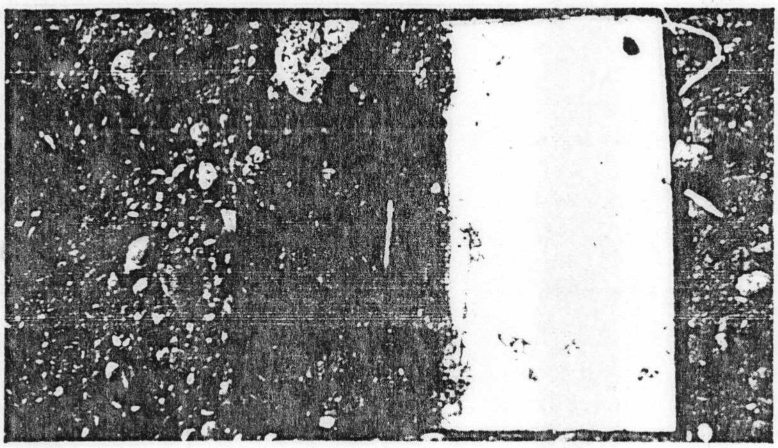
RAT SIGNS



Rat runways

Active burrows

Footprints on mud.



Footprints on inked vinyl tile.

Footprints on concrete floor.

Southwich (1969) states that eruptive population growth in rodents is effected by the following:

1. short gestation periods (21-23 days)
2. large litter size
3. rapid maturation
4. post-partum heat (making possible concurrent pregnancy and lactation of unweaned litter)

It is possible to detect a rat population build-up by the presence of some of the following signs:

1. high incidence of young or immature rats
2. evidence of early sexual maturity
3. high incidence of pregnant and/or lactating females
4. large litter size

These characteristics indicate a healthy growing population with sufficient food and harborage and unhampered by diseases, predation, and competition. Obviously, an effective pest management program would focus its concern on these factors of population control.

Reproduction and Development

Studies show that the annual reproductive cycle mirrors the local cropping patterns. In rain fed, one-season rice areas, rats exhibit a single peak of reproductive activity during the year; in irrigated two season rice areas, two peaks of reproductive activity are indicated. The seasonal peak(s) of reproduction result in a marked increase in population density as the majority of juvenile rats are the product of the peak month(s) of reproductive activity (Table 3-1).

Population explosion in cyclic population can be brought about by earlier maturation of both sexes as was observed in ricefield populations of rats in Cotabato during the 1955 breeding season where rats attained sexual maturity 1 1/2 months earlier than as normally arrived at in 3 to 7 months.

Reproductivity can be estimated from the incidence of pregnancy or lactation. Annual production per female may be derived from information on pregnancy rates and average litter sizes.

Table 3-1. Monthly changes in the prevalence of pregnant Rattus rattus mindanensis *in Siniloan, August, 1971 through July 1972 (Marges, 1972).*

Month	Percent pregnant[a]	Embryos per female	Growth stages of rice
August 1971	0	0	transplanting
September	10.52	6.50	tillering
October	31.57	9.67	booting, heading
November	48.10	9.68	mature, harvesting
December	8.75	8.86	post-harvest
January 1982	0	0	seedbed, land preparation
February	27.27	7.0	transplanting
March	80.00[b]	10.75	tillering
April	62.50	10.45	booting, heading
May	36.67	11.18	mature, harvesting
June	25.53	9.16	post-haivest
July	5.41	7.50	seedbed, land preparation
Average	28.02	9.67	

[a]Prevalence of pregnancy based on total number of females with perforated vaginal orifice.

[b]Very few samples, only 4 pregnant out of 5 females.

The average reproductive patterns of some female murids are tabulated in Table 3-2.

Table 3-2. Average reproductive patterns of female murids (unweighted averages), (Southwich, 1969).

Species	P Percent pregnant[1]	Embryos per female	F[2] Incidence of pregnancy	Production per female per year	No. of studies
R. norvegicus	19.9	8.86	4.01	35.7	12
R. rattus	25.3	6.13	5.00	31.3	13
R. exulans	29.5	3.90	6.00	25.0	3
B. bengalensis	52.6	6.15	11.29	69.6	2
M. musculus	35.4	5.37	8.09	42.6	8

[1] Visible pregnancy; approximately 17/25th (74%) of true prevalence of pregnancy.

[2] $F = P\ (t/v)$

where: P = prevalence of pregnancy, or percent pregnant in female autopsy sample.

t = time in days over which sample was taken

v = time in days of gestation during which pregnancy is macroscopically visible at autopsy; usually taken to be 18 in *R. norvegicus*, 17 in *R. exulans* and *B. bandicota*, 16 *R. rattus*, and 15 in *Mus musculus*.

Average litter size of populations of *Rattus rattus mindanensis* in different habitats in the Philippines vary from 3.24 (marsh habitat) to 9.67 (ricefield), (Table 3-3).

Table 3-3 Liter size of different populations of Rattus rattus mindanensis.

Population	Litter size mean (Range)	Reference
Field-bred females	6.38[1] (5-8)	Ferrer
Laboratory-bred	6.00[1] (5-8)	Ferrer
Marsh	3.24[2] (2-5)	Libay and Fall
Ricefield	7.4[3] (5-9.09)	Sanchez
Ricefield	9.67[3] (6.5-11.18)	Marges
Poisoned ricefield habitat adjacent to marshland	7.89[4] (3-11)	Sumangil, et al.

[1] number at birth
[2] number in net
[3] embryo counts
[4] litter size at late gestation

The apparent ability of rat populations to adapt to prevailing environmental conditions indicate the difficulty of controlling them.

Mortality

Rodents are subjected to various mortality factors from the embryonic to the adult stage. Pre and post-natal deaths could bring about small litter size. It is estimated that only about 84 percent of rats reach maturity (Table 3-4) and the life expectancy of rats in the field is about one year (Davis, 1953). Obvious exceptions occur such as the old oversized, sluggish and scarced individual Norway rats in city environs.

Table 3-4. Mortality estimates for wild Rattus rattus mindanensis *(Ferrer, 1975)*.

Life Stage	Values
Birth (number dead/total no. born)	11.8 (6/51)
Weanling (no. dead/total no. weaned)	4.4 (2/45)
Percent surviving to sexual maturity (no. alive/total number born)	83.3 (43/51)

Low levels of predation, reduced strife, cannibalism in the ricefield rats, ample available food and harborage tend to ease the mortality rate.

Movement

Immigration rather than reproduction is the main mechanism by which rodents can quickly re-populate croplands following population reduction. In some areas, sustained trapping and poisoning resulting in 50-70 percent kill failed to control the rat infestation because recovery through constant rat migration from adjacent infestation areas (mainly wasteland habitats) occurred. In small ricefields complete population recovery from physical removal of rats can take place in about two weeks, provided there is an adjacent rat reservoir.

These observations indicate that control measures should take into full account the effect of rat movement or re-population.

Radio telemetry data of *Rattus r. mindanensis* and *R. exulans* in a coconut field taken from 4:00 — 8:00 a.m. and 6:00 — 10:00 p.m. indicated peaks of movements from 6:00 — 8:00 a.m. and 8:00 — 10:00 p.m. (Sultan, 1978).

Normal range of movements over a period of four months detected by marked capture-recapture techniques is within 100 meters for *Rattus argentiventer* and *R. exulans* in Malaysia Harrison (1957) and *R. r. mindanensis* in the Philippines (Benigno, 1972). Using baits with the chemical marker dimethylchlortetracycline (DMCT), marked rats were found to move to as far as 400 meters in response to flooding and field plowing (Lavoie, et al. 1971). Land preparation displaced rats but only within 100 meters. Even flash floods displaced rats temporarily; rats can re-populate the area within two weeks after the waters receded (Fall, 1977).

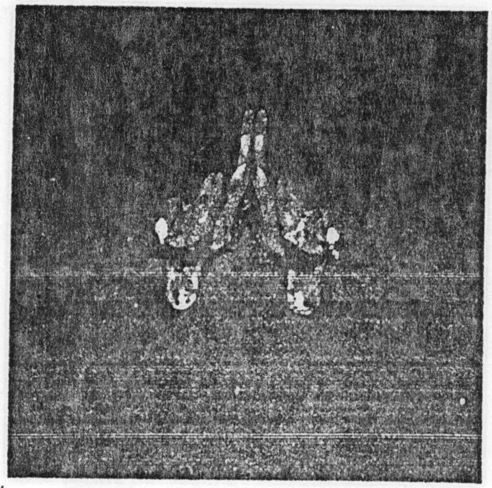
Interhabitat or intercrop movement also occurs when one field is being harvested or when a crop becomes more attractive (usually at flowering or fruiting stage). In rice-coconut farms, rats move to the cover in coconut grove when the ricefields are being harvested or plowed and return when rice is being grown. In the same manner rats move to nearby warehouses or food storage at harvest and move to fields when there is a standing crop. We have also observed that rats climb coconut trees causing extensive damage following clearing of shrubs and undergrowth. Likewise, the clearing of weeds in banana plantations drove rats to climb the plants and construct nests on fruit branches and damage the fruits. More drastic movements or displacements occur when sugarcane fields are burned before harvest.

Feeding Behavior

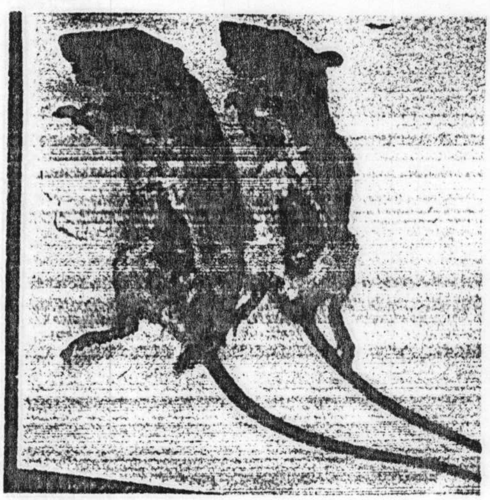
Rats are omnivorous but prefer cereal grains. Tigner (1972) identified rice, insect matter and weeds (*Digitaria* sp., *Ipomoea aquatica* and *Echinochloa colonum)* as major components of the ricefields rat's diet in Central Luzon (Table 3-5). Rats choose high energy foods such as rice seeds. In the

Chemical markers with baits mark rats feeding on bait stations.

Rat jaws marked with tetracycline as seen under ultraviolet light.



Rats marked with rhodamine B dye as seen under . . .



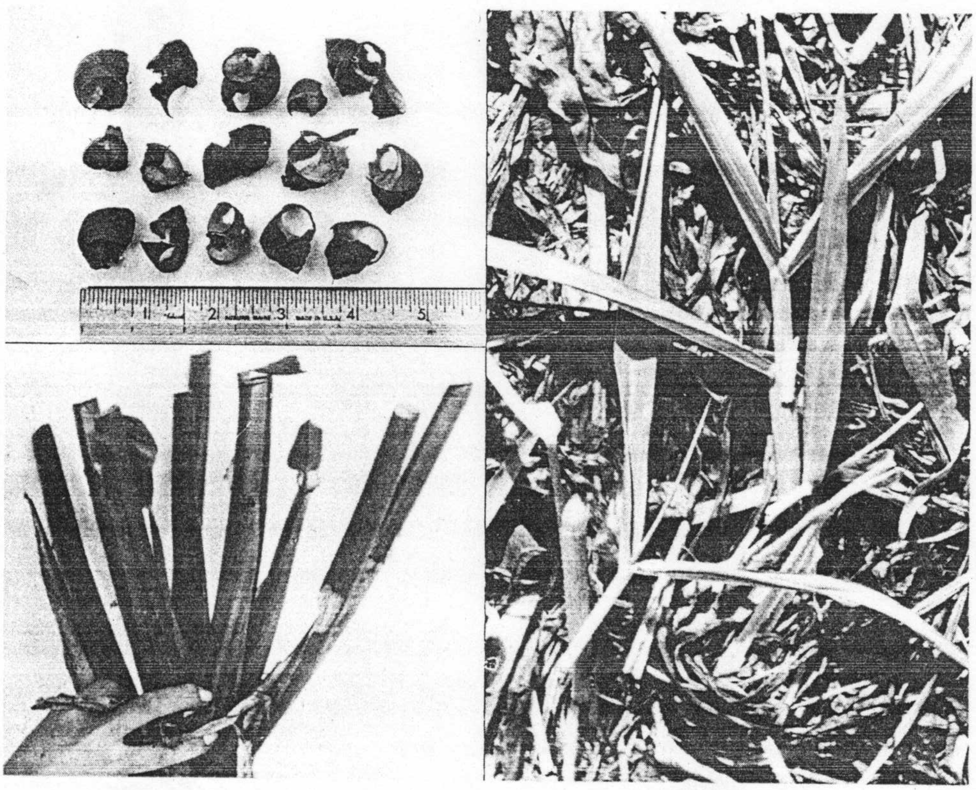
. . . natural light.

. . . ultraviolet light.

absence of rice during dry off-season months (April to June) they ate greater amounts of insect matter which is high in fat and protein and some vegetative matter (Table 3-6). Soekarna et al. (1980) also reported a food preference test in Indonesia where the rats' daily food consumption consisted of 37.4% rice, 33.5% sweet potato, 24.8% cassava, 2.8% peanut and 1.5% dry corn.

Rats cut rice tillers at the vegetative stage but when the rice heads form and eventually ripen, the rats then feed on the panicles and maturing grains (Table 3-7). Lavoie et al. (1970) reported increased damage during reproductive and ripening stages of rice. They also reported significantly greater damage per unit area in fields where surroundings rice was harvested earlier than in large tracks of uniformly planted land.

When rat population is low, tiller cutting tends to occur along rice paddy dikes, but at high population levels rats feed on the middle of the paddy. At intermediate population level, tiller cutting is randomly distributed in the paddy. In corn, more damage occurs along cornfield edges especially in bordering uncultivated areas (Benigno, 1980).



Aside from feeding on crops, rats feed on insects, snails, grasses, water hyacinth and other materials. These alternate foods help rats tide over unfavorable conditions such as floods, droughts or when croplands are fallowed.

Table 3-5. Plants utilized by Rattus rattus mindanensis *in the Bentigan area of Central Luzon (Tigner 1972).*

Family	Species	Seasonal Occurrences	Abundance	Distribution
Convolvulaceae	**Ipomoea aquatica* Forsk.	all year	very abundant	pure stands to mats
Malvaceae	**Malacra capitata* L.	all year	common	
,,	*M. fasciata* Gurtz.	all year	common	singly or small patches
,,	*Sida rhombifolia* (L.) Borss.	all year	common	
Palmaceae	***Cocos nucifera* L.	all year	rare	singly
Titliaceae	*Corschorus 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
Gramineae	*P. punctatum* (Burm.) A. Chase	wet season	rare	singly or small patches
,,	*Pennisetum polystachyon* (L.) Schult.	wet season	rare	small patches to large colonies
,,	*Ischaemum rugosum* (Cav.) Merr.	wet season	abundant	small patches
,,	*Cynodon dactylon* (L.) Pers.	all year	rare	small patches

Table 3-5. (Continuation)

Seasonal Occurrences | Abundance | Distribution

Table 3-5. (Continuation)

Family	Species	Seasonal Occurrences	Abundance	Distribution
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	common	singly
Commelinaceae	*Commelina diffusa* Burm.	all year	common	small patches
,,	*C. benghalensia* 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* Schmm. and Thorn.	all year	very rare	singly
Onagraceae (Oenotheracea)	*Ludwigia perennis* L.	all year	common	singly
Verbenaceae	**Lippia nodifolia* (L.) Rich	all year	common	small patches to pure mats
Composite	*Blumea* sp.	dry season	common to very abundant	small patches 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 3-6. Percent volume of the five most utilized food items found in R. r mindanensis *stomachs each month. Calculated as percent of the identified material (Tigner, 1972).*

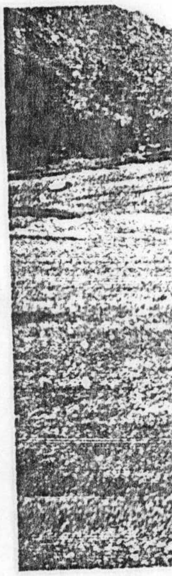
Months	Percent Volume				
	Oryza sativa	Insect	*Digitaria sp.*	*Ipomea aquatica*	*Echinochloa colonum*
June 1970	0	29.2	0.1	17.9	25.1
July	10.7	40.3	0	10.2	10.6
August	4.0	12.9	23.4	15.3	2.6
September	0.9	69.6	5.4	0.1	3.2
October	78.9	9.4	0	0	0
November	72.9	12.5	1.7	0	0
December	78.2	8.0	5.2	0	0
January	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 1971	0	3.6	29.6	39.7	0

Table 3-7. Rice tillers cut by rats (R. r. mindanensis) *caged for 24 hours in growing rice of six different ages under wet and dry season conditions. Six rats were used in each test. (West, et al. 1975)*

Week after Transplanting	Dry Season*		Wet Season*		Overall Mean**
	Range	Mean	Range	Mean	
6	7-226	71	11-252	130	101 cd
8	13-199	44	1-129	40	42 ab
10	21-138	70	32-309	164	117 d
12	32-119	66	30-97	54	60 bc
14	4-46	24	4-37	23	23 ab
16	1-7	3	2-20	9	6 a
	Mean = 46		Mean = 70		

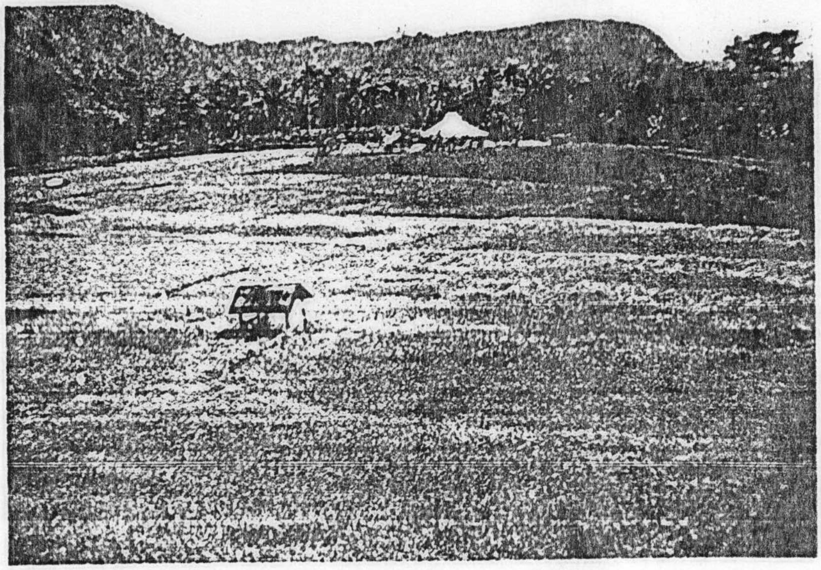
*Data are expressed as tillers cut per rat per night

**Means followed by the same letter are not significantly different by Duncan's new multiple range test at the 0.05 protection level.

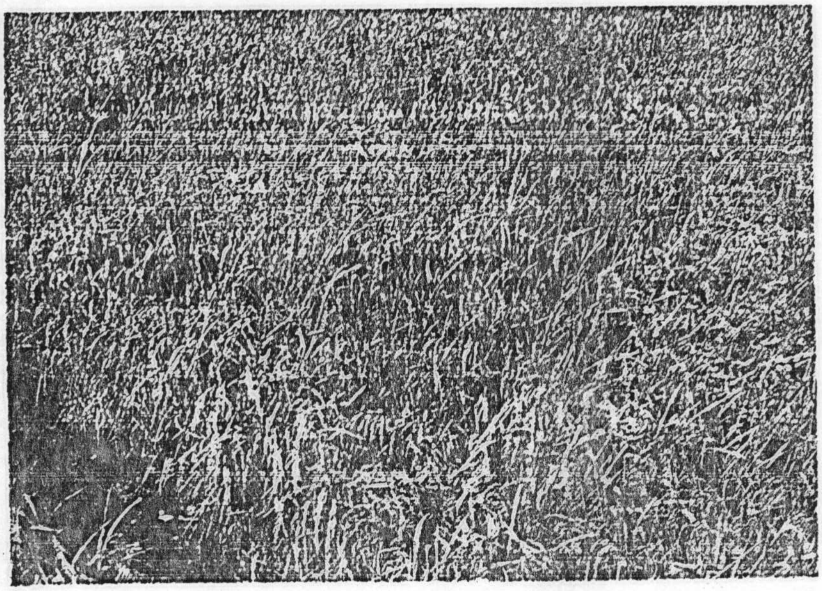


At very high r
the paddies ("

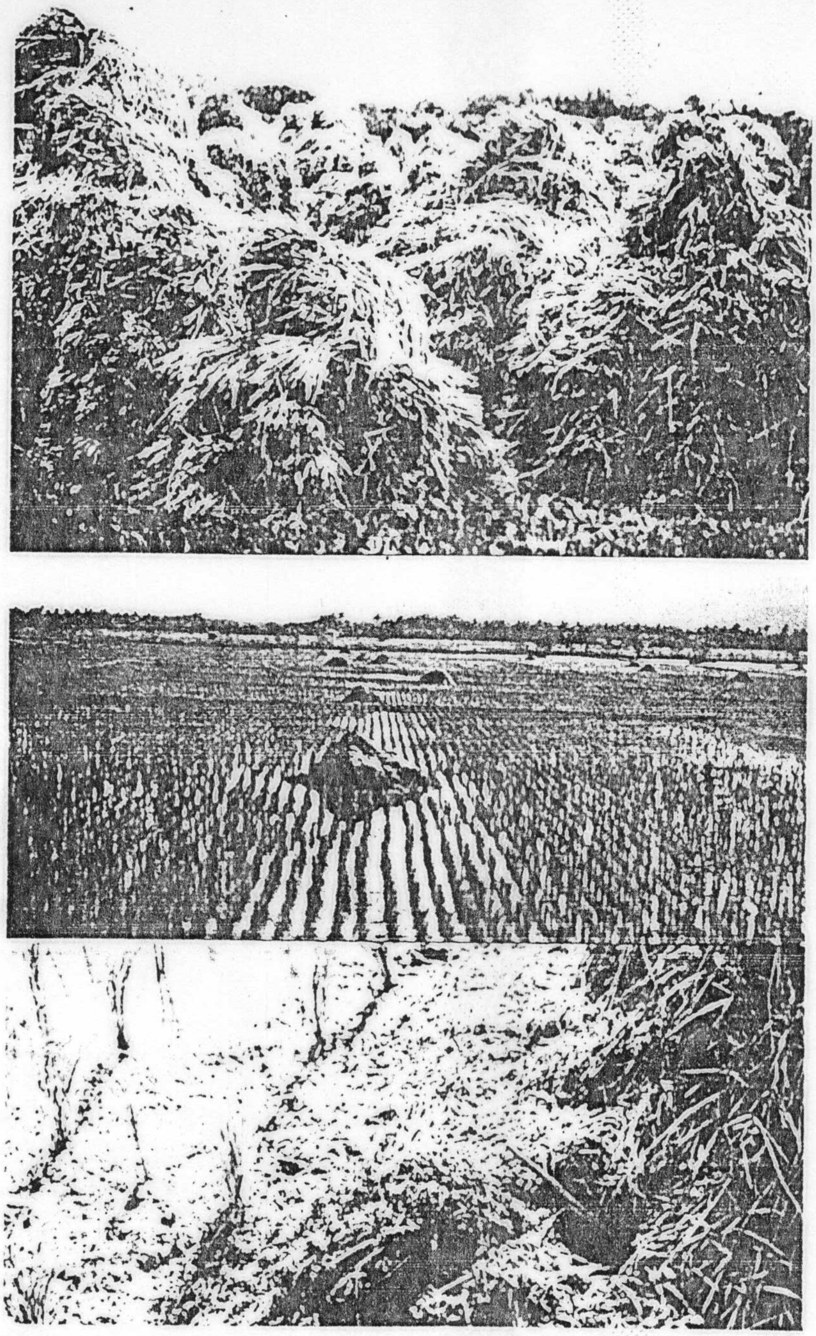
Close up of



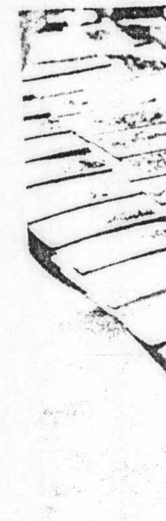
At very high rodent population, damage is concentrated in the middle of the paddies ("eat-out") resulting in uneven growth and maturity.



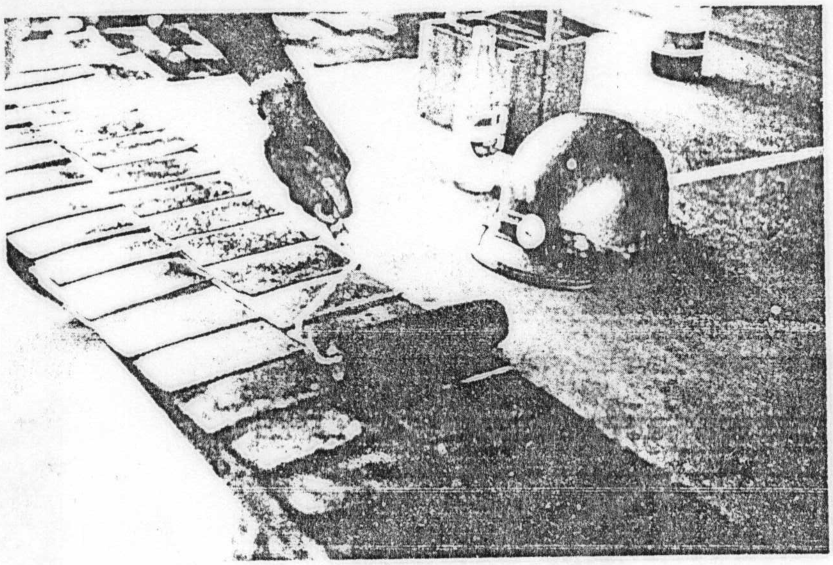
Close up of an eat-out.



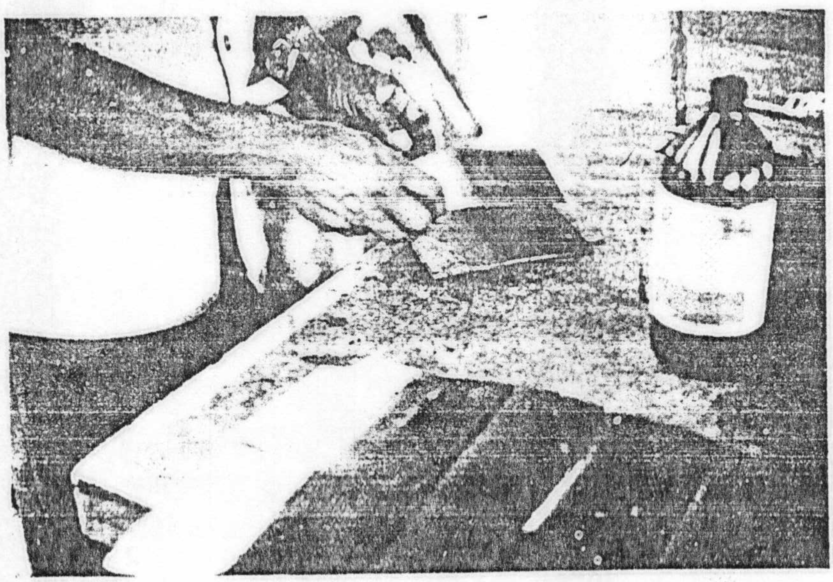
Straw piles at harvest provide cover for rats. Rats can make a good home out of a straw pile left in the field until the next planting season. Note burrow at the base of the pile straw (lowest photo). Studies, however, showed that presence of straw piles do not necessarily mean high rat population and rat damage later in the crop season (NCPC, 1982).



Vinyl tiles
spreading
with aceto



Vinyl tiles can be used as tracking tiles for studying rodent activity. Above: spreading mimeographing ink using ink roller. Below: clearing used tiles with acetone.

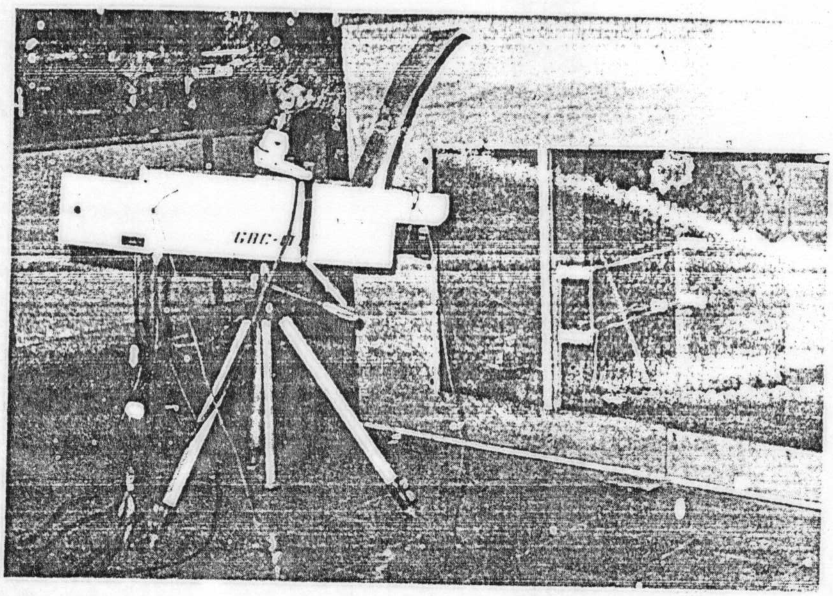


Neophobia

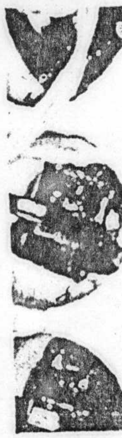
When exposed to new objects (like bait containers and traps) in their surroundings, rats exhibit two opposing tendencies: "exploration" and "fear" (neophobia). Barnett (1975) gave two important features of neophobia: it is temporary and it is always observed when there is a change in an otherwise familiar condition. It is a behavior that protects rats from consequences of curiosity. Thus, "trap-shy" and "bait-shy" (especially to acute poisons) rats are encountered in trapping and baiting programs, respectively. Neophobia can be overcome by habituation or exposure of rats to the new situation as in pre-baiting for 2-3 days with untreated bait before actual poison baiting.

Behavioral and Preference Response of Rodents to Bait Containers

By means of infra red TV camera, rats caged in different types of bait holders were observed to spend most of their time exploring (41.4%) and feeding (29.0%), followed by grooming (12.3%) and drinking (4.0%). They were inactive 11.8% of the time (Table 3-8). Bait consumption from each bait holder was proportional to the time spent in feeding (Table 3-9).

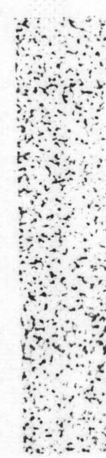


Infra-red lamp fitted closed circuit television camera for studying rat behavior, e.g. rat's response to a sub-lethal electric fence.

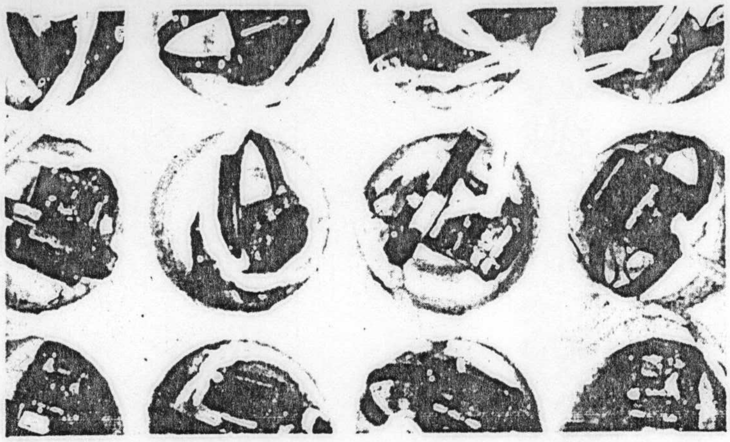


Miniature

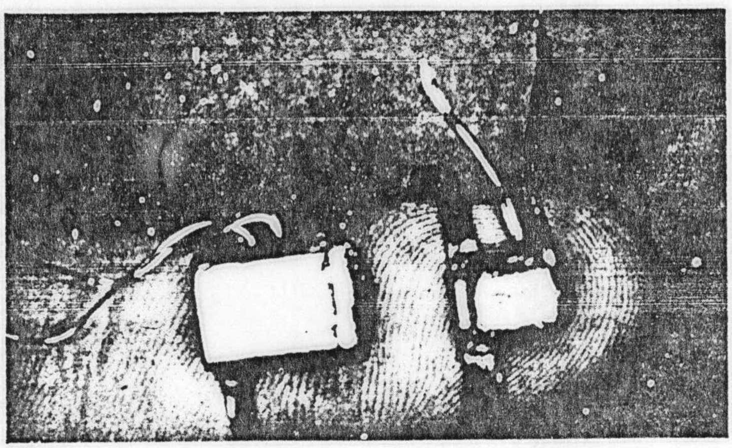
Close up



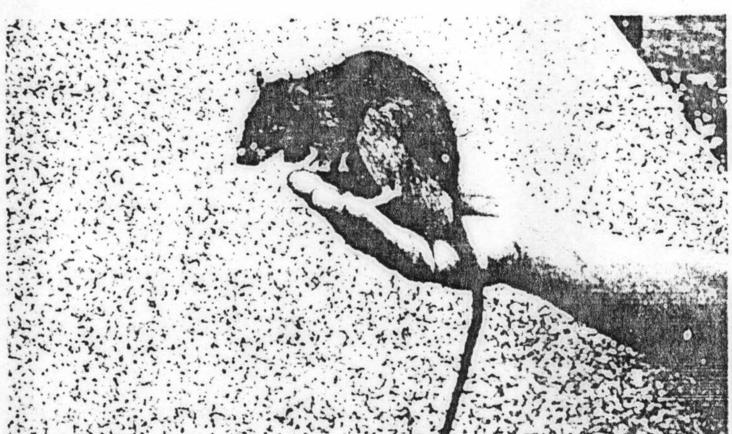
Rat with



Miniature radio transmitter used for studying rat movement.



Close up of transmitter.



Rat with a radio transmitter fitted at the neck.

Table 3-8. Behavioral time budget (seconds) and bait consumption for twelve rats exposed to six different bait containers during six nightly observations (DWRC Annual Report, 1979).

	Platform	Coconut husk	Bamboo tube	Oil can	Nipa hut	Plastic saucer	Total	$\overline{X}$	%
Feeding	2,172	2,031	1,489	1,426	1,154	908	9,180	1,530.0	29.0
Exploratory	1,771	1,804	2,206	2,303	2,736	2,297	13,117	2,186.2	41.4
Grooming	701	597	795	530	596	666	3,885	647.5	12.3
Inactive	383	596	570	523	588	1,089	3,749	624.8	11.8
Drinking	143	194	220	318	151	248	1,274	212.3	4.0
Other	110	58	0	180	55	72	475	79.2	1.5
Grand total	5,280	5,280	5,280	5,280	5,280	5,280	31,680		100.0
Bait consumption (g)	106.5	104.1	99.3	99.1	90.8	70.7	578.5	96.4	

Table 3-9. Bait consumption (g) from three bait containers grouped at three different points in two plots (DWRC Annual Report 1979).

Bait containers	Plot I[a]	Plot II[b]	Total
Plastic "floating" saucer	98	34	132
Bamboo tube	530	33	563
Coconut husk	825	51	876
TOTAL	1,453	118	1,571

[a]Single-growth stage.
[b]Several growth stages.

Given a choice of bait holders, rats prefer feeding on containers with the least confined space (nipa hut, oil can, coconut husk) to containers with more confinement (bamboo tube and plastic "floating" saucers) although the other type is more effective in protecting the bait from exposure to weather elements (Bruggers, 1979). Bait consumption on these containers, however, is reduced in fields with maturing crop.

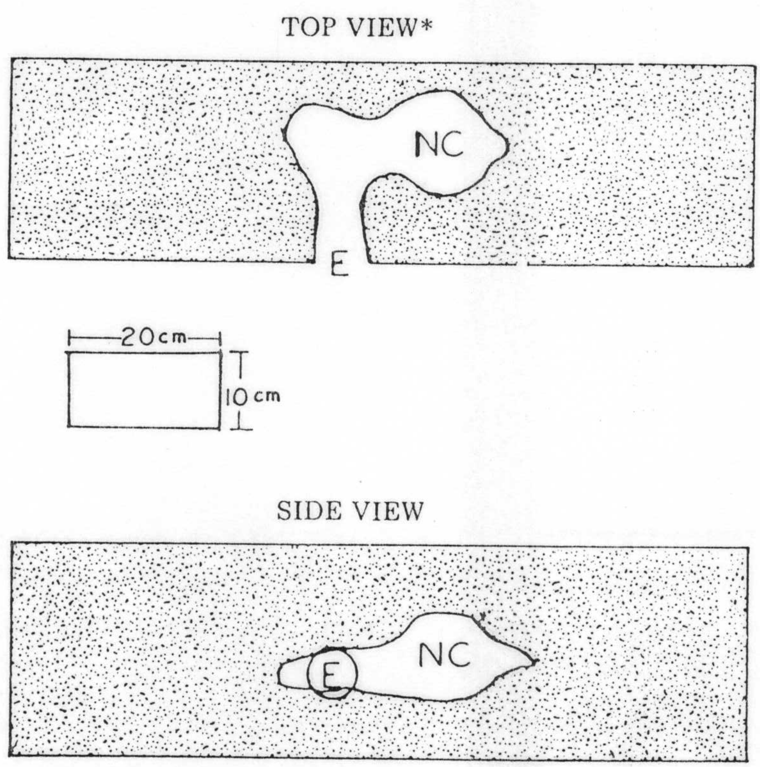
West et al. (1975) hypothesized that "the amount of bait consumed at a bait point may be limited to a great extent by the degree of crouching (mediated through social interactions) than by the number of animals actually present." These interactions and bait consumption can be reduced by having several small containers at a feeding site rather than one large container.

Rats prefer rice shorts (binlid) to most other food materials when offered as a bait base. However, under specific conditions fresh coconut, poultry feed, or other foodstuff is sometimes equally attractive to rats. Hence, pre-baiting with several kinds of bait bases would be useful in determining the most attractive material offered.

Burrow Systems

Burrow systems of ricefield rats can vary from a simple chamber (Fig. 3-1) to a complex system of openings and chambers (Fig. 3-2). Sumangil (1972) described three types of burrows of *Rattus argentiventer*. Old and unplugged (open entrance) burrows are used mainly for cover and contain the least number of rat occupants. New and unplugged burrows are actively used as cover and breeding quarters while new and plugged (closed entrance) burrows are primarily used for breeding purposes. Occurrence of new burrows in dikes is closely correlated to the number of pregnant and lactating rats and large litters.

Sumangil stressed that burrows do exert considerable influence on eruptions of rat populations in the field. A practical control method would be to reduce paddy dike size and thus, the available space for burrowing.



*See Fig. 3-2 for legend.

Fig. 3-1. A simple burrow where a Rattus argentiventer *was seen to enter. Stems and roots of Panicum repens were found on paddy floor in front of the entrance. (0.3 m in length, ricefield, pre-planting) (Sanchez, 1977)*

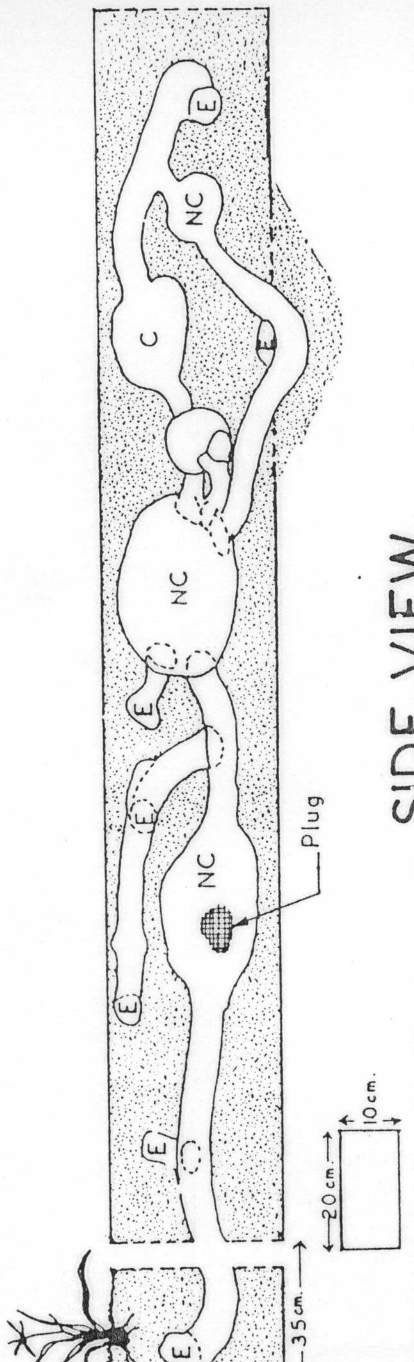


Fig. 3-2. *A complex burrow network where three* R. r. mindanensis *were caught (Sanchez, 1977). (NC = nest chamber, C = chamber, E = entrance or exit)*