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Authors

Nolte, Dale L.
Jacob, Jens
Sudarmaji
et al.

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Demographics and Burrow Use of Rice-Field Rats in Indonesia

Dale L. Nolte

USDA APHIS Wildlife Services, National Wildlife Research Center, Olympia, Washington, U.S.A.

Jens Jacob

Commonwealth Scientific and Industrial Research Organization, Wildlife and Ecology, Canberra, Australia

Sudarmaji, R. Hartono, N. A. Herawati, and A. W. Anggara

Research Institute for Rice, Sukamandi-Subang, West Java, Indonesia

Abstract: Foraging by rice-field rats (*Rattus argentiventer*) can significantly reduce rice harvest. Rat populations are cyclic responding to season and crop maturity. Rat location also reflects the crop cycle. A study conducted near Sukamandi, Indonesia described rice-field rat burrow systems and patterns of use, and assessed demographics of rice-field rats found in burrows adjacent to rice fields. Burrows ranged from simple short tunnels to complex systems. Most simple systems consisted of a straight tunnel approximately 75 cm long. Mean tunnel length of more complex systems was approximately 300 cm, but a few contained tunnels up to 700 cm. Burrow systems had between 1 and 5 entrances, with 0 to 8 choice-points within the system. A choice-point was defined as any place within the system where the animal could choose a different path (e.g., Y in the tunnel, nest). Number of chambers within systems also varied, ranging from none to six. There was no correlation between rat activity within a system, measured by the closed-hole method, and complexity of the system. Long-term monitoring suggested both male and female rats occupied burrow systems along rice banks, except relatively short periods during spring (March, April) and early fall (September) when burrows were used almost exclusively by females. These periods appear to correlate when high numbers of female rats are gestating and lactating.

Key Words: activity, burrows, demographics, Indonesia, rice-field rat, *Rattus argentiventer*

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INTRODUCTION

The rice-field rat occurs throughout most of Southeast Asia (Grist and Lever 1969, Fall 1977, Corbet and Hill 1992). Although economic losses are often difficult to fully assess (Fall 1977, Fall 1980, Buckle 1994), the rice-field rat is regarded as a primary pre-harvest pest to rice production across Southeast Asia (Mochizuki 1975, Fall 1977, Buckle et al. 1985, Geddes 1992, Singleton and Petch 1994). Rice-field rats have been consistently ranked as the number one economically important non-weed pest in Indonesia (Leung et al. 1999). Pre-harvest rat damage to rice in Indonesia is estimated to cause an average 17% annual reduction in harvest (Geddes 1992, Singleton and Petch 1994). The patchy nature of rat damage renders these losses extremely severe for some individual farmers and villages (Singleton and Petch 1994). Damage has caused total crop loss to parts of some provinces (Leung et al. 1999)

Rice-field rats evolved in lowland grasslands and easily adapted to rice field ecosystems (Leung et al. 1999), where its reproductive cycle is seasonal (Harrison 1951, 1955). Their reproductive cycle is correlated with rice phenology and is probably triggered by increasing nutritional qualities as the rice matures (Lam 1983, Tristiani et al. 1998). Rats are commonly found on earthen banks separating paddies and burrows dug into these banks are their primary source of shelter (Leung et al. 1999). Van der Laan (1981) described the rice-field rats' burrow system as a combination of shallow tunnels

with two entrances, a nest site, and a blind-ending gallery for an emergency exit. Generally, rats construct burrows in larger banks (>30 cm) when fields are flooded. Burrows appear along small banks and in the substrate of paddy fields after the fields are drained and not waterlogged (Leung et al. 1999). Rats also construct nests beneath straw remaining in fields after harvest (Leung et al. 1999).

This study was conducted to further describe burrow systems of the rice-field rat and to assess daily and long-term use patterns of burrows by rats.

METHODS

The study to describe burrows and assess daily use was conducted at the Research Institute for Rice, Sukamandi, West Java, Indonesia (6°20'S, 107°39'E) between 2 and 26 July, 2001. Rice was at the milky reproductive stage when the study started and the study was halted with the onset of harvest. Fields were not flooded after the first few days of the study. A section of banks (120 m) on either side of a water channel running through rice fields, without recent fumigation or other rodent control measures, was identified as typical habitat to monitor burrow activity and for subsequent burrow system excavation. Width of the smaller banks varied from 55 to 160 cm and was 32 to 45 cm high, while the larger bank was approximately 2 m wide and 95 cm high. The water channel was 90 to 100 cm wide, with intermittent water flow between 20 and 30 cm deep.

Long-term burrow occupancy data was collected from burrows located along rice fields near Cilamaya, Indonesia, approximately 60 km west of Sukamandi. In West Java, the dry season is from May to October and the wet season is from November to April; 75% of precipitation occurs during the wet season. In general, two crops of rice are grown each year in the irrigated lowland rice agro-ecosystem (Singleton et al. 1998, Brown et al. 2001).

Multi-live-capture traps were placed at intervals along a plastic drift fence encircling the 120-m section of banks selected for the study. Every other trap was placed inside the fence to capture rats returning to banks from the field; remaining traps were placed outside the fence to capture rats exiting burrows along banks. Initially, the drift fence was placed a short distance (<50 cm) in the rice field, but later moved between rice crop and bank. Captured rats were taken to the laboratory (<1 km), anesthetized with ketamine, body and tail length measured, weighed, inserted with a microchip, and fitted with a radio-collar. Rats were held until the next morning and released where they were originally captured.

All burrow entrances in banks within the study area (120 m) were identified, marked with flagging, and covered with mud the afternoon of June 29, 2001. Marked entrances then were checked, morning and afternoon, until the morning of July 25, and recorded active if the mud cover had been removed. Thus, there were 49 opportunities for an entrance to be regarded as active. Automatic microchip readers also were installed in burrows to monitor activity. Initially, two readers were placed approximately 5 cm apart inside entrances to enable temporal differences to indicate direction of movement. Apparent rat avoidance of readers suggested need for an alternative approach. Subsequently, the readers were threaded through holes drilled from the surface to top of entrances. Eventually an attempt to automatically monitor rat movements was halted, because rats avoided burrows with readers and because of general malfunction of automatic readers. Radio telemetry was used to monitor captured rat locations once a day until study completion.

Burrow systems were fumigated and excavation began immediately after the last activity reading. Sulfur dioxide gas was produced by burning sulfur granules with straw. Air forced over the smoldering straw was blown into burrow entrances by a fumigator. The fumigator was a tube for straw with a hand-cranked fan at one end. Burrow entrances marked to monitor activity were used to begin excavations. As burrow systems were uncovered, burrow lengths were taken and burrows along with entrances, dead-ends, choice-points, and chambers were depicted on a map. Choice-points were defined as any point within the system where rats were offered a choice (i.e., a "Y" in the tunnel or to enter a chamber).

Activity scores and complexity scores were calculated for each burrow system. Activity scores were simple counts of each time a rat uncovered an entrance to

a system. Several entrances monitored for activity were connected to the same system. Therefore, data for these entrances was compared and if any entrance was open the system was counted active, but the score did not increase if multiple entrances within a single system were open. Thus, 49 was the highest activity score possible for a burrow system. Complexity scores were calculated by adding a system's length score, entrance score, dead-end score, choice-point score, and chamber score. Length scores reflected total lengths of all burrows contained within a system, increasing numerical scores were given to categories with increasing lengths: 1 for burrows with measurements totaling 1 to 75 cm, 2 for burrows with measurements between 76 and 150 cm, 3 for measurements between 151 and 300 cm, 4 for measurements between 301 and 450 cm, and 5 for measurements totaling more than 451 cm. Entrance, dead-end, choice-point, and chamber scores were a simple count of the number each occurred within a system. Thus, a 3 was the lowest possible score because there must be at least one entrance, a tunnel, and then another entrance, a choice-point, or a dead-end also must occur. Regression analysis was used to determine whether amount of rat activity recorded for a system was correlated to the complexity of the system.

Long-term burrow use was assessed through data collected for another study being conducted by scientists of the Research Institute for Rice. Briefly, once during each of the previous 27 months they had fumigated select burrows located along rice fields near Cilamaya, excavated these burrows and identified occupants, rat gender, weight, and reproductive status were recorded along with the predominant crop stage when burrows were fumigated. These data were used to assess relationships between burrow use and crop stage. The number of burrows fumigated was not consistent among months. Therefore, rat occupancy was converted to a percentage of burrows excavated rather than an actual count. Percentage of burrows occupied by multiple adult rats, and male and female adult rats were then plotted against crop-stage. Similarly, percentage of burrows occupied by open females (non-gestating or lactating), gestating females, and litters of pups were plotted against crop-stage. Rats less than 45 g were regarded as pups, and pups found in the same burrow with similar weights (+ 2g) were considered litter-mates. Multiple litters were found within a single burrow. Therefore, percentage of burrows with litters sometimes exceeded one hundred.

RESULTS

Fifty-two burrow systems were excavated and mapped (Figure 1). Systems tended to consist of a single short tunnel (<75 cm) or were composed of multiple tunnels; most ranged in length from 151 to 450 cm (Figure 2). Length of 2 systems qualified for category 2 (76 - 150 cm) and 4 for category 5 (>451 cm); longest combined tunnel length for a single system was 685 cm. Only 1 entrance was found for half the systems, the

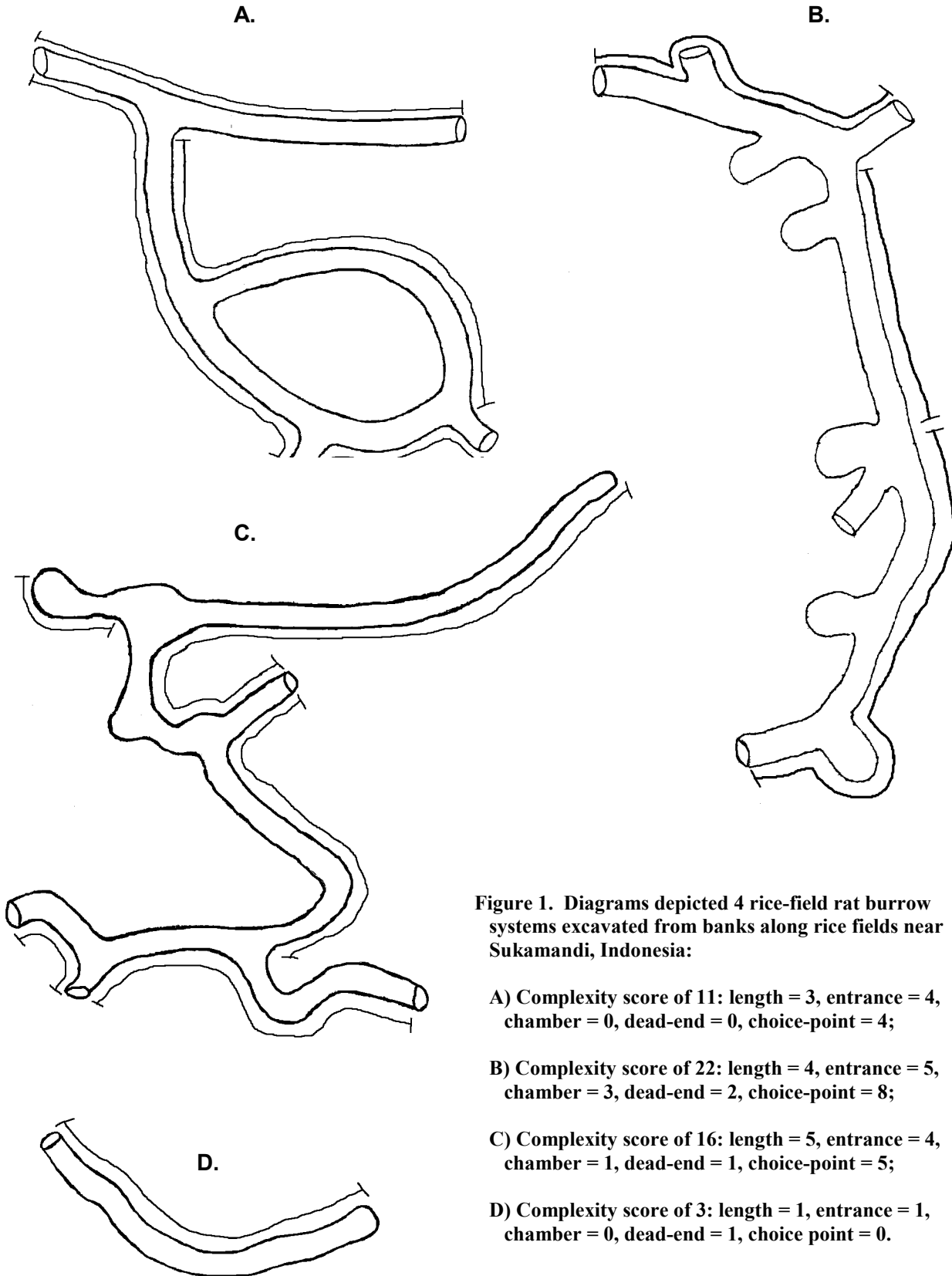


Figure 1. Diagrams depicted 4 rice-field rat burrow systems excavated from banks along rice fields near Sukamandi, Indonesia:

- A) Complexity score of 11: length = 3, entrance = 4, chamber = 0, dead-end = 0, choice-point = 4;**
- B) Complexity score of 22: length = 4, entrance = 5, chamber = 3, dead-end = 2, choice-point = 8;**
- C) Complexity score of 16: length = 5, entrance = 4, chamber = 1, dead-end = 1, choice-point = 5;**
- D) Complexity score of 3: length = 1, entrance = 1, chamber = 0, dead-end = 1, choice point = 0.**

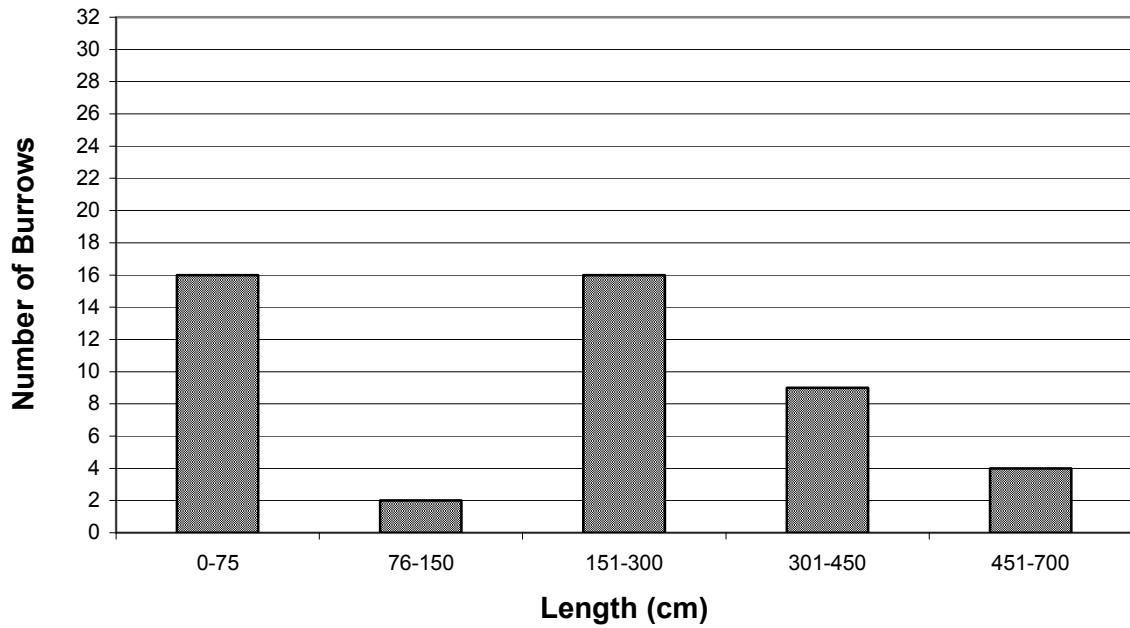


Figure 2. Number of rice-field rat burrow systems containing tunnels with total lengths that fit into one of five categories.

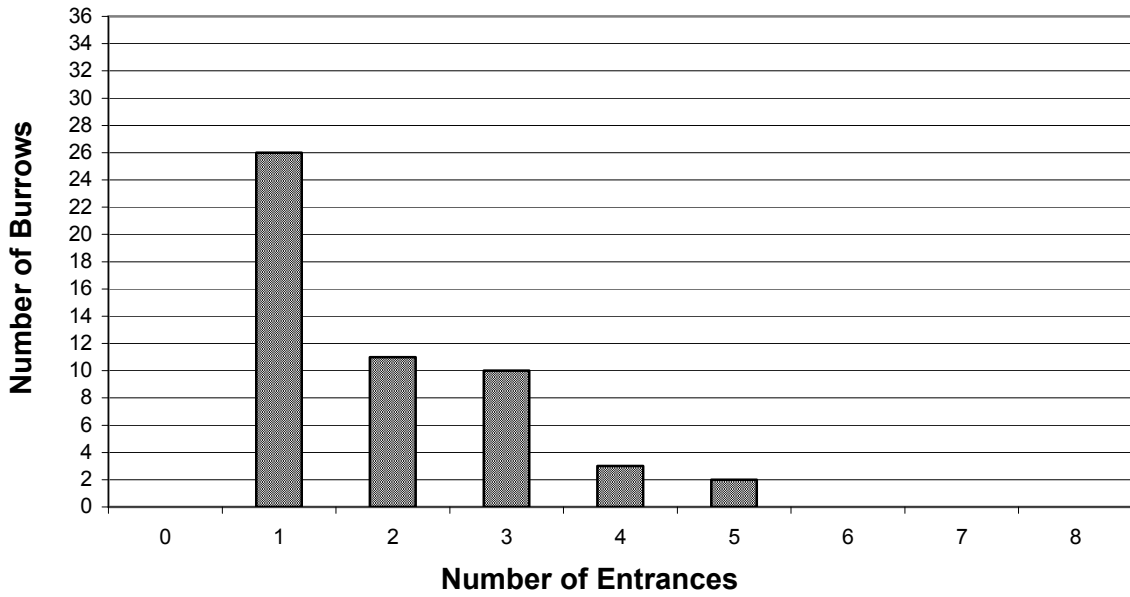


Figure 3. Number of rice-field rat burrow systems with 1, 2, 3, 4, or 5 entrances.

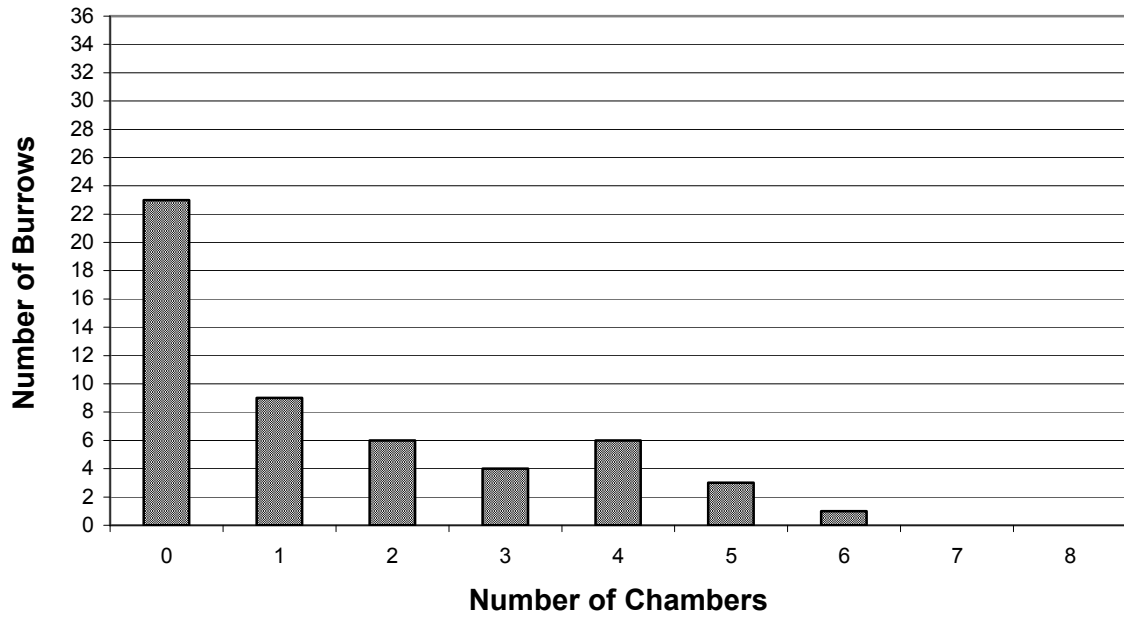


Figure 4. Number of rice-field rat burrow systems with 0, 1, 2, 3, 4, 5, or 6 chambers.

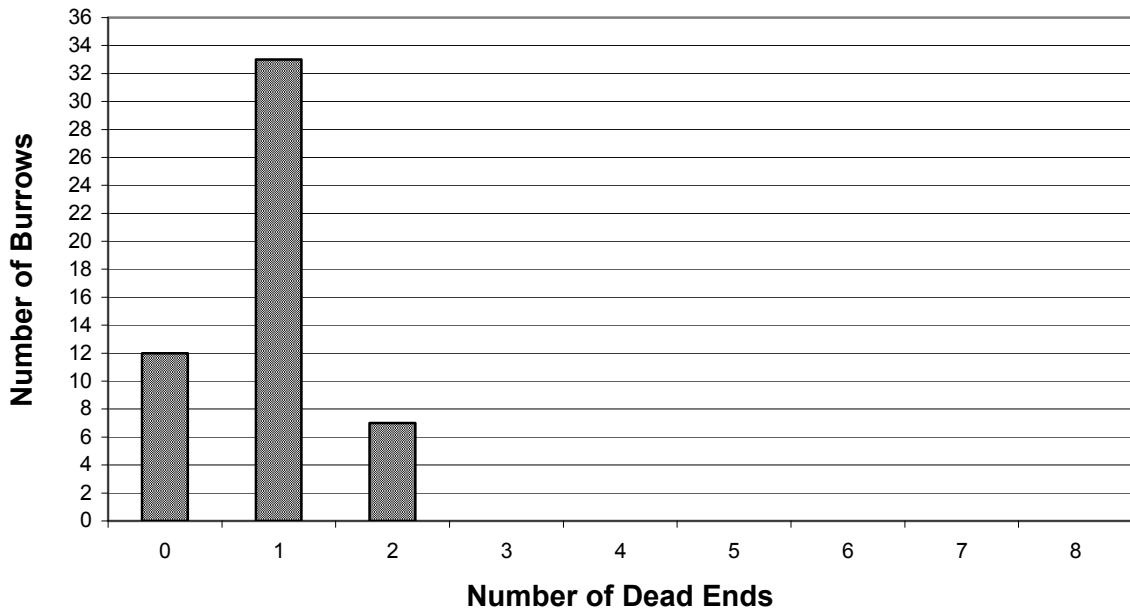


Figure 5. Number of rice-field rat burrow systems with 0, 1 or 2 dead-end tunnels.

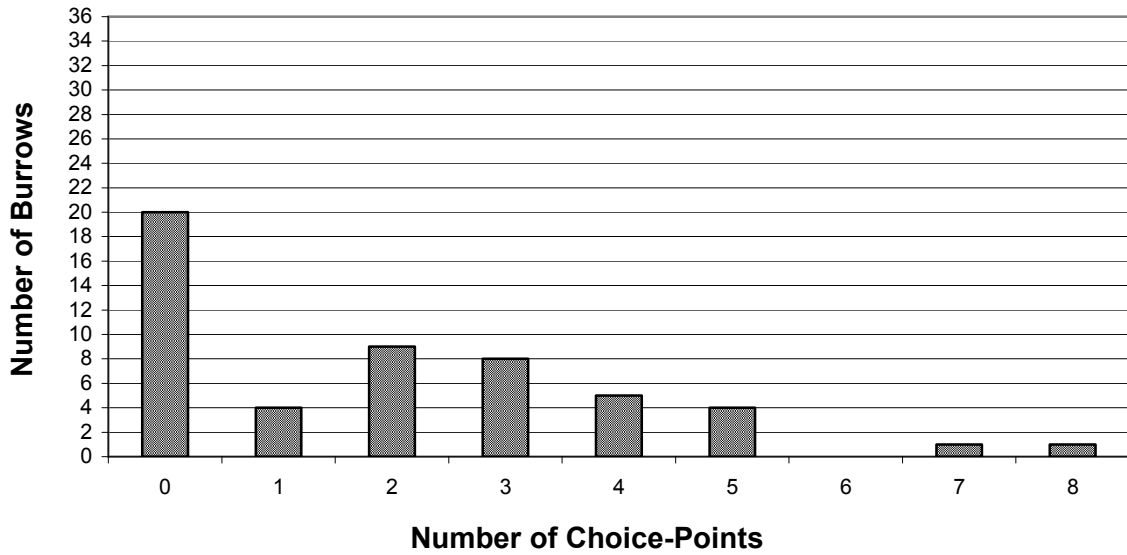


Figure 6. Number of rice-field rat burrow systems with 0 through 8 choice-points. Choice-points were defined as any point within the system where rats were offered a choice (i.e., a Y in the tunnel or enter a chamber).

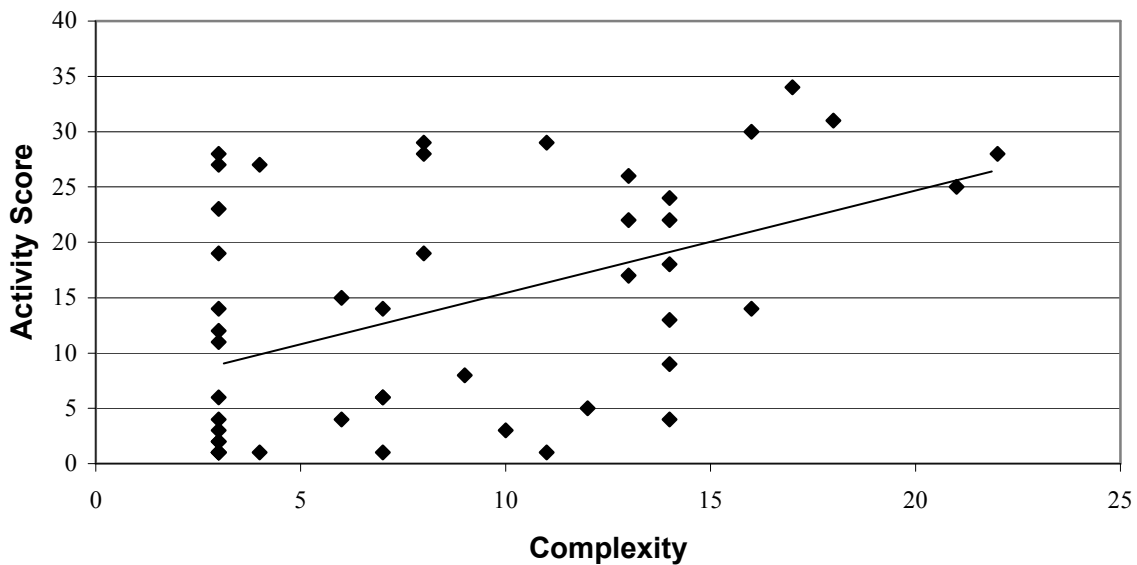


Figure 7. Activity scores of rice-field rat activity for burrow systems on the study site near Sukamandi, Indonesia plotted against complexity scores rated for each burrow.

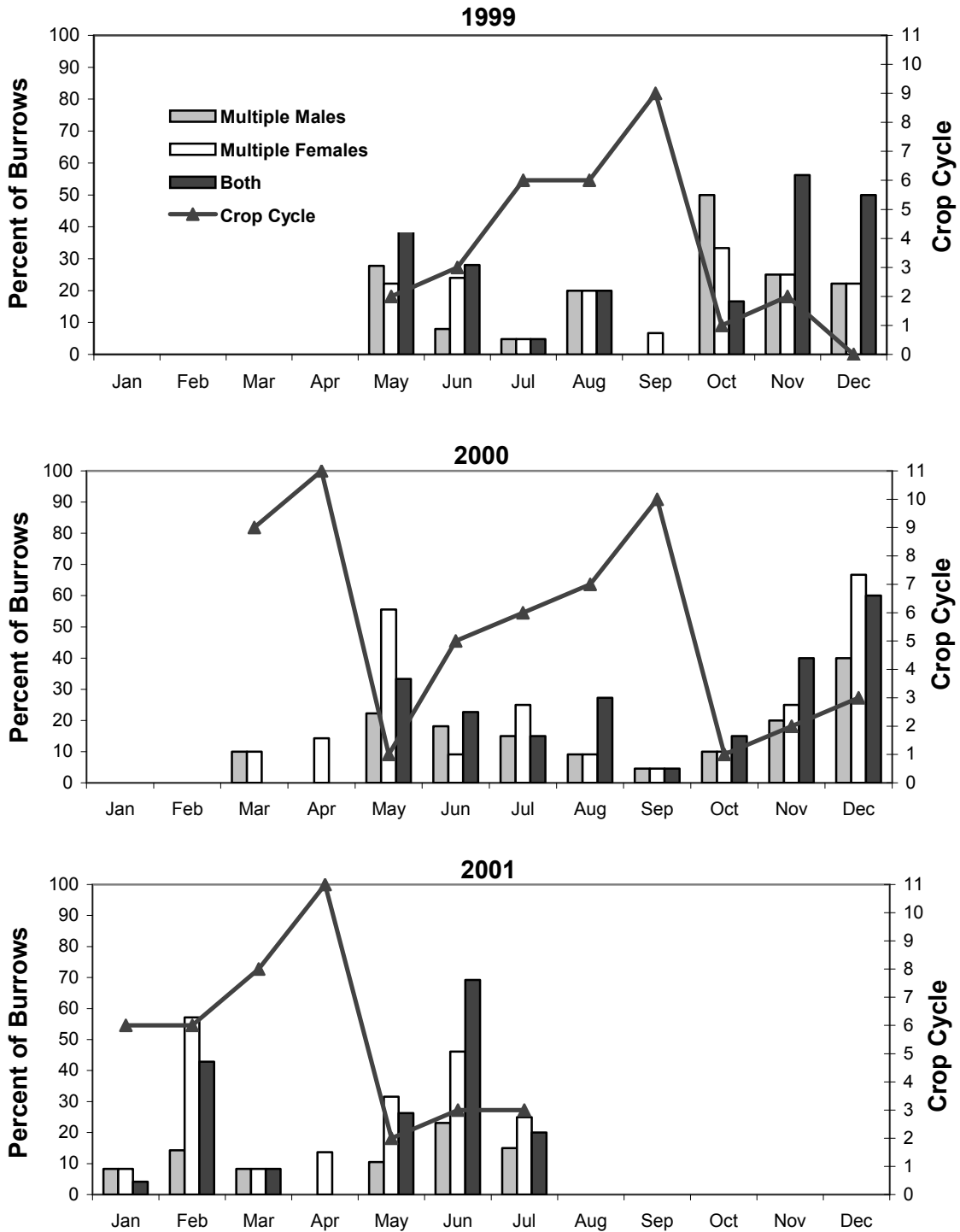


Figure 8. Percentage of burrows (left axis) fumigated at monthly intervals from May 1999 through July 2001 near Cilamaya, Indonesia with multiple males, multiple females or both multiple males and females. Predominate crop cycles (right axis) reported at the time burrows were fumigated: fallow = 1, fallow weeds = 2, ploughed = 3, seedlings = 4, transplant = 5, tillering = 6, booting = 7, flowering = 8, milky = 9, ripening = 10, harvest = 11.

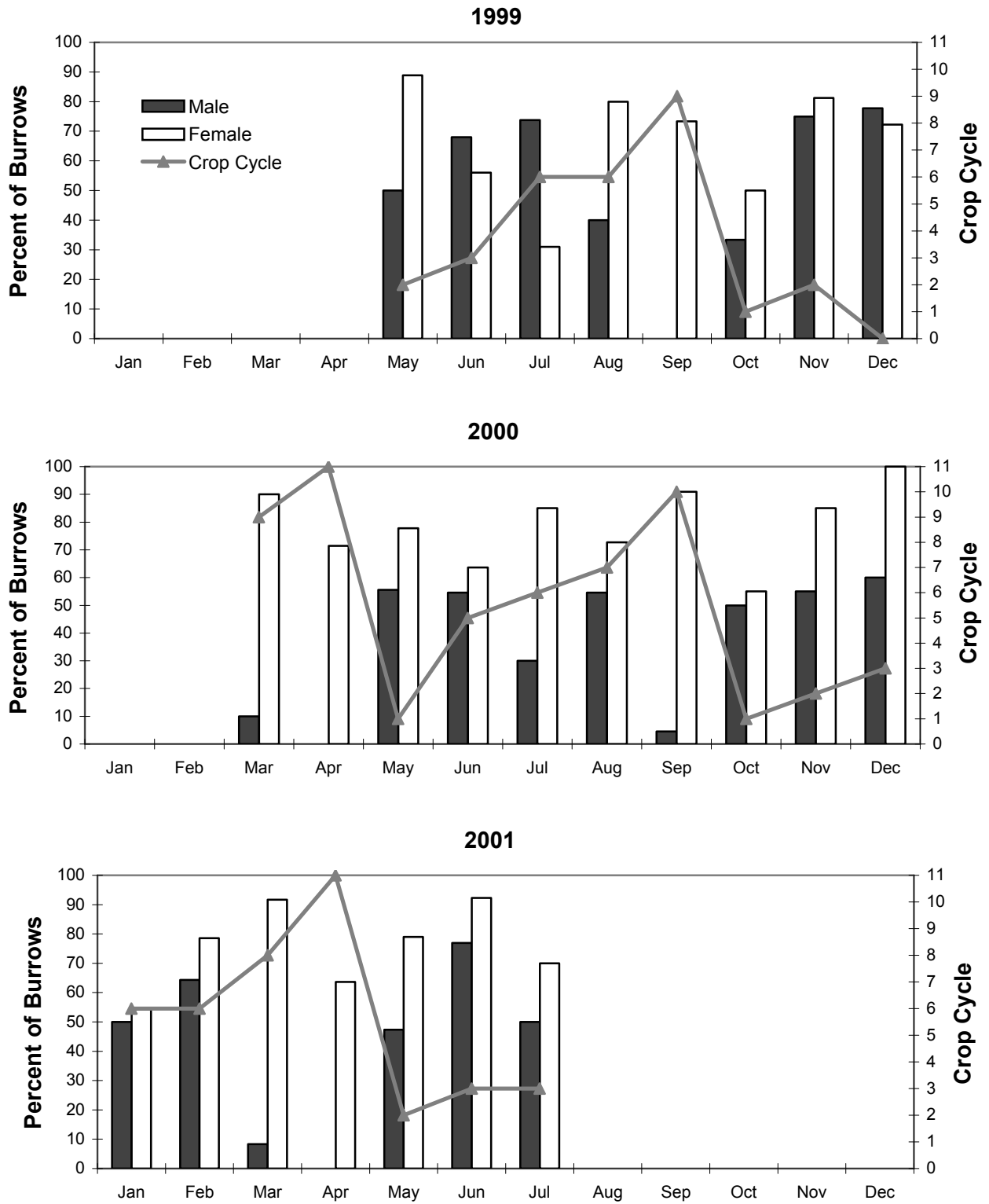


Figure 9. Percentage of burrows (left axis) fumigated at monthly intervals from May 1999 through July 2001 near Cilamaya, Indonesia with males or females. Predominate crop cycles (right axis) reported at the time burrows were fumigated: fallow = 1, fallow weeds = 2, ploughed = 3, seedlings = 4, transplant = 5, tillering = 6, booting = 7, flowering = 8, milky = 9, ripening = 10, harvest = 11.

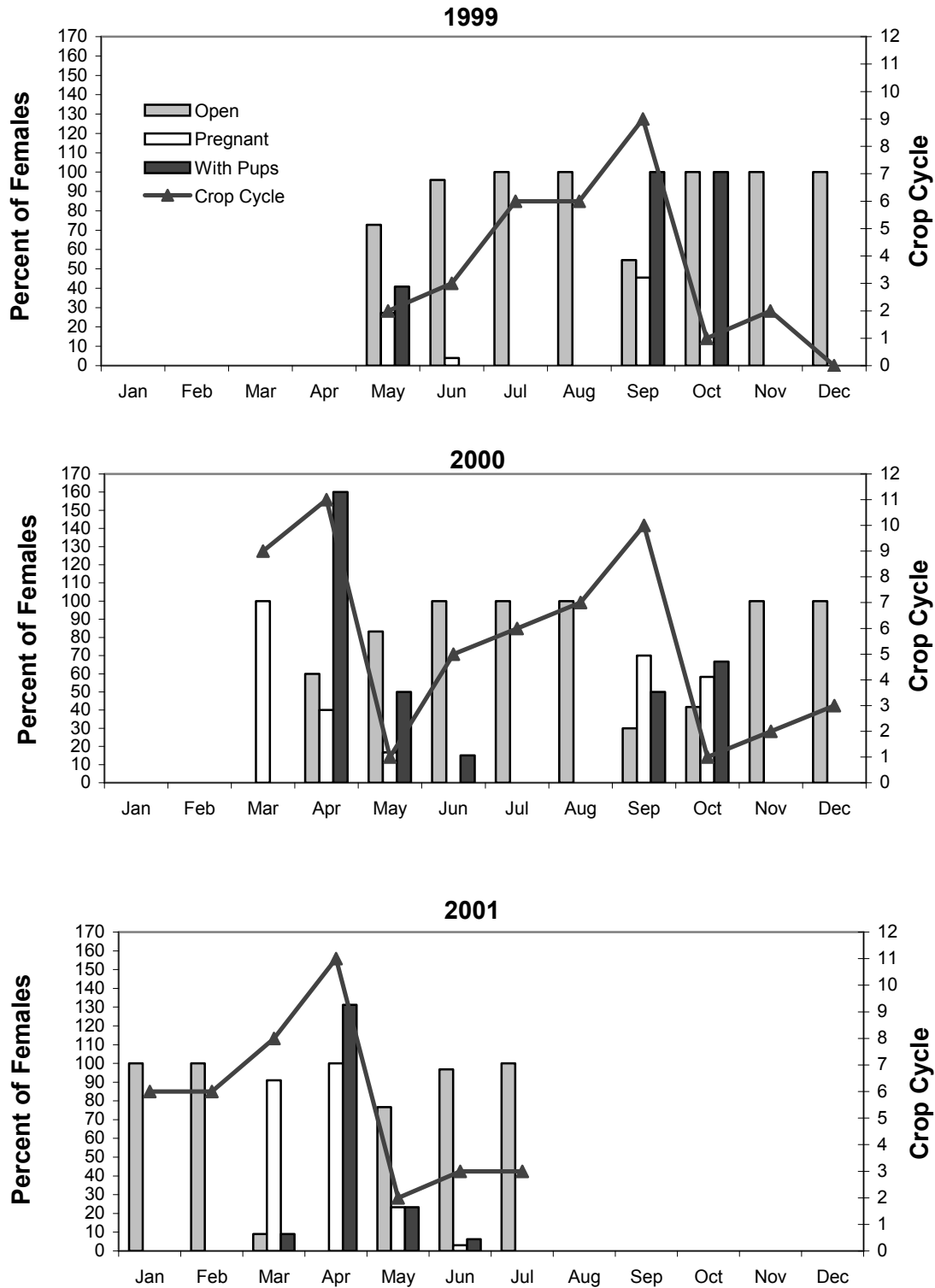


Figure 10. Percentage of burrows (left axis) fumigated at monthly intervals from May 1999 through July 2001 near Cilamaya, Indonesia with open females (non lactating and non gestating), gestating females, or containing litters of rat pups. Predominate crop cycles (right axis) reported at the time burrows were fumigated: fallow = 1, fallow weeds = 2, ploughed = 3, seedlings = 4, transplant = 5, tillering = 6, booting = 7, flowering = 8, milky = 9, ripening = 10, harvest = 11.

majority contained no more than 3, and 5 entrances were the most located for an individual system (Figure 3). Chamber numbers varied among systems (Figure 4). None of the short tunnels (16) were associated with chambers, but the length and number of entrances associated with the other 6 systems without chambers were not consistent. The system with 6 chambers had 2 entrances and 435 cm of tunnels, while the three 5-chamber systems contained 5, 2, and 2 entrances combined with 325, 365, and 189 cm of tunnels, respectively. A majority of systems (40) contained at least one dead end, but 12 systems had tunnels with entrances on either end, or circled around joining another tunnel (Figure 5). The number of choice-points within a system ranged from 0 to 8 (Figure 6).

Activity scores ranged from 1 to 34 with a mean score of 14.2, and complexity scores ranged from 3 to 22 with a mean score of 8.6. Activity scores and burrow complexity scores were not correlated ($R^2 = 0.22$; Figure 7). Some burrows with a complexity score of 3 rated among the most active systems. Conversely, some complex systems had only sporadic activity.

Crop cycle timing was similar for both years. Harvest occurred in April and then again in September during 2000 and 2001. Although multiple rats were found in burrows throughout the year, frequency tended to increase post harvest (Figure 8). Female rats were found in burrows all year, but the proportion of male rats began to decline pre harvest and remained low until after harvest (Figure 9). Virtually no males were found in burrows at harvest. Reproductive status also fluctuated with the crop cycle (Figure 10). A few burrows contained pups in March, but pups were most prevalent during April. Approximately a third of the burrows contained litters during May and less than 10% contained litters during June. A high percentage of burrows also contained pups again during September and October after the second harvest.

DISCUSSION

Capturing rice-field rats was difficult, particularly in dry fields. The only feasible approach to capture rice-field rats was setting multiple live traps along a plastic drift fence as described by Leung and Sudarmaji (1999). Our initial attempts placed the fence inside the rice field with plants leaning against the plastic. Apparently rats used these plants to climb over the fence, negating the traps. Unfortunately, by the time we placed the fence in channels adjacent to the field, water within the channels was sporadic. This lack of water enabled rats to dig beneath the plastic, again avoiding traps. Leung and Sudarmaji (1999) also reported reduced capture rates for cage traps when the associated fence suffered damage and was not repaired. A couple rats were captured when hollow bamboo tubes were extended from the trap entrance to the opening of an established trail beneath the plastic fence. However, rats appeared to be very neophobic, avoiding anything unknown. Whenever data-

logger readers were placed inside a burrow, rats would plug the entrance, often creating another entrance only a few centimeters distant from the original. Rats also detected readers buried beneath burrow entrances or hid in holes drilled from the surface.

A few burrows were similar to those described by Van der Laan (1981): a combination of shallow tunnels with two entrances, a nest site, and a blind-ending gallery for an emergency exit. However, burrow systems varied greatly and failed to fit within any single description. Sixteen (32%) were short (<75 cm) tunnels with a single entrance that merely ended. More complex system generally consisted of 150 to 450 cm of tunnels that did not necessarily intersect, 1 to 3 entrances, anywhere from zero to 6 chambers, and at least one dead-end or blind tunnel. Some tunnels ended several cm beneath the surface, but blind tunnels ending near the surface were common. Rats reportedly create these shallow blind tunnels as escape routes that can be quickly pushed through in an emergency, such as avoiding a predator (Van der Laan 1981).

Rats displayed nocturnal tendencies but also were active during the day. Brown et al. (2001) found rat activity patterns changed as the rice crop matured. When rice was at the early to late tillering stage, 84% of day locations were in banks; but as the crop matured and reached an early reproductive stage, the majority of day fixes (59%) were located in rice paddies. When this study started, the rice was already past tillering and fields were not constantly flooded. Rat activity within burrows did not correlate with complexity of the burrow system. Whether activity would be better correlated at other times of the year or during different crop cycles is unknown. The long-term occupancy data suggests that multiple rat occupancy of burrows was probably low during the study. However, limited use probably did not merely reflect population density since rats did frequently use some of the simple burrows while not using the larger systems. It was possible that dispersing males were occupying at least some of the simple burrows. The long-term data indicates males vacate burrows along banks as the crop matures. Perhaps males create these simple burrows along banks before dispersing to burrows located in smaller banks (<30 cm) or in fields, as water disappears. One male in this study, initially caught along the larger banks and fitted with a transmitter, established a simple burrow along a small bank, then dug a burrow in the rice field. Another male dispersed to a simple burrow in a small bank, remaining there until the study was halted. Unfortunately, the small sample size makes it difficult to fully assess rat preferences for burrow locations.

Burrow occupancy by rats was consistent across years and appeared to be related to crop cycles. Percentage of burrows occupied by multiple adult rats tended to increase post harvest. This increase in adult rats after harvest most likely reflected the increased number of offspring born immediately pre and post harvest. Reproductive status of female rats appeared to be

correlated with crop cycles. This correlation compares favorably with other studies reporting that breeding season is correlated with rice phenology and most likely triggered by improving available nutritional quality as the rice matures (Lam 1983, Tristiani et al. 1998). Studies conducted by Leung and Sudarmaji (1999) determined that rats first mated just prior to the maximum tillering stage, with the first litter born during booting. Then with post-partum breeding, another litter is born during the ripening stage, and a third litter is born immediately post harvest. The long-term data suggest a few litters were born during maximum tillering, but most were probably born during the ripening stage and post harvest. Burrows appeared to be the sole domains of females during the period when pups were commonly found. Females may be forcing males away to protect their young, or the dry fields permitted males to occupy space more accessible to food, while females were tied to burrows in banks because their offspring were too young to move. Offspring are born and reared almost exclusively in burrows dug into larger banks (Leung and Sudarmaji 1999).

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