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Pre- and post-harvest movements of female rice-field rats in West Javanese rice fields

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Abstract. This study examined changes in the spatial behaviour of rice-field rats (*Rattus argentiventer*) associated with the harvest of lowland irrigated rice. Radio-collared female rice-field rats were tracked before and after harvest in rice fields in West Java, Indonesia. The rice-field rats clearly reacted to the changes in habitat structure caused by the harvest by relocating their home ranges on average 300–400 m to piles of rice straw left on the fields and to unharvested areas. Post-harvest, there was a decrease in home-range size of 67% (0.6 ha pre-harvest; 0.2 ha post-harvest) and a decrease in range span of 35% (139 m pre-harvest; 90 m post-harvest), which may indicate an immediate response to predation risk. Most rats remained in the rice fields for 2–3 weeks post-harvest. This contrasts to their pre-harvest preference for refuge habitats near the margins of crops.

Introduction

Small mammals are a common feature of agricultural landscapes but for many rodent species very little is known about the impact of farming practices on spatial behaviour. Exceptions include wood mice, *Apodemus sylvaticus*, which relocate to adjacent refuges from areas disturbed by harvest (Tew and Macdonald 1993) and common voles, *Microtus arvalis*, which considerably reduce spatial activity after the harvest of grain (Jacob and Hempel 2002).

Home-range size of small mammals can vary due to intrinsic factors including breeding activity (McShea 1989; Krebs et al. 1995) and population density (Erlinge et al. 1990), as well as extrinsic factors including food availability (Ostfeld 1986) and vegetation height (Tew and McDonald 1993; Jacob and Hempel 2002). The removal of vegetation by mowing of verges and grazing stubble is often used as a management tool to minimise food and shelter. This can also expose pest rodents to predators thereby reducing pest rodent density (White et al. 1998). However, exposed prey may adapt behaviourally and decrease spatial activity as a counter-strategy to minimise predation risk.

Rice-field rats (*Rattus argentiventer* Robinson and Kloss 1916) are the most important pre-harvest pests in lowland flood-irrigated rice systems of Java, Indonesia (Singleton and Petch 1994). They and other species including black rats (*R. rattus*) and Norway rats (*R. norvegicus*) also invade facilities for processing and storing rice.

We used radio-telemetry to estimate the home-range size of female rice-field rats from about 3 weeks before harvest until about 3 weeks after harvest in lowland rice fields of West Java, Indonesia. We hypothesised that there would be (1) a decrease in spatial activity post-harvest leading to smaller home-range size and smaller range span and (2) a change in habitat use due to preference by the rats for refuge areas post-harvest.

Material and methods

The study was conducted between Sengon and Sukamandi (06°20'14"S, 07°39'24"E) Subang district, West Java, Indonesia. The climate in the region is tropical with small variations in annual average temperature (28°C). About 75% of the annual rainfall (1450 mm) occurs during the wet season (November–April) but rain is also frequent during the dry season (May–October).

The West Javanese agro-ecosystem is characterised by lowland irrigated rice fields, which are partitioned by many dikes, dams and irrigation channels. Individual farmers typically manage 1–2 ha of rice. Usually, one rice crop is grown in each of the seasons. Rice is sown in nurseries and after 2–3 weeks transplanted by hand into the fields. The main crop stages are tillering (55 days after sowing), booting (75 days) and ripening (95 days). Rice is harvested by hand about 120 days after sowing. Rice-field rats usually breed from about 2 weeks before maximum tillering until a few weeks after harvest (Leung et al. 1999).

We used a contiguous rice-growing area of about 400 ha for the study. Harvesting (rice variety 'Ciherang') was conducted from 25 July to 31 July 2001. Rice-field rats (*n* = 14) were trapped with multiple-capture wire-cage live-traps set along a drift fence in early June and fitted with 4.8 g single-stage radio transmitters (Sirtrack, New Zealand). For this study, we tracked the rats from 10 July (generative stage of rice crop) until harvest. Four of these rats were also followed for about three weeks post-harvest. Seven additional rats trapped and radio-collared in mid-July were tracked until the end of August. Radio locations (fixes) were obtained once a day and twice a night. Incremental area analysis (Kenward and Hodder 1996) revealed that 20 locations were sufficient to determine 80% of the 95% minimum convex polygon (MCP) home ranges of the rats. Therefore, only rats with ≥20 radio locations pre- or post-harvest were included in the analyses of home-range size and range span (pre-harvest, only n = 10; post-harvest, only n = 3; pre- and post-harvest n = 4). For seven individuals radio-tracked before and after harvest we calculated centres of activity using the recalculated arithmetic mean (Kenward and Hodder 1996) to detect shifts in the position of home ranges during harvest.

Rats were radio-tracked in five plots of about 2–23 ha within the study area. The distance between plots was at least 400 m. For each of the plots, habitat was classified as rice field, refuge (channel banks, gardens, roadsides) and village. Vegetation height of the ripe rice plants was about 0.9 m and the height of the stubble after harvesting was about 0.25 m.

We compared ln-transformed data of 95% MCP home ranges and range spans of rats pre- and post-harvest using general linear regression. We calculated the Jacobs' index (Jacobs 1974) as a measure of habitat use relative to habitat availability for all rats that were located in >1 habitat. The index results in values between 1 (complete preference) and –1 (complete aversion). The proportion of the rat population that did not move outside rice fields was compared pre- and post-harvest with generalised linear regression for binomially-distributed data (radio locations in rice field only yes/no) using a regression model including time (pre- and post-harvest) and plot. Range measurements were calculated in Ranges V (Kenward and Hodder 1996).

Results and discussion

Home range and range span

A total of 672 radio-locations were used for analyses. Home ranges pre-harvest of 0.59 ha (se = 0.12 ha) were about 67% larger than home ranges post-harvest (F = 20.99, df = 1,18, p < 0.001) (Figure 1a). Similarly, range spans pre-harvest of 139 m (se = 13 m) were about 35% larger than post-harvest range spans (F = 9.75, df = 1,18, p = 0.006) (Figure 1b). This was in agreement with hypothesis 1. Pre-harvest home ranges were similar to the home ranges of rice-field rats during the vegetative stage of the rice crop (Brown et al. 2001). However, post-harvest home ranges were much smaller, indicating a considerable decrease in spatial activity shortly after harvesting.

Vegetation height was considerably shorter after harvest and consequently the shelter available to rice-field rats decreased. The reduction of shelter exposes small mammals to increased predation risk (Sheffield et al. 2001) and can lead to changes in spatial behaviour (Jacob and Hempel 2002). We believe the changes in home-range size found post-harvest were due to decreased vegetation height and not a result of a potential decrease in food availability. A decrease in food availability should have caused an increase in home-range size but home range size decreased. An effect of breeding on home range size seems also unlikely because breeding in rice-field rats continued for 2–3 weeks post-harvest when the study was completed. Given high activity by farmers in conducting rat control measures, 'predation by humans' could have

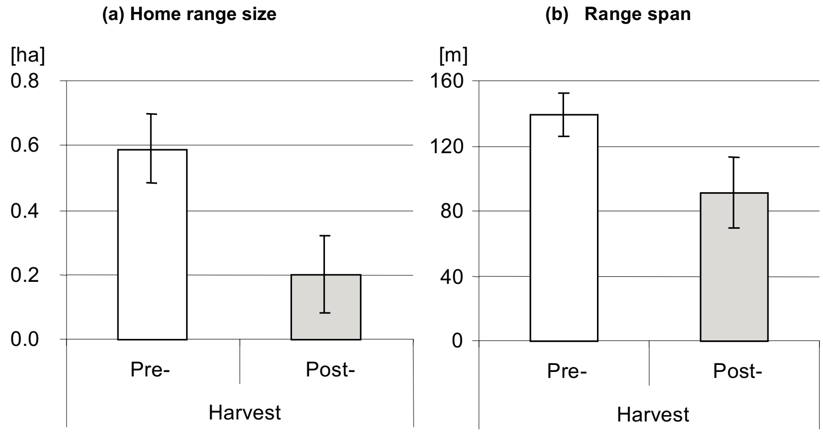

Figure 1. 95% minimum convex polygon home ranges (a) and range span (b) for female rice-field rats pre- and post-harvest. Rats were radio-tracked on three plots (13 rats pre-harvest, 7 rats post-harvest). Error bars are standard errors.

been a major factor in determining the rice-field rats' home-range size.

Centres of activity

For the seven rice-field rats we were able to track pre- and post-harvest, we found a relocation of the centres of activity by an average of 367 m (se = 130 m) during harvesting. This is a distance more than three times longer than the average range span before and after harvest (115 m). Other species of small mammals, such as common voles, do not shift home ranges when grain fields are harvested (Jacob and Hempel 2002). Harvesting of the rice continued for about one week and unharvested patches as well as piles of rice straw left on the fields provided shelter during that time. Two of the radio-tracked rice-field rats moved >700 m to reach unharvested patches of rice field. The rats left their pre-harvest home range, which resulted in a shift of their centres of activity. The pre- and post-harvest home ranges overlapped for only one rat. The concentration of the activity of the rice-field rats in unharvested patches may have led to high rat densities there. This may have resulted in smaller home ranges post-harvest because high density is correlated to small home ranges in small mammals (e.g. Erlinge et al. 1990). The aggregation of rats in unharvested areas could have led to pronounced damage in areas harvested late.

Habitat use

The mean availability of the different habitat types in the five plots were: 94% (±3%) rice field, 8% (±4%) refuge and 1% (±0.2%) village. Pre-harvest, rats tended to not prefer rice fields (Jacobs' index = –0.50, $n = 7$) and to prefer refuge habitats (Jacobs' index = 0.38, $n = 7$). There was a difference in habitat use pre- and post-harvest. Pre-harvest, 74% (±14%) of the rats did not leave the rice fields, while post-harvest, all of the rats stayed in rice fields only ($F = 5.69$, df = 1,23, $p = 0.017$). The avoidance of refuge habitats post-harvest was unexpected (hypothesis 2). The rats may have stayed in the rice fields because this habitat became suitable for nesting after the water was drained from the rice fields shortly before harvest. The piles of rice straw left on the fields post-harvest may also have provided shelter. In addition, nesting in the fields may have provided the rats with the opportunity to avoid rat control by farmers who focus fumigation and digging on refuge habitats (channel banks, dikes). The pre-harvest strategy to travel between refuge habitats and rice fields may have become more risky post-harvest because it would have resulted in moving through unharvested sections of the crop. It is possible that the rats tried to avoid exposure to predators in unharvested sections by remaining in the rice fields.

Conclusions

The behavioural response of rice-field rats to harvesting of rice may have general relevance for population trends and management of rice-field rats in rice-based agro-ecosystems. The relocation of rice-field rats from harvested to unharvested patches may lead to higher rat damage in the fields harvested last. Targeting these areas for rat management may help the owner of these fields to minimise damage there. A carry-over effect of such management to the next growing season would only occur if there were a short fallow period. This is normally not the case after a dry season crop, when the fallow period lasts for 2–3 months before the wet season crop is planted.

Our findings emphasise the importance of synchronous harvesting because removal of shelter and food within a short period of time will maximise the length of the fallow period and minimise the risk of sustaining populations of rice-field rats during the fallow period. Grazing stubble as well as the removal or burning of rice straw will minimise shelter for rice-field rats after harvest. Prey perceive tall vegetation as good protection (Tchabovsky et al. 2001) and removal of shelter leads to higher direct and indirect risk of predation. However, low vegetation post-harvest restricted spatial activity that may in turn lessen the direct impact of predation. Therefore, the success of pest rodent management relying only on the decrease of vegetation height may be compromised.

Our study showed that rats persist in rice fields until 2–3 weeks post-harvest. From a management perspective, it would be beneficial to know when the rats leave harvested rice fields and to where they move.

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