

# FOOD PREFERENCE AND THE EFFECT OF PREDATOR CUES ON THE FORAGING BEHAVIOUR OF HOUSE RAT (*Rattus tanezumi*)

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## ABSTRACT

The House Rat (*Rattus tanezumi*) is a major pest in the agriculture and food industry, a carrier of zoonotic diseases, and a source of nuisance to society. Poisoning is not an ecologically desirable method to control the rat population due to its effect on non-target animals. This article reported on the use of predator cues to control the rat's foraging behavior. Food preference for sugarcane, corn, oil palm fruit, and young coconut flesh was determined first using a modified "cafeteria method" with a central cage connected to four feeding stations by PVC tubes. Then the effect of predator cues (3-D model and call of an owl, a combination of model and call and no predator cue as control) on foraging behavior was tested by manipulating these cues near the feeding station. Giving up density (GUD), which is the amount of food remaining at the feeding stations, was measured in both experimental phases. Treatment means were analyzed using ANOVA and compared using the Tukey test. The finding showed that House Rats preferred young coconut flesh over other test foods. All predator cues increased GUD significantly ( $p < 0.01$ ) but the 3-D model was the most effective. This study suggests a potential use of predator cues to control rat pest.

**Key words:** House rat (*Rattus tanezumi*), visual cue, auditory cue, giving-up density (GUD), foraging behavior

## INTRODUCTION

Rodent, with 2,552 species worldwide (Burgin *et al.*, 2018), is the most diverse and successful mammalian group in the world. They play various ecological roles such as seed dispersal, assisting in nutrient cycling through faecal deposition (Pimsai *et al.*, 2014) as well as being an important prey base for many predator species (Witmer, 2004). Rats are also a major pest of crops by competing for food with humans and livestock leading to significant economic loss (Singleton, 2003; Stenseth *et al.*, 2003; Rehman *et al.*, 2019). A study in Indonesia estimated that every 1% increase in tiller damage by rats translates to 58 kg/ha loss in rice yield (Singleton *et al.*, 2005). *Rattus tiomanicus* attacked oil palm at all stages of growth, causing 5 – 30% damage to fruits and 7 – 10% of the palms (Wood & Chung, 2003). Wood and Chung, (2003)

estimated damage due to rats ranged from USD48-288/ha, depending on the price of palm oil. Meanwhile, the close association of some murids with a human has brought health concern of zoonotic diseases (Himsworth *et al.*, 2013; Kosoy *et al.*, 2015; Strand & Lundkvist, 2019; Modlinska & Pisula, 2020).

Methods of managing the rat population have included trapping, poisoning, and biological control. Poisons such as anticoagulant rodenticides have been used successfully to control the rat population in agricultural areas (Wood & Chung, 2003; Atta *et al.*, 2018) but there is evidence that rats are developing some resistance to them (Lam, 1982; Quy *et al.*, 1995; Andru *et al.*, 2013; Strand & Lundkvist, 2019). The use of poison is ecologically inappropriate and undesirable due to its secondary effect on non-target animals (Howald *et al.*, 1999; Serieys *et al.*, 2019). The barn owl has been used to control the rat population in rice fields and oil palm plantations in Malaysia (Hafidzi &

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Naim, 2003; Wood & Chung, 2003; Puan *et al.*, 2011) either on its own or together with rodenticide. The combination of the barn owl and rodenticide has proven to be more effective than either method alone, but the poison has lethal as well as a non-lethal but negative effect on the owl (Salim *et al.*, 2014; Omar *et al.*, 2016). The presence of owl has also reduced the cost of rodenticide application by 53 – 60% (Kross & Baldwin, 2016) while Duckett, (1991) estimated the cost of using barn owl is only 20% the cost of baiting.

The idea of using owl in rice fields and oil palm plantations is to kill the rat thereby reducing its population through the natural biological cycle. However, the reduction in crop damage due to the presence of the owl is more than what is estimated from the number of rats killed, based on remains under the nesting boxes (Smal, 1990). Studies by Puan *et al.* (2011) and Naim *et al.* (2014) established a relationship through which the damage to oil palm fruits can be estimated from the number of rat present. This suggests that fear of predator (non-lethal effect) may indeed be a bigger contributor to the owl effect. According to Wang *et al.* (2016), direct killing by predators alters the behavior and physiology of the prey to such an extent that they are more fearful of perceived predation than direct predation. Studies with predator cues showed that prey responded to predator cues (urine, playback recorded calls, scent and fecal odor of a predator), by reducing their foraging activity in exposed areas that they perceived as risky (Hendrie *et al.*, 1998; Orrock *et al.*, 2004; Sivy *et al.*, 2011; Sanchez-Gonzalez *et al.*, 2018). This suggests the potential of using predator cues instead of real predators to control rodent pests. Predator cues have the advantage over real predators as they can be used in all scenarios and may still elicit a behavioral response from prey.

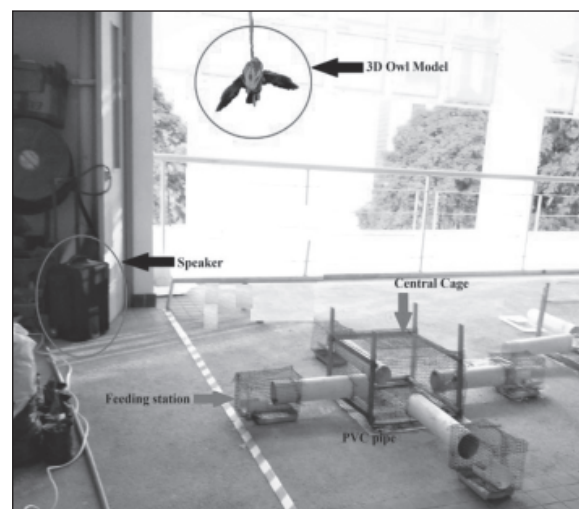
We used a “modified cafeteria test” method to determine which locally available food types are preferred by House Rats and then test the effect of predator cues (3-D owl model, owl calls, a combination of owl calls and 3-D model and without predator cue) on the rat’s foraging behavior towards its preferred food. Also, Scops owl was chosen as the origin of predator cues because it is common in Borneo (Puan *et al.*, 2015) and its call can be heard clearly in oil palm plantation (Mohd Azlan *et al.*, 2019), suburban areas (Puan, 2013) and forest at night.

Optimal foraging theory defines how an organism makes the best foraging decision to maximize energy intake, minimize handling time, and based on not only the quantity but the nutritional content of the food (Pyke, 1984). A higher GuD indicates a higher perceived risk of predation (Brown, 1999), higher environmental or

psychological stress, or less valuable food (Tuen & Brown, 1996). A subset of the optimal foraging theory is the optimal diet theory, which states that animals should prefer foods that yield more energy per unit handling time (Pulliam, 1974; Sih & Christensen, 2001). The optimal diet of an animal also can be affected by predators, real or perceived. The predator effect increased the cost of foraging of an animal through increased vigilance, decreased the animal’s energy intake, and left higher GuDs of food behind. Based on previous research studies, it is hypothesized that (i) rodents will show a food preference by having a lower GuDs on preferred food (Bernard, 2003; Sivy *et al.*, 2011), (ii) predator cue will affect the foraging behavior of rodent by having a higher GuDs on preferred food (Abramsky *et al.*, 1996; Hendrie *et al.*, 1998; Sivy *et al.*, 2011; Mahlaba *et al.*, 2017).

## MATERIALS AND METHODS

Four House Rats (*R. tanezumi*), consisting of three males and one female (non-pregnant and non-lactating) captured in Universiti Malaysia Sarawak (UNIMAS) campus and nearby residential area using live cage traps (Aplin *et al.*, 2003) were used for this study. Each rat was placed individually in a wire cage (50 cm × 50 cm 30 cm), which was connected to four feeding stations by four 50 cm long PVC tubes, with a diameter of 10 cm each (Figure 1). The rats were acclimatized to their cages for three days before the experimental trials, fed on pellets and water before the treatment phase was applied (Eilam *et al.*, 1999; Morris & Davidson, 2000). The treatment phase was the food preference experiment and predator cue experiment. All tests were done simultaneously on all four rats.



**Fig. 1.** “Modified” cafeteria test which has a square central cage with four feeding stations (adapted from Murua *et al.*, 1980) that are connected to the central cage via a PVC tube.

The food preference experiment followed the “modified cafeteria test” method of Murua *et al.*, (1980) by placing a rat in a central rectangular cage surrounded by four tubes instead of a central octagonal cage surrounded by eight tubes. In each feeding station, 20 g of raw food material (sugarcane without the outer layer, corn kernel, oil palm fruit, and young coconut flesh which is removed from the nut) were placed separately. House Rats are known to cause damage to crops like maize, sugarcane, oil palm (Rehman *et al.*, 2019), and coconut (Hegade *et al.*, 2017). The foods were rotated to avoid bias due to the location of the feeding station. The foods were offered in the evening (5:00 p.m.) and left for 24 hr. The leftover was collected in the following evening (5:00 p.m.) and weighed. This multi-choice-feeding test was carried out for four days for each individual rat and was replicated with four different rats ( $n=16$  for each bait, 4 x 4 latin square design).

For the predator cue experiment, we tested (i) auditory cue, in which the calls of a Scops owl (obtained from xeno-canto) were played back once every 15 min interval using a speaker, which was 1.5 m away from the nearest feeding station; (ii) visual cue, which is a 3-D model of the owl, 1.5 m diagonally above floor level from the nearest feeding station (Figure 2); (iii) combination of the auditory and visual cue; and (iv) no predator cue, as control. These treatments were conducted using the rat’s most preferred food (young coconut flesh) identified from the previous experiment. Exposure to treatment was carried out simultaneously on four rats over four consecutive days. The calls were played intermittently within 12 hr and the 3-D model of the owl was hanged for 12 hr.

Data collected was in the form of giving up density (GUD) which is expressed as the amount of

food left behind by the rat after each night of foraging (Brown, 1988). The experimental design was a 44 Latin square for the food preference experiment. The data was analyzed using One-way ANOVA for both experiments, and the GuD means were compared using the Tukey test at  $p=0.05$ .

**RESULTS**

**Food preference**

All rats showed exploratory behavior by visiting the four food types as soon as it had presented them. The rats also exhibited hoarding behavior as shown by the presence of food inside the pipe connecting the feeding stations and the central arena of the cage.

Figure 3 presents the bar graph with mean values (+ S.E.) of the GUDs for the four different test foods. From the graph, young coconut flesh was preferred by the rats as it showed the lowest value



Fig. 2. A 3-D owl model is used as a predator cue.

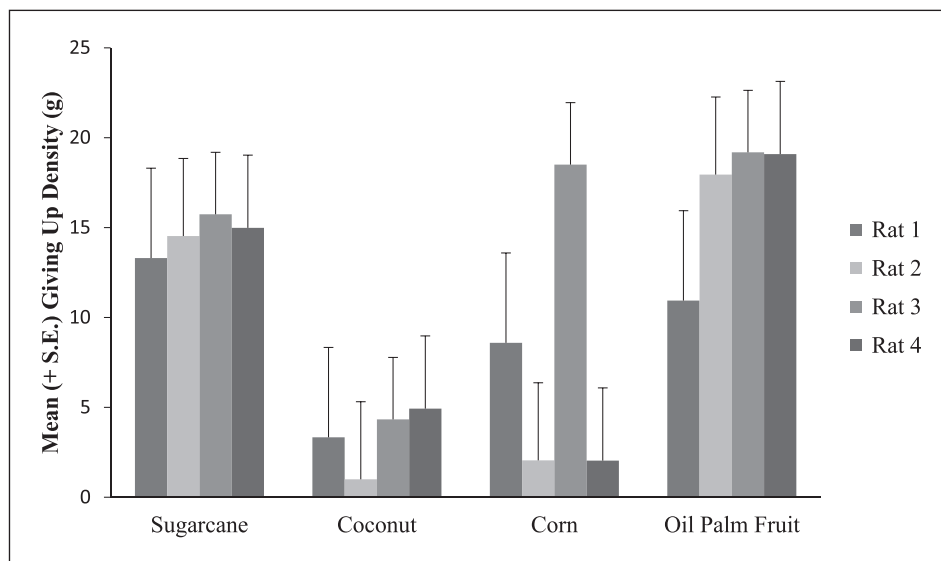


Fig. 3. Effects of food types on giving-up densities in food trays by the rats. Lower values represent a stronger preference for food.

of GUDs while oil palm fruit is the least favored, with the highest value of GUDs.

ANOVA on GUD showed statistically significant differences between means ( $p < 0.01$ ). Tukey test indicated that the mean of GUD of coconut (3.4 g) was significantly different ( $p < 0.05$ ) from that of oil palm (16.79 g) and sugarcane (14.64 g) but not from corn (7.79 g) (Table 1).

### Effect of predator cues

Figure 4 shows the bar graph with mean values (+ S.E.) of the GUDs under the influence of predator cues versus no predator cue. All rats responded to the predator cues by having a much higher GUD for their preferred food, which is the flesh of the young coconut, compared to when the predator cue was absent. Interestingly among the predator cues tested in this study, a visual cue (3-D owl model) has the greatest effect while an auditory cue (owl call) has the least effect.

ANOVA showed highly significant effects of treatments, with  $p = 0.00000001$ , indicating that all predator cues strongly influenced the foraging behavior of rodents. The Tukey test at  $p = 0.05$  showed that the GUD of rats frightened with the 3-D owl model (15.52 g) is significantly different from owl call (12.31 g) and the effect of all the predator cues are significantly different compared to the control (Table 2).

## DISCUSSION

### Food preference

The result demonstrated that House Rats showed lower GUDs on their preferred food which is the young coconut flesh. The animal's food

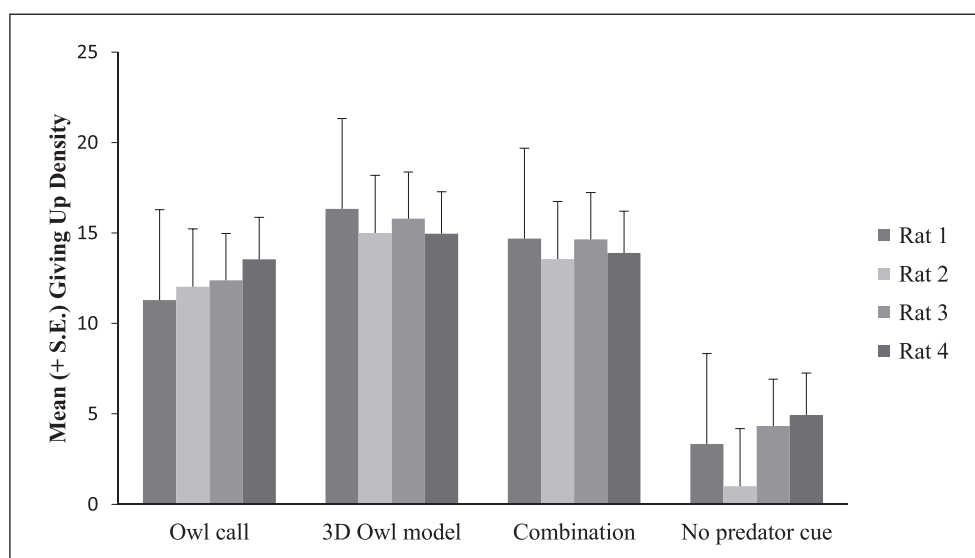
preference is influenced by the physical and chemical characteristics of food, especially characteristics that influence palatability. The choice of the rat is influenced by the palatability of food which varies in texture, color, hardness, and taste. The food also varies in terms of fiber contents, the gross energy values, and the source of energy. Sugarcane has the highest crude fiber content (23.5% of DM, Mui *et al.*, 2000) while young coconut has the least (0.61%, Wynn, 2017). Rats, being monogastric animals, cannot digest fiber, and the fiber content of more than 5% is detrimental to its digestion and often avoided (Caroline *et al.*, 2003). Adam *et al.* (2014) detected increased circulation of satiety hormone in the blood of rats fed diets containing fermentable dietary fiber leading to reduced food intake. Young coconut also has the highest gross energy value (32.1 MJ/kg DM gross energy, Hauze *et al.*, 2015) compared to

**Table 1.** Result of Tukey test on mean GUDs (g) for food preference experiment. Values showing different superscript letters are significantly different at  $p = 0.05$

Coconut	Corn	Sugarcane	Oil Palm Fruit
3.40.86 <sup>a</sup>	7.79 <sup>ac</sup>	14.64 <sup>bc</sup>	16.79 <sup>bc</sup>

**Table 2.** Result of Tukey test on the mean GUD (g) of predator cue and control (no predator cue). Values with different superscript letters are significantly different at  $p = 0.05$

Control	Owl Call	Combination	3-D Owl Model
3.40 <sup>a</sup>	12.31 <sup>bc</sup>	14.20 <sup>cd</sup>	15.52 <sup>d</sup>



**Fig. 4.** Effects of predator cues on giving up densities of rats for preferred food.

sugarcane (18 MJ/kg DM gross energy, Hauze *et al.*, 2018a), corn (16.6 MJ/kg DM gross energy, Kwon & Kim, 2015), and oil palm fruit (16.7 MJ/kg DM, Hauze *et al.*, 2018b). Coconut, corn, and sugarcane have carbohydrates as the main source of energy while oil palm fruit has fat as the main source of energy. Hegab *et al.* (2014) found that Norway Rats preferred corn over other novel food types, showing a significant positive correlation with carbohydrates, suggesting this rat choose food with high energy content. The total intake of energy will determine the growth of the animal. In this study, all House Rats gained 10 g on average due to high energy consumption than energy expenditure, notably due to the restricted space in the arena (Chalvon-Demersay *et al.*, 2017).

Whether the House Rat select food based on its chemical composition or physical characteristics cannot be ascertained in this study. It is more logical to assume that the rats having tried each of the food on offer then decided as to which one they prefer. Despite having a reputation of being neophobic (fear of new things) rats are always curious, and they tried to sample and approach a new food cautiously (Whishaw & Whishaw, 1996; Hegab *et al.*, 2014). Rats have a remarkably strong and well-developed sense of smell, which it uses more than their other senses, to locate and discover potential food sources (Bessieres *et al.*, 2017; Carlson *et al.*, 2018). In the food preference test, the House Rats revealed their curiosity by trying every food which was provided in each station.

#### **Effect of predator cues on foraging behavior**

All rats responded to the predator cues by having a much higher GUD for their preferred food, which is the flesh of the young coconut, compared to when the predator cue was absent. The increased in GUDs for young coconut flesh in the presence of predator ranged from 8 g for owl call to 12 g for 3-D model, respectively. At the gross energy content of 32.1 kJ/g, this represents an energy cost amounting to 257 to 385 kJ, which is huge compared to the energy required for growth of 213 kJ/day for a 100 g rat (NRC, 1995).

The increase in GUD was the result of reduced foraging activity as reported by Brown *et al.* (1988), Abramsky *et al.* (1996), Sivy *et al.* (2011), and Mahlaba *et al.* (2017). Abramsky *et al.* (1996) reported that gerbils responded to predation risk from barn owl by avoiding risky open areas and limiting their activity to bush habitat. The flight of barn owl elicited the strongest response and its hunger call the least (Abramsky *et al.*, 1996). Similarly, a visual cue (3-D image of owl) has a significantly greater effect on GUD compared to an auditory cue (owl call) in the current study.

According to Bovet and Vauclair, (2000), many animals responded to pictures of their predator and behaved in similar ways to real-life objects. A study by Pongracz and Altbacker, (2000) also showed that a stuffed predator increased the defensive response of the rabbit, although it had no previous experience with predators. The findings suggested that prey might possess an inherited “picture” of a predator.

The GUDs of owl call is the lowest among the predator cues used in this experiment, meaning it was the least scary of the predator cues. Studies by Hendrie *et al.* (1998) suggest that species of wild rodents exhibited a different behavioral response to owl calls, ranging from no response to spending more time in their burrows. Eilam *et al.* (1999) showed that the behavior of spiny mice did not change when exposed to owl call although elevated cortisol levels indicated the rats were stressed by it. Another potential explanation is that the rodents are more afraid of a real-life object that they can see rather than the call which is difficult to locate especially at night and difficult to assess the distance between it and the predator. It was suggested that rodents have a hierarchy of responses towards aerial predators such as an owl, freezing when it assessed the predator is quite far away, fleeing when a predator is closer, and fighting back when there is no space or time to run (Eilam *et al.*, 1999). Graded responses to predator cues by Wood mice were also reported by Sanchez-Gonzalez *et al.* (2018). Indeed, prey may learn the risk level when a more detailed assessment of threats experience (in the form of a visual as opposed to auditory cue) is provided to them (Lima & Dill, 1990).

Since the 3-D model and owl call had both elicited responses as increased in GUD, it was expected that the response to a combination of both treatments to be additive. However, this is not the case, and the magnitude of response to the combination is in between the owl call and the 3-D model. The likely explanation probably lies in the sequence at which the rats were exposed to predator cue treatment. In the current experiment, all the rats were exposed to predator cues in the following sequence for four days: control, call, 3-D image, and finally the combination of call and 3-D image. It could be that by the time the rats were exposed to the combination treatment, they had become familiar with the environment and predator cues used. A previous study indicated that Norway rats do not show any behavioral signs of stress when exposed to predators' scents in a familiar environment (Stryjek *et al.*, 2018). Simon *et al.*, (2009) stated that rats were able to recognize and respond to changes in predation risk even though the risk was altered.

## CONCLUSION

In conclusion, the House Rat *R. tanezumi* preferred young coconut flesh over corn, sugar cane, and oil palm fruit, as shown by the significantly ( $p < 0.05$ ) lower GUD for young coconut flesh. All three predator cues (call, 3-D model, and combination of call and 3-D model of Scops Owl) successfully frightened the House Rat leading to significantly higher GUDs of its preferred food. The 3-D owl model elicited the highest fear factor. The finding of this study has potential application in the integrated management plan for the pest in an agricultural and household environment.

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