Diet composition of introduced barn owls (*Tyto alba javanica*) in urban area in comparison with agriculture settings

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Abstract

This study investigated the diet of introduced barn owls (*Tyto alba javanica*, Gmelin) in the urban area of the Main Campus of Universiti Sains Malaysia, Penang, Malaysia, based on collected regurgitated pellets. We also compared the diet of the introduced barn owls with the diet of barn owls from two agricultural areas, i.e. oil palm plantations and rice fields. Pellet analysis of introduced barn owls showed that commensal Norway rats, *Rattus norvegicus*, made up the highest proportion of the diet (65.37% prey biomass) while common shrews, *Suncus murinus* were the second highest consumed prey (30.12% prey biomass). Common plantain squirrel, *Callosciurus notatus*, made up 4.45% of the diet while insects were taken in a relatively small amount (0.046% prey biomass). Introduced barn owls showed a preference for medium-sized prey, i.e. 40–120 g (52.96% biomass and 38.71% total). In agricultural areas, rice field rats, *Rattus argentiventer* predominated the diet of barn owls (98.24% prey biomass) in rice fields while Malayan wood rats, *Rattus tiomanicus*, were the most consumed prey in oil palm plantations (99.5% prey biomass). Food niche breadth value was highest for barn owls introduced in an urban area with a value of 2.90, and 1.06 in rice fields and 1.22 in oil palm plantations. Our analysis reiterates the prey preference of barn owls in various landscapes for small mammals. Our results also indicate the suitability of utilizing barn owls as a biological control not only in agricultural areas, but also as a biological control agent for commensal rodent pests in urban areas.

Key words: barn owl, diet, pellet analysis, urban, agriculture
Introduction

The barn owl, Tyto alba (Tytonidae), is a common species of owls which occurs on almost all continents and in most open lands and farmlands (Bunn et al. 1982; Taylor, 1994). Like many other cosmopolitan nocturnal raptors, barn owls display an astonishing breadth of habitat association and have been able to adapt and persist in areas that are becoming urbanized (Hindmarch et al. 2017). The diet of barn owls has been well studied throughout its range because of the ease of identifying prey remnants recovered inside regurgitated pellets. Owls swallow their prey whole and expel pellets, which are composed of undigested remains such as bones, compacted in hair and feathers (Taylor 1994). Analysis of barn owl pellets has provided information on the diet composition of owls and dynamics of prey species communities within the owl foraging areas (Alivizatos and Goutner 1999; Kitowski 2013).

Extensive studies of barn owls across their foraging range report that barn owls feed primarily on small mammals, i.e. rats, mice, voles and shrews, with birds, insects, amphibians, reptiles and invertebrates taken in relatively small amounts (Martí 2010; Paspali et al. 2013; Hindmarch and Elliot 2015). In Peninsular Malaysia, several studies on the food selection of barn owls in major agricultural crop areas report rats as the main prey. Diet analysis of the owl’s regurgitated pellets show that rats comprise >98% of the prey in oil palm plantations (Lenton, 1984) and 94.7% in rice fields (Hafidzi, Zulkifli, and Kamarudin 1999).

Barn owls are an effective small mammal predator, which has led to it being introduced into various landscapes such as islands (Au and Swedberg 1966; Emmerson and Ascani, 1985), agricultural areas (Hafidzi and Naim 2003b; Rizuan et al. 2017) and semi-urban areas (Meyer 2008) for the purpose of controlling pest rodent populations. Barn owls are also translocated as part of reintroduction programs for declining local barn owl populations (Meek et al. 2003). In this study, Southeast Asian barn owls, T. alba javanica, were translocated from their native agricultural habitats and introduced to the urban-garden area of the Main Campus of Universiti Sains Malaysia to serve as a biological control agent for the rat pest population. Here, we report the analysis of the diet composition of introduced barn owls in an urban area and compare the diet of introduced barn owls to the diet of barn owls in oil palm plantations and rice fields in Peninsular Malaysia.

Methods

Study area and introduced barn owls

In total, 24 barn owls were released intermittently from April 2016 to August 2018 in the urban-garden area of the Main Campus of Universiti Sains Malaysia Penang, Malaysia (5.3579° N, 100.2943° E). Prior to the release, 14 artificial nest boxes were installed around the campus area. Providing nest boxes is a common practice to attract barn owls and increase nesting performance and hence sustain a barn owl population. Two types of artificial nest boxes, i.e. wooden and fibreglass, were installed early in January 2016 and placed around the campus in open areas of vegetation (Fig. 1).

The translocated barn owls were harvested from three different locations in Peninsular Malaysia; oil palm plantations at

Figure 1: Study site of introduced barn owls and location of nest boxes
the Tun Razak Agricultural Research Centre, Bandar Jengka Pahang (3.77796° N, 102.517238° E), rice fields of Bumbung Lima, Kepala Batus, Pulau Pinang (5.51707° N, 100.4265° E) and rice fields in the Kerian District, Parit Buntar, Perak (5.0081° N, 100.5394° E). Owls were harvested from areas with 100% occupancy of provided nest boxes, indicating a healthy population. No more than one-third of individual fledglings and/or older owlets in the nest were harvested from the same nest-box. Owlets were only harvested if they were of the age of one month or more. The owls were temporarily held in the USM Aviary (5.3579194° N, 100.2941667° E) for about one month before release to allow the birds to acclimatize to their new urban surroundings.

All introduced barn owls were banded with customized metal leg bands prior to release. Transmitters were fitted to the owls using backpack style (Saufi, Ahmad, and Salim 2018). The transmitter and harness weighed ~9 g, i.e. <2% of total body mass of the barn owls (range between 430 and 580 g) to avoid affecting bird behaviour and movement (Gaunt et al. 1997). Very high-frequency (VHF) radio-tracking (TRX-48S, Wildlife Materials Inc.) was used to observe the post-release movement of released barn owls. The detection distance for the radio tags was reported to be from 2 to 4 km without obstruction (Wildlife Materials Inc., personal communication) and transmitters typically detached themselves in about a year. Each owl was followed for at least 10 cumulative days immediately following its release, starting from dusk (20:00 h) to dawn (06:30 h). Radio-tracking was initially done from vehicles and when a signal was detected, tracking was done on foot till the strongest signal could be detected. The last detected location of an owl during a tracking session is crucial as it determines the owl roosting site of the day, from which there is a high probability of finding a regurgitated pellet.

Regurgitated pellets of introduced barn owls were collected from August 2018 to December 2018 at various locations scattered around the campus. Several structures were identified within the campus that were used regularly by barn owls as perching and roosting sites and pellets were collected on the ground below these sites.

**Diet of barn owls in agricultural areas**

Pellets of barn owls inhabiting rice fields were collected from rice fields of Bagan Serai, Perak and Kepala Batus, Penang. Surveys for barn owl nest boxes and roosting sites were conducted from August 2017 to July 2018. Pellets of barn owls in oil palm plantations were collected from the plantations in Tun Razak Agricultural Research Centre, Bandar Jengka, Pahang, from July 2017 to August 2018. Pellet samples from both agricultural settings were collected in and around nest boxes and identified perching sites of barn owls.

**Pellet analysis**

Pellets were soaked in water individually and processed carefully by taking them apart (Terry 2004). Bone remnants from pellets were preserved in alcohol prior to identification. For rodent identification, skull and lower jaw of the prey were used for identification down to species level following the identification key of Harrison (1962). Rattus norvegicus and Rattus rattus species were differentiated based on temporal ridges as seen from above (Harrison 1962). In Norway rats, the ridges are straight and almost parallel while in roof rats, the temporal ridges are curved along the sides of the braincase. A scientific calliper (Mitutoyo USA) was used to measure the size of bones to determine the size of the prey (0.01 mm accuracy). Insects found in pellets were identified using Borror and White (1970), whereas other vertebrate prey were determined up to family level using identification keys by Beisaw (2013).

The biomass of prey items recovered from pellets were estimated using a standard log-log regression of right mandible length as a function of body weight (Morris 2009; Hamilton 1980; Marti 2009). The food niche breadth (FNB) of barn owls in all the areas was calculated to determine the dietary diversity of barn owls in each habitat. FNB (Levins 1968) was calculated as follows:

\[
FNB = \sum_{i=1}^{p} p_i^2,
\]

where \( p \) is the proportion to prey category \( i \) in the barn owl diet. Higher values on this index represent a higher diversity of the diet.

**Results**

**Diet of barn owls**

Twenty-four barn owls were translocated and released in the study area. Among these released owls, only three barn owls were successfully introduced in an urban area and pellets analysed were collected from these owls. A total of 252 pellets were collected and 10 groups of animal taxa were identified from prey remnants from all three different study habitats (Table 1). Small mammals from the family Muridae were the staple prey in all three different habitats, though the main prey species differed in each habitat.

A total of 62 individual pellets were collected from barn owls introduced in the urban area and 95.49% of prey biomass of the diet was composed of commensal rodent pests. Norway rats, R. norvegicus, were the most abundant prey item; making up 45.05% of total pellet contents and 65.37% of prey biomass. House shrews, Suncus murinus, were the second most common prey item in the urban area (35.16 % of pellet content and 30.12 % prey biomass). Another rodent prey identified was the common plantain squirrel, Callosciurus notatus, with two prey items (2.20% total and 4.45% biomass). Other prey identified in pellets was insects; grasshoppers (9.26% total and 0.11% biomass) and termites (12.65% total and 0.002% biomass).

In rice fields, a total of 90 pellets were collected with rodent pests making up 99.52% of the prey biomass. Rice field rats, Rattus argentiventer, were the main prey item in the diet of barn owls (96.77% total and 98.24% biomass) while shrews constituted a smaller fraction of the diet at 2.15% of total prey individuals and 1.28% of prey biomass. Amphibians were also recorded in the diet of barn owls in rice fields (1.07% total and 0.46% of prey biomass).

A total of 100 pellets were collected in oil palm plantations and 92.83% of total prey were rodents. Malayan Wood Rats, Rattus tiomanicus, were the main prey species in terms of prey total (90.16%) and prey biomass (94.35%). Two squirrels were also found in barn owl pellets with the diurnal rodent making up 2.45% of individual prey total and 3.71% of prey biomass. Though only constituting 3.27 % of total prey consumed, grasshoppers were the second most abundant prey item of barn owls in oil palm plantations (0.02% biomass). A small percentage of barn owls diet in oil palm plantations were made up of birds, reptiles and amphibians, making up 1.63 % (0.76% biomass), 0.81 % (0.66% biomass) and 1.63 % (0.47 % biomass) of total prey consumed, respectively.
The FNB of barn owls in all the areas was calculated to determine the dietary diversity of barn owls in each habitat (Table 1). The released barn owls in the urban area recorded the highest FNB value at 2.90, while the FNB value was second highest for barn owls in oil palm plantations (1.22 FNB) and barn owls in rice fields recorded the lowest FNB value (1.06 FNB). Thus, introduced barn owls had a relatively higher diet diversity compared with the diet of barn owls at agricultural areas.

Prey weight of introduced barn owls

The biomass of identified preys inside the collected pellets were estimated using a standard log-log regression of right mandible length (mm) as a function body weight (g) as described by Hamilton (1980). Figure 2 shows the weight groups of introduced barn owls prey by numbers and biomass. Weights of prey were identified as extra small (<3 g), small (3–40 g), medium (40–120 g) and large (120–160 g). Medium-sized prey was the most preferred weight group by owls (52.96% biomass and 38.71% total). Small-sized prey was the second highest preferred prey of introduced barn owls, making up 31.18% total prey consumed. However due to the small size, this prey category only contributed 16% of the prey biomass. Large-sized prey made up 12.90% of total prey and >30% of prey biomass. The extra small-sized prey made up 17.20% of total prey and contributed only 0.15% of prey biomass.

As Norway rats were the most preferred prey of the barn owls, further analysis was carried out on the size of the rats. Our analysis showed that the most consumed weight group of rats were medium-sized rats, i.e. individuals weighing 80–120 g (Fig. 3). Seventeen individual medium-sized rats were consumed (44.74%). Twelve small-sized rats weighing from 40 to 80 g were the second highest weight group consumed by barn owls (31.58%) and the least consumed weight group were large-sized rats weighing >120 g (9 individuals, 23.68%). Norway rats weighing <40 g and >160 g were not found in our pellet analysis.

Discussion

Diet of introduced barn owls versus barn owls residing in agricultural landscapes

The barn owls that were introduced and released in an urban area were seen roosting and perching in trees, roof spaces of

Table 1: Diet composition of introduced barn owls and barn owls residing in agricultural areas

| Prey species               | Urban (%) | Rice field (%) | Oil palm plantation (%) |
|----------------------------|-----------|----------------|-------------------------|
|                            | Biomass   | Individuals    | Biomass                 | Individuals   |
| Norway rat (R. norvegicus) | 65.37     | 45.05          | 0                       | 0            |
| Rice field rat (R. argentiventer) | 0          | 0              | 98.24                   | 96.77        |
| Wood rat (R. tymanicus)     | 30.12     | 35.16          | 1.28                    | 2.15         |
| House shrew (S. murinus)    | 0         | 0              | 0                       | 0            |
| Bird sp.                    | 0.11      | 5.49           | 0                       | 0            |
| Reptile sp.                 | 0.002     | 12.10          | 0                       | 0            |
| Amphibian sp.               | 4.45      | 2.20           | 0                       | 0            |
| Plantain squirrel (C. notatus) | 2.90     | 1.06           | 1.22                    |              |
| FNB                        |           |                |                         |              |

FNB, food niche breadth.
buildings and houses, as well as abandoned structures. The owls were also seen hunting in open grass habitats near road-sides, human settlements, and backyards of shop lots. One of the barn owls also started occupying one of our installed nest boxes near the aviary, indicating the successful release of barn owls in an urban area. On the other hand, a substantial number of released barn owls in this study (21 out of 24 released owls) were untraceable a week after their release. These released young barn owls dispersed further away from the release site and are probably foraging around the urban areas of Penang Island or could have travelled further to mainland Peninsular Malaysia (Sanfui, Ravindran, and Salim 2019).

Similar to various studies on the diet of barn owls, our study reports that barn owls in agricultural areas and urban areas prey mostly on small mammals (e.g. Marti 2010; Hindmarch and Elliot 2015; Horváth, Morvai, and Horváth 2018). Norway rats and house shrews (80.12% total and 95.49% prey biomass) were the dominant prey group in the diet of barn owls in the urban area. Our study shows that introduced barn owls were able to adapt to an urban setting and consume abundant urban small mammal species. The high number of Norway rats and house shrews consumed by barn owls indicate the owls managed to hunt close to their release site and did not have to travel a great distance for more suitable open hunting grounds. Clark and Bunck (1991) reported that North American barn owls do consume commensal rodents along their distribution, though only in low frequencies. Studies by Álvarez-Castañeda, Cárdenas and Méndez (2004) in Mexico and Magrini and Facure (2008) in Brazil reported that pellets from barn owls in periurban areas contain none to very little prey remnants from urban areas, suggesting that barn owls spend more time hunting in areas away from human settlements. In Canada, Hindmarch and Elliot (2015) reported that barn owls retained their preference for voles despite being in an urban landscape, although rats were consumed in higher amounts in urban areas.

The commensal rodent pests, Norway rats, R. norvegicus, and Black rats, R. rattus, are among the most widespread urban pest species in the world and they reside in close proximity to human habitation and are rarely found in the wild (Feng and Himsworth 2014). The substantial occurrence of Norway rats in the diet of introduced barn owls show that the barn owls are taking advantage of the abundance of this pest species (Amni et al. 2019). Common house shrews were the second most consumed prey of barn owls and the second most trapped species in residential areas of our study site (Amni et al. 2019). This small mammal species was also reported as the second most abundant prey species in urban and rural areas in Canada (Hindmarch and Elliot 2015; Hindmarch et al. 2017) and the species is more abundant in urban settings compared with agricultural settings (Chang et al. 1999). During tracking of released barn owls, Norway rats and house shrews were frequently encountered in residential neighbourhoods, eateries, garbage dump areas and commercial areas within the study site (personal observation). It is however interesting to note that other detrimental rodent pests, i.e. house mice and roof rats, were not found in collected pellets despite being captured occasionally during rat trapping sessions we conducted as part of the study on population diversity of rats in urban areas around Penang Island (Amni et al. 2019). Timm (1994) documented that house mice and roof rats are typically found inside buildings and house mice rarely travel outside, hence have low chances of falling prey to barn owls. Meanwhile, Norway rats and house shrews mainly inhabit and forage in open habitats (Timm 1994), hence the two species inhabiting open areas and vegetation were the primary source of food for the owls (Bonvicino and Bezzera 2003).

Barn owls have been well documented to take advantage of other temporarily abundant types of prey that are vastly different from their usual diet, though extreme exceptions are unusual and usually occur in situations where small rodents are absent or scarce (Taylor 1994). In Malaysia, most studies report that the diet of T. alba javanica is composed >90% of rats (Smal 1990; Puan et al. 2011), with barn owls also preying on squirrels, birds and lizards in smaller numbers (Smal 1990). Introduced barn owls in this study consumed small rodents from the family Sciuridae. The common plantain squirrel, an uncommon barn owl prey, constituted a small fraction in the diet of barn owls (2.20% total and 4.45% biomass). An interesting result from our analysis is that there were no bird remnants found in the pellets of introduced barn owls despite the abundant occurrence of passerine birds in our study site. In contrast, several reports analysing the diet of barn owls in rural and urban areas document that Norway rats, R. norvegicus and birds make up a substantial proportion of the diet of owls (Salvati, Ranazzi, and Manganaro 2002; Teta, Hercolini, and Cueto 2012; Hindmarch and Elliot 2015). The pellet analysis of introduced barn owls also showed that the owls preyed on insects, i.e. grasshoppers and termites. Though infrequent, barn owls have been reported to consume high amount of insects during insect swarms, such as termites (e.g. Taylor 1994) and locusts (Szabo et al. 2003).

Comparing diet of introduced barn owls in urban area and barn owls in agricultural areas

Though members of the Muridae family dominate the diet of barn owls in all habitats, the main prey species differed by habitat. Rattus norvegicus were the most preyed upon by introduced owls while R. tiomanicus and R. argentiventer were the most preyed upon small mammal in oil palm plantations and rice fields, respectively. Barn owls prey-species preference in agricultural areas from our study is similar to other reports by Lenton (1984) and Hafidzi and Naim (2003a) which assessed the diet of barn owls in rice fields and oil palm plantations, respectively.

FNB value of barn owls in the study was highest in the urban area when compared with agricultural areas. There was a higher component of unusual prey items in the urban area compared with agricultural lands, with squirrels and insects accounting for 19.79% of individual prey and 4.51% of total prey.
biomass of owls in the urban area. This observation is similar to reports of Salvati, Ranazzi, and Manganaro (2002) and Teta, Herculini, and Cueto (2012) who report an increase in non-roost prey items in the pellets of barn owls as their habitat becomes more urbanized. Barn owl prey selection was showed by previous food-niche studies to be associated with rodent accumulations and density (e.g. Marti 1988; Taylor 1994; Leveau et al. 2006; Bernard et al. 2010; Marti 2010, Milana et al. 2016). Similar to other food-niche analysis of barn owls in Europe (e.g. Milchev 2015; Horváth, Morvai, and Horváth 2018), North America (Marti 1988, 2010) and South America (e.g. Leveau et al. 2006; Teta, Herculini, and Cueto 2012), the low values of niche breadth analysis from agricultural areas in this study reflect the high abundance of an available and profitable prey, i.e. the dominance of R. tiomanicus and R. argentiventer in oil palm plantations and rice fields, respectively. It is fairly well established that R. argentiventer is common in rice fields (Lam 1983, 1988) and R. tiomanicus is common in oil palm plantations (Wood and Liao, 1984).

Prey size preference of introduced barn owls

Barn owl diet depends on the abundance of food supply, prey accessibility, which is affected by habitat characteristics, and general opportunistic feeding strategy (Taylor 1994; Bond et al. 2005; Horváth, Morvai, and Horváth 2018; Arlettaz et al. 2010). Morphological features, such as body size and conspicuousness, and behaviour can also affect prey vulnerability to predation by barn owls (Derting and Cranford 1989). Studies on differential prey selection by barn owls yield differing and often, contrasting results. Some studies show barn owls have a preference for smaller prey weighing <50 g (e.g. Dickman, Predavec, and Lynam 1991; Rizuan et al. 2017), whereas other studies have reported a preference for larger prey, i.e. prey weighing >50 g (Derting and Cranford 1989; Castro and Jaksic 1995). Our analysis show that barn owls prefer medium-sized Norway rats (40–120 g) in an urban area, a finding similarly reported by Gaunt et al. (1997) and Hindmarch and Elliott (2015).

Barn owls as urban rodent pest biological control agents

There are various ways to study the success of released barn owls. Pellet analysis is a well-known and frequently used method to analyse owl prey content and preference (e.g. Bonvivino and Bezerra 2003; Andrade, de Menezes, and Monjeau 2016). Meyer (2008) who studied the success of released barn owls in a semi-urban area in Johannesburg evaluated the rodent population size using live-trapping before and after barn owl releases. Meyer (2008) reported a declining rat population following the release of barn owls. Although these are positive reports, trap catchability could have biased the results as rats may have developed trap shyness over time (Griffin 2004). Additionally, some studies report that the mere presence of barn owls simply affects the behaviour of prey, i.e. the prey ventures less in the open (Abramsky et al. 1996; Zanette and Clinchy 2019).

Though some studies question the ability of barn owls to significantly reduce rodent populations (Van Vuren, Moore, and Ingels 1998; Marti, Poole, and Bevier 2005), results from this study show a tendency for barn owls to consume abundant commensal rodent pest species. Although our results are preliminary, more studies are planned to further study the efficiency of introduced barn owls in controlling rodent pest populations in an urban setting.

Conclusion

Our study shows that barn owls in urban and agricultural areas are opportunistic predators that hunt almost exclusively on small- to medium-sized small mammals. Our study also showed that barn owls can switch their prey species preference in different areas according to variations in small mammal abundance. Barn owls introduced in an urban area mostly consumed Norway rats and house shrews, which are ubiquitous commensal small mammal pests. Squirrels and insects were also preyed by the introduced barn owls but made up only a small fraction of their diet. Our results strongly indicate that barn owls introduced to urban areas have the potential to be an effective biological control agent against commensal small mammal pest populations following their high consumption by barn owls.

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