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Barn owl for field rat control in cocoa

(Burung hantu 'barn owl' untuk kawalan tikus di ladang koko)

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Key words: barn owl, cocoa, rat control, prey, predator

Abstrak

Potensi penggunaan burung hantu 'barn owl' untuk mengawal tikus di ladang koko telah dikaji. Burung hantu ini menjajah sangkak di kawasan koko-kelapa di Hilir Perak serta di kawasan kelapa sawit yang bersebelahan ladang koko dan sawah di Felcra Seberang Perak selepas 6–7 bulan sangkak tersebut disediakan. Penghunian sangkak bermusim dengan dua fasa pembiakan setahun. Kadar penghunian yang lebih tinggi dan bilangan burung hantu serta bilangan anak yang lebih besar diperhatikan di Felcra Seberang Perak berbanding dengan di Hilir Perak. Tiada pemangsaan telur mahupun anak burung hantu dicatatkan dan until pembuangan terdiri daripada hampir 100% tulang tikus. Bangkai tikus tanpa kepala yang mempunyai ekor yang sepanjang 8.0–15.5 cm ditemui di sangkak di kedua-dua kawasan. Ekor ini kepunyaan tikus yang sederhana besar dengan berat badan 40–100 g. Di Felcra Seberang Perak, bangkai yang dikenal pasti kebanyakan *Rattus tiomanicus* (94.9%) dengan sebilangan kecil *R. argentiventer* (2.9%) dan *R. rattus diardii* (2.2%). Di Hilir Perak pula, kesemua bangkai tikus tersebut ialah *R. tiomanicus* iaitu pemangsaan khusus pada spesies utama perosak tikus. Kajian ini bukan sahaja menunjukkan penghunian burung hantu 'barn owl' yang berjaya untuk mengawal tikus di kedua-dua kawasan ladang tetapi juga merupakan penghunian burung hantu 'barn owl' yang pertama berjaya dilaksanakan dalam agroekosistem koko-kelapa untuk kawalan tikus.

Abstract

The potential of establishing barn owls for field rat control in cocoa was studied. Barn owls colonised nesting boxes in cocoa-coconut fields of Hilir Perak, and in oil palm fields adjacent to cocoa and rice fields of Felcra Seberang Perak after 6–7 months of placement. Occupancy was cyclical with two breeding phases a year. A higher colonisation rate and abundance of barn owl with a larger brood size were noted in Felcra Seberang Perak as compared to that in Hilir Perak. No predation of barn owl eggs or chicks were noted and regurgitated owl pellets were almost 100% of rat bones. Decapitated rat carcasses found in nest boxes of both fields had tail lengths of 8.0–15.5 cm, which belonged to rats of medium body weight (40–100 g). In Felcra Seberang Perak, the carcasses identified were mainly *Rattus tiomanicus* (94.9%) with a few *R. argentiventer* (2.9%) and *R. rattus diardii* (2.2%). In Hilir Perak, the decapitated rats were solely *R. tiomanicus*, indicating predation was mainly on the predominant pest species.

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This study not only indicated the successful establishment of barn owls for field rat control in both the areas but also marked the first successful establishment of barn owls in a cocoa-coconut agro-ecosystem for rat management.

Introduction

Chemical control of rats has progressed from acute and highly toxic poisons to the safer and more potent anticoagulants (Greaves 1971; Lee and Kamarudin 1987). However, the problem of rat infestation not only still lingers but is compounded with problems of resistance to warfarin, cross resistance and increase in tolerance to the second generation rodenticides (Lee et al. 1983; Linowsky 1983; Lee et al. 1990). Other than relying on chemical control when rat infestations become severe with immense losses, rat control with natural predators should be given due consideration.

Snake predation upon rats in oil palm estates totaled 1–2 rats/snake per week (Lim 1974) in contrast to barn owls that preyed upon 1–2 rats/owl per day (Lenton 1980; Lee 1991), thus the latter of more potential. The barn owl *Tyto alba* (Scopoli) is being exploited within oil palm areas in anticipation of it contributing substantially towards biological control of rats, the predominant vertebrate pest in oil palm plantings (Lenton 1980; Duckett and Karuppiah 1989). Similarly, the barn owl has potential for rat control in cocoa as the main vertebrate pest in cocoa plantings is rat, i.e. *R. tiomanicus* (Kamarudin 1982; Lee and Kamarudin 1990). Thus, this study was undertaken to establish barn owls in (a) oil palm fields of Felcra Seberang Perak adjacent to cocoa and rice fields, and (b) cocoa-coconut plantings of Hilir Perak. The findings are important to the overall rat control in both cocoa and oil palm areas in Malaysia.

Materials and methods

A total of 12 barn owl nesting boxes in accordance to the method proposed by Lenton (1980) were set up in a 1980 oil palm planting in Felcra Seberang Perak in April 1990. Adjacent to the oil palm field were rice fields while on the other side were young cocoa fields. The oil palm field was selected because of the height of oil palm trees (4 m tall) which provided a relatively good shade in contrast to the open rice fields and young cocoa plantings. Furthermore, this was the initial attempt to establish barn owls in this area. The nesting boxes were set up between the third and fourth oil palm row at 500 m apart. These nesting boxes were visited monthly.

At each visit, the sex and the number of birds in each box were recorded. Inspection of the boxes was also made for the presence of nesting material, eggs, young, number of dead rats or carcasses and owl pellets. The number of owl pellets was recorded and removed to the laboratory for further analysis. Fresh dead rats and remnants (lower body portion) were weighed and measured, and returned to the boxes. Rat carcasses and remnants that were old were removed from the boxes and measured especially the tail length.

Similarly, 12 nesting boxes were also set up in April 1991 in 10-year-old cocoa plantings established in twin rows within old coconut fields of MARDI Research Station in Hilir Perak. The nesting boxes were also visited monthly and similarly examined as in the case of the nesting boxes in Felcra Seberang Perak.

Results

Barn owls occupied the nest boxes provided in the fields of Felcra Seberang Perak and MARDI Hilir Perak 6–7 months after set up *(Table 1* and *Table 2)*. In January 1991 (7 months after set up of nesting boxes in Felcra Seberang Perak), eight out of 12 nesting boxes were occupied. Four boxes were occupied by single females and another four were occupied by paired barn owls (a

Table 1. Barn owl establishment and development cycle in 12 nesting boxes in oil palm fields of Felcra Seberang Perak

Month	Parameter	Nesting box no.											
		1	2	3	4	5	6	7	8	9	10	11	12
Jan. 91	Ad	0	1P	0	0	1F	0	1F	1P	1F	1F	1P	1P
	FP	0	10	0	0	6	0	3	8	1	4	4	6
Feb. 91	Ad	1F	1F	1F	0	1F	1F	1F	1P	1F	1F	1F	1F
	Egg	7	10	4	0	5	8	7	4	5	7	6	8
	FDR	1										1	
Mar. 91	Ad	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1P
	Egg	0	6	4	0	2	7	2	3	3	5	1	2
	Yg	5	4	0	0	3	1	5	1	2	2	5	6
	FDR	2	1	0	0	2	0	6	0	0	1	1	1
Apr. 91	Ad	1F	1F	1F	0	1F	1F	1F	1F	1F	1F	1F	1F
	Egg	0	5	6	0	0	0	0	0	0	0	0	0
	FB	4	3	0	0	3	1	4	1	2	2	4	5
	FDR	0	0	0	0	0	0	0	0	0	1	0	1
May 91	Ad	0	0	0	0	0	0	0	1F	0	0	1F	1F
	FB	0	0	0	0	0	0	0	1	0	0	1	1
June 91	Ad	0	0	0	0	1F	0	0	0	0	1F	0	1F
July 91	Ad	1F	0	0	1F	0	0	0	1P	0	1F	0	1P
	Egg	0	0	0	0	0	0	0	0	0	1	0	0
Aug. 91	Ad	1P	0	1F	0	0	0	1F	1F	0	1F	1P	1F
	Egg	1	0	5	0	0	0	0	9	0	8	0	0

Recordings of nesting was continued until Dec. 1993

Ad = no. of adult barn owls
FP = no. of faecal pellets found in nest
1P = 1 pair of barn owls (a male and female)
1F = 1 single female barn owl
Egg = no. of eggs found in nest
Yg = no. of young found in nest
FB = no. of fledging owls found in nest
FDR = no. of fresh dead rats found in nest

male and a female). In MARDI Hilir Perak, out of 12 boxes set up, nesting began with three boxes, two occupied by single females and one by a pair. In both areas, upon disturbance, the male birds flew out immediately followed by the females. Thus, to minimise disturbance, inspection of the nesting boxes was done monthly.

By the second month of occupancy, eggs were found in 11 nesting boxes occupied. Nest occupancy by paired owls declined from four to one in Felcra Seberang Perak. It remained the same for Hilir Perak. Out of the 12 nesting boxes studied in Felcra Seberang Perak for 36 months (100% occupancy would be 432 nestings), a total of 252 nestings were recorded for 34 months; 59 nests were occupied by paired owls (a male and a female) and the remainder 193 by single females *(Table 3)*. The mean monthly single female occupancy of 6.1 ± 3.7 nests was significantly (t = 3.240, D.F. = 22, p = 0.005) higher than 2.4 ± 1.4 nests occupied by paired owls. The monthly nest occupancy in Felcra Seberang Perak ranged from zero to 12 (100%) with a mean of 7.9 ± 3.3 nests which was significantly higher (t = 4.1337, D.F. = 22, p <0.001) than 3.1 ± 2.3 nests in MARDI Hilir Perak (range 0–9 nests). In MARDI Hilir Perak, there were 50 barn owl nestings for 16 months, with 19 nests

Table 2. Barn owl establishment and development cycle in 12 nesting boxes in cocoa fields of MARDI Hilir Perak

Month	Parameter	Nesting box no.											
		1	2	3	4	5	6	7	8	9	10	11	12
Oct. 91	Ad	0	0	0	1P	0	0	1F	0	1F	0	0	0
	FP	0	0	0	6	0	0	3	0	4	0	0	0
Nov. 91	Ad	0	0	0	1P	0	0	1F	0	1F	0	0	0
	Egg	0	0	0	3	0	0	6	0	3	0	0	0
Dec. 91	Ad	0	0	0	1F	0	0	1F	0	0	0	0	0
	Egg	0	0	0	3	0	0	5	0	3	0	0	0
	Yg	0	0	0	0	0	0	1	0	0	0	0	0
Jan. 92	Ad	0	0	0	1F	0	0	1F	0	0	0	0	0
	Egg	0	0	0	3	0	0	3	0	3	0	0	0
	Yg	0	0	0	0	0	0	3	0	0	0	0	0
	FDR	0	0	0	0	0	0	1	0	0	0	0	0
Feb. 92	Ad	0	0	0	0	0	0	1F	0	0	0	0	0
	Egg	0	0	0	0	0	0	3	0	0	0	0	0
	Yg	0	0	0	0	0	0	3	0	0	0	0	0
	FDR	0	0	0	0	0	0	2	0	0	0	0	0
Mar. 92	Ad	0	0	0	0	0	0	1F	0	0	0	0	0
	FB	0	0	0	0	0	0	3	0	0	0	0	0

Recordings were continued until Dec. 1993

Ad = no. of adult barn owls
FP = no. of faecal pellets found in nest
1P = 1 pair of barn owls (a male and a female)
1F = a single female barn owl
Egg = no. of eggs found in nest
Yg = no. of young found in nest
FB = no. of fledging owls found in nest
FDR = no. of fresh dead rats found in nest

occupied by a pair and 31 nests by single females. The mean monthly nest occupancy between single females (2.6 ± 2.2) and paired owls (2.1 ± 1.4) was not significantly different (t = 0.6642, D.F. = 22, p = 0.52, *Table 3*).

The total number of broods in Felcra Seberang Perak was 150 with an average of 5.28 ± 3.3 broods/month (range 1–12). Each brood had 6.5 ± 2.5 eggs (range 2–10) with a total of 722 eggs for the period. Hilir Perak had a total of 25 broods with an average of 2.5 ± 2.0 broods/month (range 1–7) and the brood averaged 5.1 ± 1.4 eggs (range 2–9) with a total of 118 eggs. The mean monthly brood in Felcra Seberang Perak was significantly (t = 3.002, D.F. = 173, p <0.001) larger than that of Hilir Perak, whereas the mean monthly number of eggs per brood did not differ significantly (t = 1.6926, D.F. = 22, p = 0.10).

Other than eggs, owl regurgitated (faecal) pellets *(Figure 1)* containing bones and hair remnants of the rats were also found inside the nest boxes. The number of faecal pellets ranged from one to 10 although the interval between inspection rounds was 30 days *(Table 1* and *Table 2).* In February 1991, five nest boxes of Felcra Seberang Perak were found having a layer of bedding material (approx. 1 cm thick) formed from mashed faecal pellets. Thus quantification of faecal pellets was discontinued.

By the third month of occupancy, young owlings were present with the female adults in some of the nests *(Table 1* and *Table 2).* The average monthly number of

Table 3. Occupancy of nesting boxes by barn owls and other parameters in Felcra Seberang Perak and MARDI Hilir Perak

Parameter	Felcra Seberang Perak	MARDI Hilir Perak
No. of nestings	252	50
Nesting with paired owls	59	19
Nesting with single females	193	31
Av. monthly nest occupancy	7.9 ± 3.3 (0–12)	3.1 ± 2.3 (0–9)
Occupancy by paired owls	2.4 ± 1.4 (1–5)	2.1 ± 1.4 (1–5)
Occupancy by single females	6.1 ± 3.7 (1–11)	2.6 ± 2.2 (1–7)
Total no. of broods	150	25
Total no. of eggs	722	118
Av. monthly no. of broods	5.3 ± 3.3 (1–12)	2.5 ± 2.0 (1–7)
Av. monthly no. of eggs/brood	6.5 ± 2.5 (2–10)	5.1 ± 1.4 (2–9)
Total no. of nests with young	90	15
Total no. of young	362	39
Av. monthly no. of nests with young	3.9 ± 2.8 (1–9)	2.2 ± 1.3 (1–4)
Av. monthly no. of young/nest	3.6 ± 1.9 (1–7)	2.1 ± 0.9 (1–3)
Total no of nests with fledging birds	90	15
Av. monthly no. of nests with fledging birds	2.7 ± 1.6 (1–6)	2.0 ± 1.7 (1–4)
Av. monthly no. of fledging birds/nest	2.8 ± 1.4 (1–5)	2.3 ± 0.8 (1–3)
Total no. of nests with dead rats	78	13
Total no. of dead rats	136	14
Av. monthly no. of nests with dead rats	3.4 ± 2.4 (1–8)	1.8 ± 1.2 (1–4)
Av. monthly no. of dead rats/nest	1.6 ± 1.1 (1–6)	1.3 ± 0.5 (1–2)

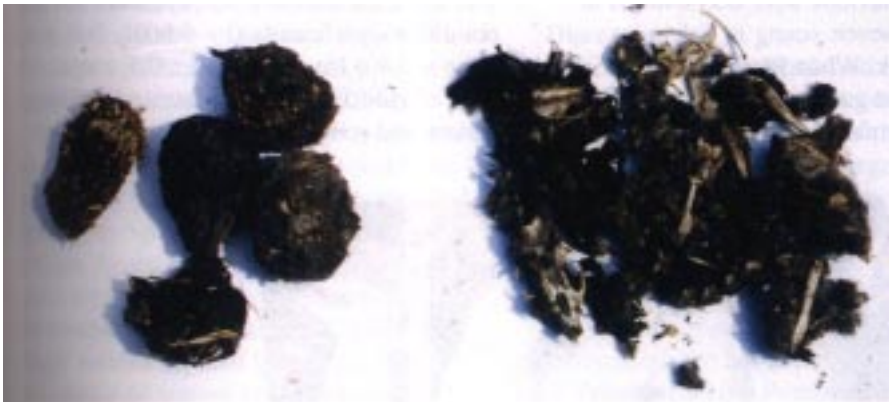

Figure 1. Regurgitated pellets (bones and hairs of rats) found in barn owl nesting boxes

nests with young was 3.9 ± 2.8 (range 1–9) with a total of 90 nests (over the 34 months) with young in Felcra Seberang Perak. The number of young in each nest averaged 3.6 ± 1.9 (range 1–7 young) per month. The average hatching rate was 50 ± 27% (range 14–100%). In Hilir Perak, there was a total of 15 nests with 39 young. The monthly number of nests with young averaged 2.2 ± 1.3 (range 1–4) and the number of young in each averaged 2.1 ± 0.9 (range 1–3) per month. The average hatching rate was 31 ± 26% (range 16–100%). The monthly number of nests (t = 1.9076, D.F. = 22, p = 0.05) and the number of young in each nest (t = 2.4716, D.F. = 22, p = 0.025) in Felcra Seberang Perak were significantly higher than that in Hilir Perak. In both areas, there

were instances of no hatching (60 broods in Felcra Seberang Perak and 10 broods in Hilir Perak). Most of the nests containing these broods had only single female parents (55 in Felcra Seberang Perak and seven in Hilir Perak) and the remainder (five in Felcra Seberang Perak and three in Hilir Perak) had paired parents.

By the fourth and fifth month after occupancy, the 2 to 3-month-old owls learned to fly and their feathers changed from primary to secondary plumage. The mean monthly number of nests with fledging birds in Felcra Seberang Perak was 2.7 ± 1.6 and did not differ significantly (t = 1.039, D.F. = 22, p = 0.31) from that (2.0 ± 1.7) of Hilir Perak. The number of fledging birds per nest which averaged 2.8 ± 1.4 (range 1–5) per month in Felcra Seberang Perak, also did not differ significantly (t = 1.0742, D.F. = 22, p = 0.30) from that (2.3 ± 0.8; range 1–3) of Hilir Perak. About 80% of the owlings in Felcra Seberang Perak and 90% of the owlings in Hilir Perak reached the fledging bird or adult phase.

Owling carrions were encountered in 10 nests with seven young in Felcra Seberang Perak. When four or less eggs were laid, these gave rise to young and eventually completed their life cycle. If there was mortality, only one young was involved. In 26 nests in which five eggs were laid, four young were raised, of which all four in 22 nests and three birds in four nests completed the life cycle. However, when seven or more eggs were laid, at the most seven would hatch and not more than five would complete the life cycle. Each life cycle lasted 4–5 months.

During the egg incubation period in Felcra Seberang Perak, 78 nests had freshly decapitated rats *(Table 3)*. The average monthly number of nests with decapitated rats was 3.4 ± 2.4 (range 1–8) and was significantly (t = 2.0656, D.F. = 22, p = 0.05) higher than that (1.8 ± 1.2; range 1–4) of Hilir Perak which had 13 nests with decapitated rats. Decapitated rats and rat carcasses *(Figure 2)* were more frequently (75 out of the 78 nests in Felcra Seberang Perak; 12 out of 13 nests in MARDI Hilir Perak) encountered in the nests during the phase of young raising.

The average number of decapitated rats per nest in Felcra Seberang Perak *(Table 3)* was 1.6 ± 1.1 (range 1–6) per month and did not differ significantly (t = 0.8601, D.F. = 22, p = 0.40) from that (1.3 ± 0.5; range 1–2) of Hilir Perak. There were no definite pattern and relation between the brood size

Figure 2. Decapitated rats and rat carcasses found in some barn owl nesting boxes during phase of young raising

and the number of decapitated rats. Similarly, there was no pattern or relation between the brood size and the size of decapitated rats. All decapitated rats and carcasses had the lower body portion and the whole tail intact.

There were 136 freshly killed and decapitated rats from the nests in Felcra Seberang Perak, i.e. 129 *R. tiomanicus,* 3 *R. rattus diardii* and 4 *R. argentiventer*. There were 60 males and 76 females. Most of these freshly killed rats weighed 40–70 g, with tail lengths of 8.0–12.2 cm. The decapitated rats had tail lengths of 11.2–19.6 cm. At Hilir Perak, only 14 freshly killed and decapitated rats were found in the nesting boxes. All were *R. tiomanicus* and the tails measured 10.8–15.5 cm.

The pellets varied in size. A large pellet might contain two sets of jaws, one of a medium-sized rat and the other of a smaller-sized rat, or a set of large skull and other body bones. Small pellets had cervicle and other small bones but without skull. Other than owl faecal pellets, freshly killed rats, rat carcasses and owl carrion, a nest each had remnants of the cow shepherd bird, common mynah and snake scales respectively at Felcra Seberang Perak.

Occupancy of the nest boxes appeared to be cyclical *(Figure 3)*. There were two phases in a year, from July to October and January to April. In Felcra Seberang Perak *(Figure 3)*, the low occupancy period was quite distinct from May to August and November to January although there were larger number of birds in the latter. The occupancy of nesting sites appeared to correspond with the rainfall pattern in which a higher owl abundance/occupancy rate occurred in the wetter months of the year. At Hilir Perak, the pattern of nest occupancy was not that apparent although there were distinct periods of nest occupancy *(Figure 3)* from January to May, and September to November, and non-occupancy period from June to September/October. Similarly, the lower occupancy tended to coincide with the drier months.

Nest occupancy was normally less than 100% (except for 4 months) throughout the study duration. At most times (except for the 4 months), more than a nest box were unoccupied. Nest occupancy was low in Hilir Perak but high in Felcra Seberang Perak. Two nest boxes in Felcra Seberang Perak occupied by barn owls on four occasions were never used for breeding (no eggs were found). These boxes were more exposed to light while the others shaded by oil palm fronds were occupied most of the time.

The total number of birds recorded at each occasion of inspection also corresponded with the rate of occupancy *(Figure 3)*. A larger number of birds were recorded in Felcra Seberang Perak than in Hilir Perak. The phases of eggs to young, and to fledging birds tended to follow in sequence *(Figure 4)* for both Felcra Seberang Perak and Hilir Perak. A large number of eggs were followed by a smaller number of young hatched and a smaller number of fledging birds.

Discussion

In Felcra Seberang Perak and Hilir Perak, a duration of about 6 months taken to establish nesting indicates fairly rapid area colonisation by barn owls, regardless of crop. The large numbers of owl arrivals and departures at the dispersal phase are characteristic of a successful avian colonist. Differences in the time and interval of colonisation should be considered when interpreting the larger number of barn owls in Felcra Seberang Perak than in Hilir Perak. A higher rate of barn owl colonisation occurred in Felcra Seberang Perak although both sites apparently were unoccupied habitats made available by the presence of nesting boxes, coupled with an abundance of food source. The food source (rat population) in oil palm fields is larger (Wood 1969; 1984) than that of cocoa fields (Kamarudin 1982, 1986; Lee and Arikiah 1984; Lee and Kamarudin 1986). This is probably one of the factors for the higher

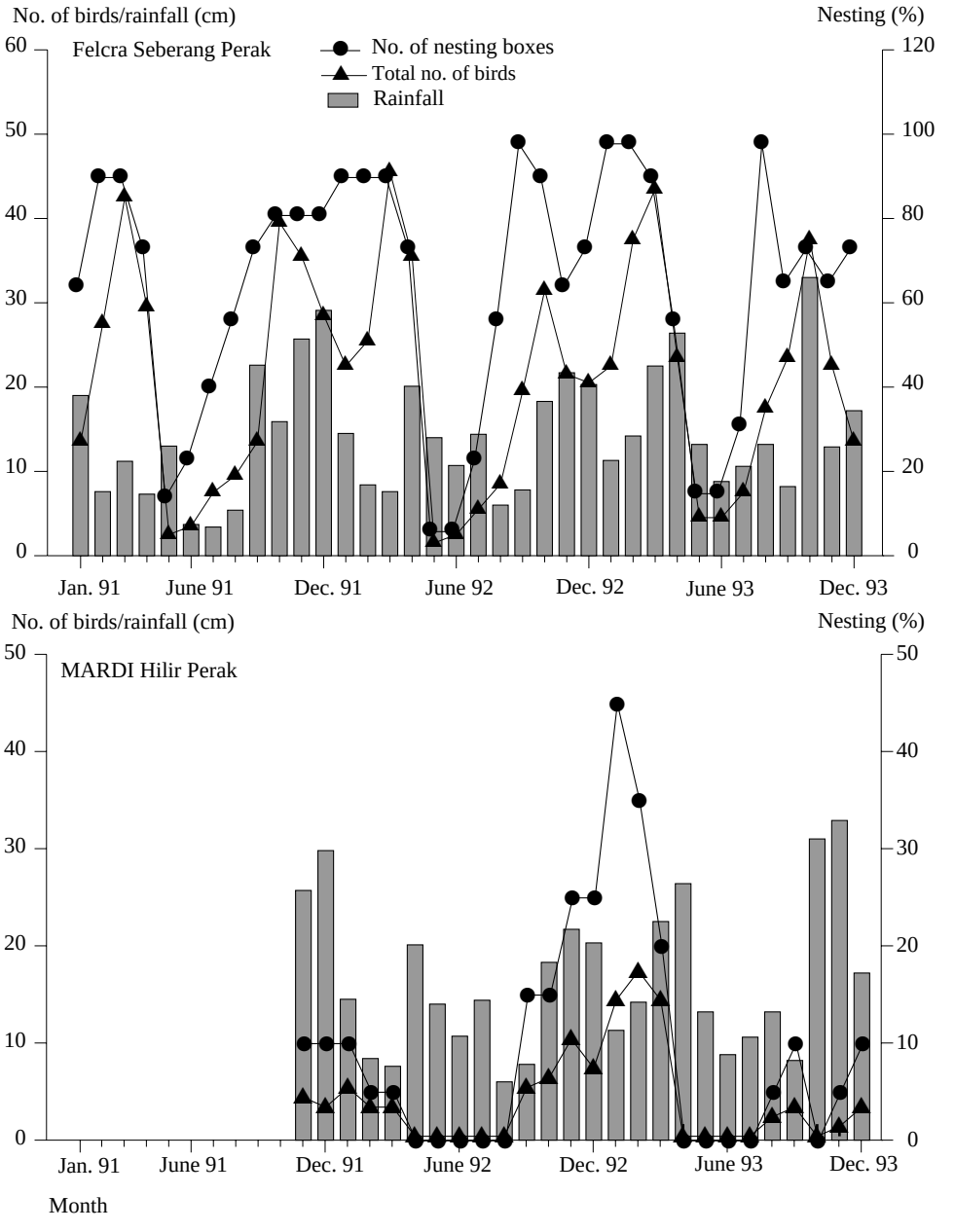

Figure 3. Occupancy of nesting boxes by barn owls in Felcra Seberang Perak and MARDI Hilir Perak

rate of colonisation. Lenton (1980) envisaged that the barn owl in Peninsular Malaysia had shifted from its original open country to tree plantation habitat.

The brood size (5.1 and 6.5 eggs respectively) noted in the cocoa fields of Hilir Perak and oil palm fields of Felcra Seberang Perak was similar to that (4.6–6.6 eggs) in Carey Island, Muar and Labis as reported by Lenton (1980). Owling mortality, cannibalism and fledging success of the birds were similar to those reported by other workers (Hoekstra 1975; Lenton 1980). The smaller brood average and owl

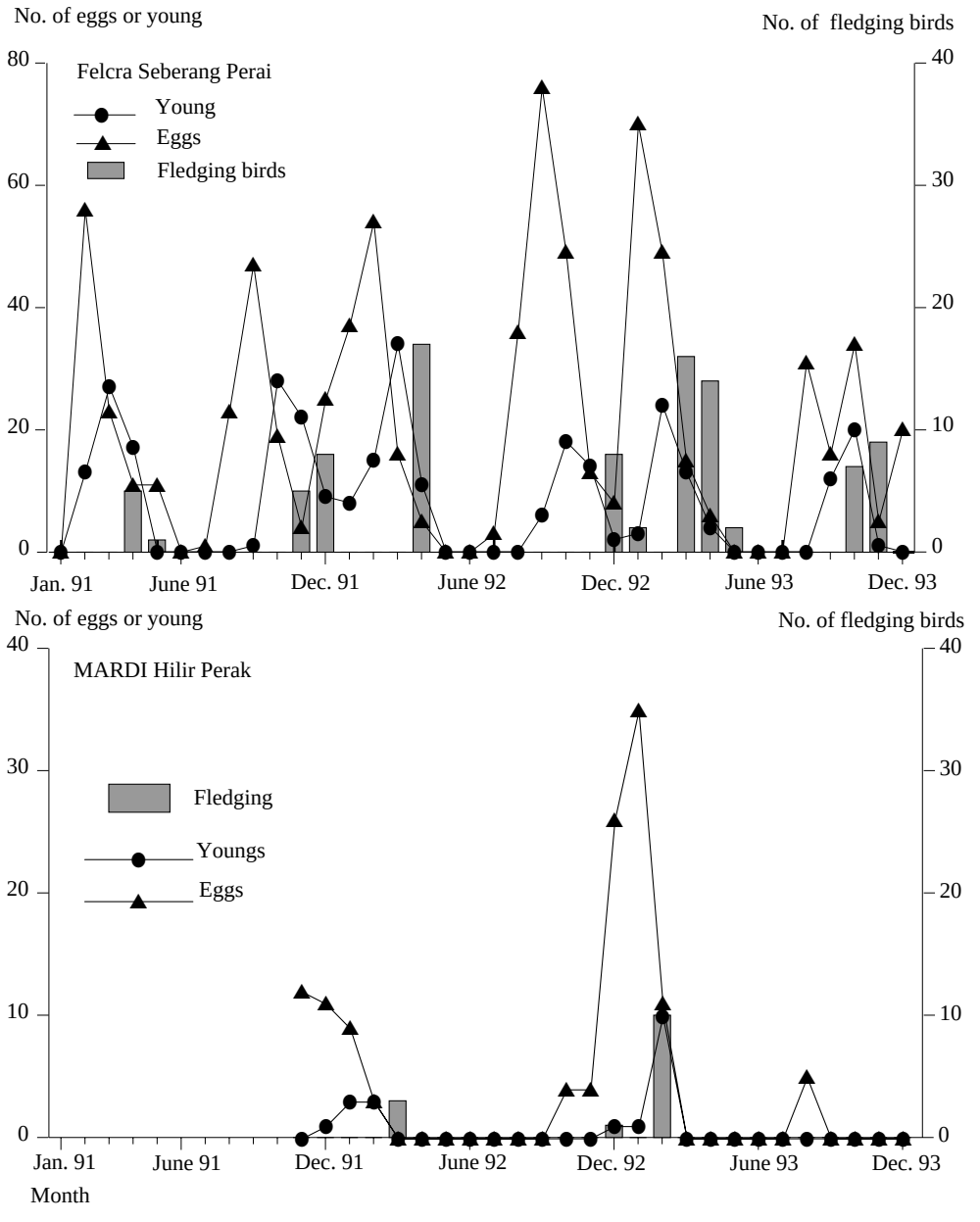

Figure 4. Number of eggs, young and fledging birds raised in barn owl nesting boxes of Felcra Seberang Perak and MARDI Hilir Perak

abundance in Hilir Perak could be due to its initial establishment or the smaller rat population/abundance in cocoa fields (Lee and Arikiah 1984; Lee and Kamarudin 1986; Kamarudin et al. 1991) as compared to that of oil palm (Wood 1984). This may be because birds of prey are reliant on and respond to their fluctuating food source, especially the brood size and breeding frequency. Lenton (1980) reported that constant long nights and consistently abundant prey in oil palm fields would favour the maintenance of large broods. It is apparent that the breeding potential of barn

owls in cocoa and coconut fields is lower than that in oil palms.

Nesting and parental care of the young showed that more decapitated rats were found in the nest boxes of Felcra Seberang Perak as compared to that in Hilir Perak. This points to the availability of more food source in oil palm areas culminating with a larger brood size, as the niche is probably far from being filled; thereby r-selection is operative to enable a high rate of reproduction to exclude possible competitors. This indicates that natural selection is proceeding to maximise 'r', the reproductive rate for populations that are below the carrying capacity (Cody 1966).

Some remnants of the cow shepherd bird (its light greenish egg in the nests), common mynah and snake scales noted in the owls' nests showed a low degree of predation upon these animals. Snake scales could indicate owl predation culminating with the owl being the victor. Predation of barn owl eggs or chicks was not observed throughout the study although Shamsiah and Goh (1991) mentioned that barn owl eggs in nest boxes of Seberang Perak rice fields were preyed upon by crows. These findings show that predation upon owls if any is very low, and the owl could play a dominant and effective role in field rat control. The presence of almost 100% of rat bones in the faecal pellets shows that barn owls are exclusively rat predators and useful as a natural means of rat control.

In this study, monthly faecal pellet collection was discontinued from the second month as the number of pellets collected from each nest (1–10) was less than 30 (the expected number based on 1 pellet/owl daily), the time interval between collection. This indicates that prey consumption and pellet regurgitation did not always occur within the nest box. Furthermore, laboratory findings indicated faecal pellets were either regurgitated in the nest or at the feeding site (Lee 1991), hence reducing the usefulness of faecal pellet collection at the nest. Pellet analysis could not be used to identify the rat species preyed upon for the bone dimensions for all 'field rat' species overlapped (Yong 1968). However, the presence of rat carcasses and remnants with the head missing in the nests is useful for the confirmation of the rat species preyed upon.

The presence of *R. tiomanicus, R. r. diardii* and *R. argentiventer* carcasses in the barn owl nest boxes of Felcra Seberang Perak showed that all three species of field rat present in rice, cocoa and oil palm fields were preyed upon. The large number of *R. tiomanicus* carcasses found in Felcra Seberang Perak nests in contrast to very few *R. argentiventer* and *R. r. diardii* may be that the former was presence in abundance and easier to prey upon. In Hilir Perak nests, the presence of only *R. tiomanicus* carcasses substantiates that the predominant pest in the field is preyed upon. Both field findings substantiate that barn owls preferably fed upon *R. tiomanicus* as found in laboratory findings (Lee 1991).

The rat carcasses showed that average and medium-sized *R. tiomanicus* were predominantly preyed upon. The tail length of 11.2–19.6 cm of decapitated *R. tiomanicus* from Felcra Seberang Perak showed rats preyed upon were 80–160 g while that (10.8–15.5 cm) of Hilir Perak were 50–80 g rats, further substantiated the above. Other than efficient in predation, the barn owls could have much more impact than just 'harvesting' the rats. They reduce the number of potential breeding animals, thereby reducing the intrinsic rate of field rat increase.

The presence of rat carcasses and regurgitated faecal pellets in the field nesting boxes of barn owls, especially in cocoa fields, substantiates earlier laboratory studies of barn owls' ability to prey upon rats with cocoa seedlings to impede their movement (Lee 1991). Furthermore, the preference and selection for preys of smaller body weight can be easily found in cocoa-coconut fields.

The cyclical pattern of barn owl reproductive activity is not apparent from

the recordings of adult birds and nest occupancy. However, it is clearly reflected in the breeding and development cycle of the barn owl beginning with the egg phase. The cyclical correspondence of higher owl occupancy and breeding during the wetter months is in rhythm with that of rats reported in population studies (Kamarudin 1982; Lee 1995). Field rat activity has been reported to increase from the dry to the wet periods (Harrison 1952). Studies in Algeria have also shown the rodent population increases at the onset of the raining season (Fiedler, L. A., USDA, pers. comm. 1992). In rice fields, the rat activity and population also increase at the onset of seeding during the wet planting season (Lam 1980). Despite the relatively high uniformity of the equatorial tropics without seasonal fluctuations of food flush seen in higher latitudes, the seasonal changes in food supply between wet and dry spells could contribute to these rhythmic changes.

Double broodedness observed here was also generally noted by Lenton (1980). In two other oil palm sites of Johor, he noted that there could be three broods over 14 months. The number of broods depends on the duration for completing the development cycle with sufficient food and time, which in temperate zones is directly related to season (Newton 1978). Thus in places such as Great Britain, Utah and Maryland (U.S.A.), *T. alba* would produce one brood a year (Lenton 1980). The phenomenon of two broods a year is typical in areas where there are two wet seasons giving rise to two seasons of prey abundance in relation to raptors of short breeding cycles (Macdonald 1977).

The factors responsible for the onset of egg laying are unclear although synchrony in nest occupancy and breeding coincided with the wetter months of the year. The wet period in the hot equatorial area probably provides a relatively cool and airy environmen that favours breeding. Selection and use of nests within shaded palm areas, and non-selection of nests exposed to direct sun further substantiate the preference for a ventilated airy environment. This is further supported by the low presence of birds and the low or non-occupancy of the nesting boxes in the drier months.

The findings of the field study showed that barn owls could be established in cocoa-coconut fields as in oil palms. Although the establishment of barn owls in cocoa-coconut fields is lower than that in oil palm, it nevertheless provides evidence for the successful establishment of barn owls in cocoa-coconut agroecosystem. This supports the possibility of using barn owls as a component for the control of rats in such an agroecosystem as in oil palm fields.

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