Surveys of nocturnal birds at Bala rainforest, southern Thailand

ALAN KEMP, MEG KEMP and SIRIPORN THONG-AREE

We conducted surveys for nocturnal birds (Strigiformes, Caprimulgiformes) at Bala rainforest, southern Thailand, in the ten lunar months from March to November 2004, mainly between dusk and midnight of successive nights in the week preceding full moon. At 0.5-km intervals along the 12.6 km of road that bisects Bala, we listened for calls both before and after broadcasting a 1-min recording of the loud call for each of the species that we expected. We also searched, by day and on non-survey nights, for additional signs of nocturnal species along or near the road, especially of Buffy Fish Owl *Ketupa ketupa* and nightjars. From all detections of a species, whether heard calling, responding to our broadcast, or seen, we estimated its distribution, temporal and spatial relative abundance, and density along the road. Two species were new records for Bala, Oriental Bay Owl *Phodilus badius* and Brown Wood Owl *Strix leptogrammica.* Two small insectivorous species were the most widespread and abundant, Collared Scops Owl *Otus bakkamoena* and Javan Frogmouth *Batrachostomus javensi,* at ~8.0/km² and ~5.5/km², respectively. We detected three medium-sized to small species, Oriental Bay Owl, Reddish Scops Owl *Otus rufescens* and Brown Hawk Owl *Ninox scutulata*, as well as a possible fourth species, Gould's Frogmouth *Batrachostomus stellatus*, only in lowland forest below ~300 m asl; all were at low overall densities of ≤1.6/km². Three large species also occurred at low densities, but probably as widely spaced territorial pairs along the road: Barred Eagle Owl *Bubo sumatranus* at ≤2.5 km/pr, Brown Wood Owl *Strix leptogrammica* at ≤4.2 km/pr, and Buffy Fish Owl at ≤2.5 km/pr, the last estimated from spacing of signs along streambeds. Smaller species were most vocal during the middle of the dry season (May) and larger species during the south-west monsoon (August–September). Grey Nightjar *Caprimulgus indicus* was the only common caprimulgid, a boreal migrant detected during November to April. Our results are useful for preliminary ecological and management analyses, but require repetition, refinement of technique and comparison with results from different Indomalayan forests to improve their applicability.

INTRODUCTION

Nocturnal birds are difficult to survey in any habitat, especially in forests where the prospects of seeing them by day are slight and finding them at night are difficult. Fortunately, most nocturnal forest species are vocal, utter loud and/or distinctive calls, and respond to broadcast of their calls (Gerhardt 1991, Takats *et al.* 2001, Delport *et al.* 2002, Newton *et al.* 2002) or even those of other species (Enriquez and Salazar 1997). We conducted a survey over ten lunar months for nocturnal species in a lowland and submontane rainforest of southern Thailand, based on repeated broadcasts of their calls. In rainforests of the Thai-Malay Peninsula, owls (Strigiformes), and frogmouths and nightjars (Caprimulgiformes) are the main nocturnal orders (Wells 1999). Other mainly diurnal orders with species that show crepuscular and/or nocturnal activity, such as Bat Hawk *Macheiramphus alcinus* (Falconiformes), Great Argus *Argusianus argus* (Galliformes) and Helmeted Hornbill *Buceros vigil* (Bucerotiformes), were present but are discussed elsewhere (Kemp and Kemp 2007).

Southern Thailand is on the Isthmus of Kra and so is the only part of that country to include habitats with a comprehensive representation of the rich Sundaic fauna and Malesian flora (Wells 1999). The few conservation areas within these habitats are therefore of particular national significance, but also of regional importance given the conservation threats facing the high biodiversity of the entire Sundaic region, especially its lowland forests and birds (Wells 1999, Ibrahim *et al.* 2005). Efforts have been made in southern Thailand to establish the presence and population status of various taxa (e.g. Gale and Thong-aree 2006, Kemp *et al.* 2007, Kemp and Kemp 2007, Pattanavibool *et al.* 2007), but so far no attempt has been made to survey nocturnal birds other than establish a preliminary list of species (Thong-aree 2004). Two of the species on this list are of international conservation concern, Reddish Scops Owl *Otus rufescens*, which is listed as Near Threatened, and White-faced Scops Owl *O. sagittatus*, listed as Vulnerable (IUCN 2007). Our survey attempted to confirm which species were present, their abundance, and how best to monitor their populations.

STUDY AREA

The Bala section of Hala-Bala Wildlife Sanctuary covers 111.5 km² of the San Kala Kiri mountains on the southern border of Thailand, at altitudes ranging from 50–960 m asl (5°44′–57′N 101°46′–51′E; Fig. 1). The Hala section, which has forests rising to about 1,400 m asl, is a larger area of 314 km² about 22 km to the west of Bala, and separated from Bala by a ≥5 km wide corridor of agricultural land. The high rainfall on the sanctuary has eroded the granite, sandstone and laterite geology into a series of sharp ridges and deep valleys. The vegetation at Bala is rainforest, classified as Malayan-type Tropical Lowland Rainforest and comprised of dipterocarp and palm communities, dominated along the ridges by *Shorea* trees and *Eugeissona* and *Johannesteijsmannia* palms (Niyomtham 2000). Selective logging occurred at Bala prior to the national logging ban of 1989, mainly during the 1970s, with additional felling along the road during its construction in 1987–1992. Declared a wildlife sanctuary in 1997, Hala-Bala was by then already surrounded by secondary forest and agriculture (details in Gale and Thong-aree 2006, Kemp *et al.* 2007). However, the entire Hala-Bala Wildlife Sanctuary still supports at least 366 species of birds (Thong-aree 2004), including most of those expected for this Sundaic fauna (Wells 1999), and it retains Malesian flora of sufficient quality to provide food and nest sites for many species.

Rainfall occurs in all months at Bala, least during the hot season (February–July), mainly as afternoon thunderstorms during the south-west monsoon (August–

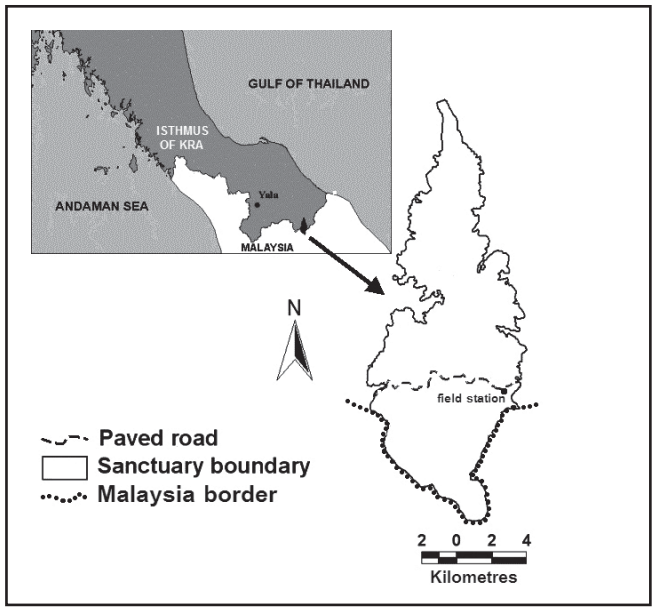

Figure 1. Map showing the position of Bala within southern Thailand and of the road through the Bala section of Hala-Bala Sanctuary.

October), and with a peak during the north-east monsoon (November–January). Mean annual rainfall at Waeng (weather station 583008; 13 km NNE of the east end of the Bala road; 50 m asl) was 3,455 mm (1992–2004; SD 650 mm), but the total rainfall during 2004 was only 77% of the mean and only above the monthly average in September–October. The mean annual temperature at Sukhirin (weather station 553201; 16 km NNW of the east end of the Bala road; 120 m asl) was 27°C (maximum monthly mean 32°C, minimum mean 24°C) and mean annual relative humidity 82% (monthly mean maximum 94%, mean minimum 67%). The hottest months were March–May and the coolest November–January, while relative humidity, although consistently high, varied inversely with temperature.

We conducted our survey along the 12.6 km of paved road that bisects Bala from east to west, and is marked off at 0.5-km intervals (see Fig 1). The altitude along the road ranges from 99 m asl (at 0.0 km and the east gate) to 572 m asl (at 10.0 km and the highest point), and then drops to 308 m asl (at 12.6 km and the west gate). Bala forms part of the catchment area for the Ko-lok River and some of its tributaries, including the Khlong Ai Krading stream that runs alongside much of the eastern part of the road.

METHODS

We searched for 13 nocturnal species already reported from Bala (Thong-aree 2004). These species, listed wherever possible in the sequence of Inskipp *et al.* (1996), with their size indicated by body mass (del Hoyo *et al.* 1999), are as follows: White-fronted Scops Owl, 120 g; Reddish Scops Owl, 77 g; Collared Scops Owl *Otus bakkamoena*, 100–120 g; Barred Eagle Owl *Bubo sumatranus*, c.600 g; Buffy Fish Owl *Ketupa ketupa*, c.600 g; Spotted Wood Owl *Strix seloputo*, 1011 g; Collared Owlet *Glaucidium brodiei*, c.53–63 g; Brown Hawk Owl *Ninox scutulata*, 172–227 g; Gould's Frogmouth *Batrachostomus stellatus*, 47–49 g; Javan Frogmouth *B. javensis*, 46–47 g; Malaysian Eared Nightjar *Eurostopodus temminckii*, c.80 g; Grey Nightjar *Caprimulgus indicus*, 60–108 g; and Large-tailed Nightjar *C. macrurus*, 54–79 g. We also searched for another species known from the nearby Hala rainforest (Mountain Scops Owl *Otus spilocephalus*, 55–120 g), and three additional species indicated from the literature (Lekagul and Round 1992, del Hoyo *et al.* 1999, Wells 1999, Robson 2002) as likely for the area (Oriental Bay Owl *Phodilus badius*, 255–308 g; Brown Wood Owl *Strix leptogrammica*, 500–700 g; and Large Frogmouth *Batrachostomus auritus*, 206 g.

We conducted our survey over the 10 lunar months from March to November 2004 (Table 1). We performed a standard routine for each lunar month of broadcasting calls and listening for responses at 0.5-km intervals along the 12.6 km of road (see Appendix for details). We attempted to confine our surveys to between the onset of darkness and midnight, spread over several successive nights in the week preceding full moon, and continuing each night from where we had left off the previous night. Initially we started our surveys at the eastern end of the

Table 1. Details of surveys along the road through Bala rainforest, southern Thailand, over 10 successive lunar months of 2004, showing the date of full moon, dates of surveys, earliest and latest times of night for broadcasts, whether done at the 0.50- or 0.25-km markers, whether started at 0.0 or 12.5 km, and the total number of locations where broadcast.

Date of full moon	Survey duration	Broadcast start and finish		Markers used		Starting location, km	No. of broadcast locations used in analyses
		Earliest	Latest	0.5-km	0.25-km		
6 March	2–5 March	19h24	22h15	x		4.0*	17
5 April	31 March–10 April	19h05	23h05**	x		2.0	25
4 May	30 April–5 May	18h40	22h10		x	0.25	24
3 June	29 May–4 June	18h45	22h00	x		0.0	25
2 July	27 June–1 July	18h50	21h40		x	12.25	24
31 July	25–31 July	18h45	21h55	x		0.0	25
30 August	25–29 August	18h50	21h55		x	0.25	25
28 September	21–26 September	18h50	22h00	x		0.0	24
28 October	10–27 October	18h20	21h15	x		0.0	15***
26 November	18–21 November	18h20	22h00		x	12.25	24

*Only most eastern locations tested in first month.
**Three locations at the west end of the road had to be completed during 04h10–05h15 on 10 April.
***Military orders curtailed survey.

road (0.0 km) and conducted our broadcast routine at each 0.5-km road marker, but on alternate lunar months from 5 April we broadcast from midway between the 0.5-km markers (i.e. at the 0.25-km and 0.75-km positions along the road; Table 1). In this way, over two successive lunar months, we carried out our broadcast routine at each 250-m interval, and so ensured a finer scale for detection. We also alternated the start of successive lunar-monthly surveys from opposite ends of the road for the 0.25/0.75-km surveys, starting at the western end from the 12.5 km mark, to minimise effects of broadcasting earlier or later in the evening and on different days before full moon. We recorded the coordinates and altitude at each broadcast location with a portable GPS (Garmin Etrex Vista). We never attempted to broadcast or listen at 4.25 km and 4.5 km, where a broad treeless verge and noisy waterfalls made the effort futile, but we included both locations in our calculations as this unsuitable habitat was still part of our overall survey area.

To broadcast the calls, we used a cassette tape player with four speakers built into a 3-door Suzuki SF413 Caribian 4×4 vehicle, with one speaker in each of the front door panels and one on either side of the rear luggage compartment. We opened all doors during each broadcast, the player was set to maximise base tones and minimise tape noise, and we turned the volume as high as possible without causing distortion. Under normal conditions and along the open road, we could hear the broadcast of each target species's calls from at least 250 m, and we knew from their responses that all species were heard and able to hear from at least that distance. We did not attempt to broadcast or listen during periods of rain or strong wind.

On arrival at each broadcast location, our basic technique was to listen for 5 min, broadcast a 1-min cut of the loud call of a target species, listen for a response, then play and listen for the next species, and so on until we had broadcast and listened for all target species for that lunar month and location. Which species were broadcast, the order in which they were broadcast, the source of recordings used for each species, and the intervals of silence between successive recordings evolved during the study, and so changed between lunar months as we developed our experience of the area and species involved, and obtained new or improved recordings (see Appendix). We compiled a new cassette tape for each lunar month that included all periods of silence and calls played, thereby presenting a consistent lunar-monthly routine and quality of broadcast at each location (Takats *et al.* 2001). From July, for the last six lunar months, we did not broadcast recordings of Oriental Bay Owl, Reddish Scops Owl and Brown Hawk Owl (and some other undetected species) between 4.0 km (287 m asl) and 12.0 km (389 m asl), and we also moved these species to the latter part of the playback tape for convenience during broadcasts. This excluded highland areas above ~300 m asl, where these species had been undetected previously, and so reduced the time necessary to complete the lunar-monthly surveys (see Appendix).

At each broadcast location, whenever we heard a call or saw a bird, we identified the species involved and estimated its distance (to the nearest 50 m) and direction (to the nearest octant) from the broadcast point. We also noted if the call/sighting was a 'response' to our tape (i.e. if, within the broadcast or subsequent listening period for the species concerned, the individual either made its first call or appearance or, if it had been calling previously, responded again and/or moved closer).

We used additional search methods for some species. For Buffy Fish Owl, we paddled along stretches of river by day looking for characteristic owl-like droppings or pellets on rocks, logs, branches and bridges. We did this mainly in April–September, when river levels were lowest, especially after drier periods with little or no rain to wash away any signs. For nightjars, we attempted some broadcasts initially (see Appendix), but after failing to obtain any vocal responses we searched with the vehicle's headlights along the road and with a spotlight on road verges in the course of our regular broadcast surveys and other work. In addition, by night or day throughout 2004 we recorded any calls heard or sightings made of nocturnal birds, especially around the Hala-Bala Wildlife Research Station where we resided (see Fig. 1) and along the road and adjacent trails where we conducted most of our other fieldwork.

We analysed our data by species, location and lunar month using two measures per broadcast location: (1) the mean number of individuals detected over all relevant broadcast periods and (2) the highest number of different individuals ever detected within a single broadcast sequence. We compared mean and highest numbers by species using Spearman's Rank Correlation, and considered $P=0.05$ significant, as calculated with SigmaStat 3.5. For comparison with altitude, we compared mean number of detections per location at 0.25-km intervals, to provide maximum resolution, but note that we did separate lunar-monthly surveys at only 0.50-km intervals, so that adjacent means at 0.25-km intervals were statistically independent with respect to the probability of detecting an individual at that particular altitude. However, when we estimated the density for each species, within the habitats encompassed by a circle of 250 m radius around each broadcast location (an area of 0.196 km² or a total survey area of 4.71 km² for all 24 lunar-monthly locations combined), we calculated the estimates twice, first using surveys done at the 0.5-km markers, and second using surveys done midway between the 0.5-km markers (at 0.25 km and 0.75 km), so that the surveys formed separate samples and excluded false replication of individuals detected.

RESULTS

Species detected

Our surveys along and around the road through Bala forest detected seven species of owl (Oriental Bay, Reddish Scops, Collared Scops, Barred Eagle, Buffy Fish, Brown Wood and Brown Hawk Owl), one or probably two species of frogmouth (certainly Javan, probably Gould's) and one or probably two species of nightjar (certainly Grey, probably Malaysian Eared). Two owl species were new records for Bala (Oriental Bay and Brown Wood Owl). We did not detect four nocturnal species reported previously for Bala (White-fronted Scops Owl, Collared Owlet, Spotted Wood Owl and Large-tailed Nightjar), or two other species considered possible for the area (Mountain Scops Owl and Large Frogmouth).

All responses were aural, except twice when we detected Barred Eagle Owl visually before it started to call. The percentage of detections for the commoner owl

Table 2. Results of broadcast surveys for nocturnal species detected at 0.25 km intervals along the paved road through Bala rainforest, southern Thailand, during 10 lunar months in 2004. We recorded for each lunar month (a) the number of locations broadcast for each species, (b) the number of individuals detected across all broadcasts, separated by a "/" from the number of uncertain detections or detections during other non-survey activities in the lunar month preceding, and (c) the mean number detected per broadcast-location within each lunar month. For each species detected, the mean for the lunar months with the highest value is underlined.

Nocturnal species	Broadcast results	Lunar months by date of full moon: 6 Mar	5 Apr	4 May	3 Jun	2 Jul	31 Jul	30 Aug	28 Sep	28 Oct	26 Nov	Overall total or mean	% detections as responses during broadcasts
Oriental	a. Number of locations	0	0	12*	5	12	9	9	5	7	4	63*	
Bay Owl	b. Detections	0/0	0/0	0/0	0/0	1/0	3/0	0/1	0/1	0/0	0/0	4/2	100
(OBO)	c. Mean detections	x	x	0.00	0.00	0.08	0.33	0.01	0.02	0.00	0.00	0.06	
Reddish	a. Number of locations	12	15*	15*	5	12	9	9	5	7	4	93*	
Scops Owl	b. Detections	1/0	1/1	4/0	0/0	3/0	1/2	2/0	1/1	1/0	1/0	15/4	53
(RSO)	c. Mean detections	0.08	0.07	0.27	0.00	0.25	0.11	0.22	0.20	0.14	0.25	0.16	
Collared	a. Number of locations	17	25	25	24	25	25	25	25	12	26	229	
Scops Owl	b. Detections	4/1	6/2	26/2	9/1	9/4	18/0	14/1	16/1	8/0	6/1	116/13	27
(CSO)	c. Mean detections	0.23	0.24	1.04	0.38	0.36	0.72	0.56	0.64	0.67	0.23	0.51	
Barred	a. Number of locations	12	0	25	0	25	25	25	25	12	26	175	
Eagle Owl	b. Detections	0/1	0/0	0/1	0/2	0/1	3/0	3/2	3/1	1/0	0/1	12/9	40
(BEO)	c. Mean detections	x	x	x	x	0.00	0.12	0.12	0.12	0.08	0.00	0.07	
Brown	a. Number of locations	0	0	0	0	25	25	25	25	12	26	138	
Wood Owl	b. Detections	0/0	0/0	0/0	0/0	2/0	2/0	2/0	6/0	0/0	2/0	14/0	63
(BWO)	c. Mean detections	x	x	x	x	0.08	0.08	0.08	0.24	0.00	0.08	0.10	
Brown	a. Number of locations	12	14*	14*	14*	14*	9	9	5	7	4	102	
Hawk Owl	b. Detections	2/0	3/0	7/0	4/0	1/0	1/0	0/0	2/0	1/0	2/0	23/0	58
(BHO)	c. Mean detections	0.17	0.21	0.50	0.29	0.07	0.11	0.00	0.40	0.14	0.50	0.23	
Javan	a. Number of locations	17	25	25	24	25	25	25	25	12	26	229	
Frogmouth	b. Detections	8/0	11/0	15/0	8/0	15/0	14/0	8/0	11/0	3/0	7/0	101/0	75
(JFM)	c. Mean detections	0.48	0.44	0.60	0.33	0.60	0.56	0.33	0.44	0.25	0.27	0.43	

*For lunar-monthly comparison of species restricted to low altitudes, we calculated the mean in each lunar month only for the 12–15, or fewer, locations that covered the range within which we had detected each of these species in the first three months of our survey. See text for further explanation.

x = months without recordings available to broadcast.

and frogmouth species that were judged as responses to conspecific broadcasts varied from 27% to 100% (Table 2). Some species also responded to calls of other species: Collared Scops Owl to the similar calls of Reddish Scops Owl (3 times); Barred Eagle Owl to Brown Wood Owl (1) and Javan Frogmouth (1); and Javan Frogmouth to Oriental Bay Owl (3), Reddish Scops Owl (3), Gould's Frogmouth (2) and Barred Eagle Owl (1).

We detected a few owl species outside the lunar-month surveys by means other than broadcasting (Table 2). In particular, in our search for Buffy Fish Owl along the catchment area of the Khlong Ai Krading stream, upstream and within 5 km of the Hala-Bala Research Camp, we found three locations with suggestive signs (thick owl-like droppings and large pellets with crab and fish remains). At one location, just below the research station, an owl was flushed and positively identified by day by another observer in May (Surachai Rungkunakorn pers. comm.), while we also positively identified an owl at a fourth location, on the handrail of the bridge over the road at 3.8 km, during our September lunar-monthly survey.

For species other than owls, we recorded only two brief responses that could have been Gould's Frogmouth (May at 1.0 km and August at 0.75 km), despite a total of 215 broadcasts all along the road, and both of these responses were at low elevations, within 1 km of an even lower site well known to birders for this species. We counted at least six Grey Nightjars on roadside embankments at 4.5–6.0 km on the survey of 2 March, and during that week we caught a male and female by hand for examination. We continued to observe Grey Nightjars in the same area until 10 April, after which we did not see them there again until 21 November. On 10 March, by day, we flushed two nightjars from the forest floor near the road, one of which was suspected to be a Malaysian Eared Nightjar, and in May an unidentified large nightjar flew silently over the 1.0-km location when the call of this species was being played; these tentative records were from elevations below ~150 m asl.

Temporal and spatial distribution

The mean number of detections per location varied temporally for each species (Table 2). We detected the smaller species most frequently in May (Reddish Scops, Collared Scops and Brown Hawk Owls, and Javan Frogmouth), with the last two species also vocal in November and July respectively, while the intermediate-sized Oriental Bay Owl was detected most frequent in July, and the larger Barred Eagle and Brown Wood Owls even later, during July–September and September respectively.

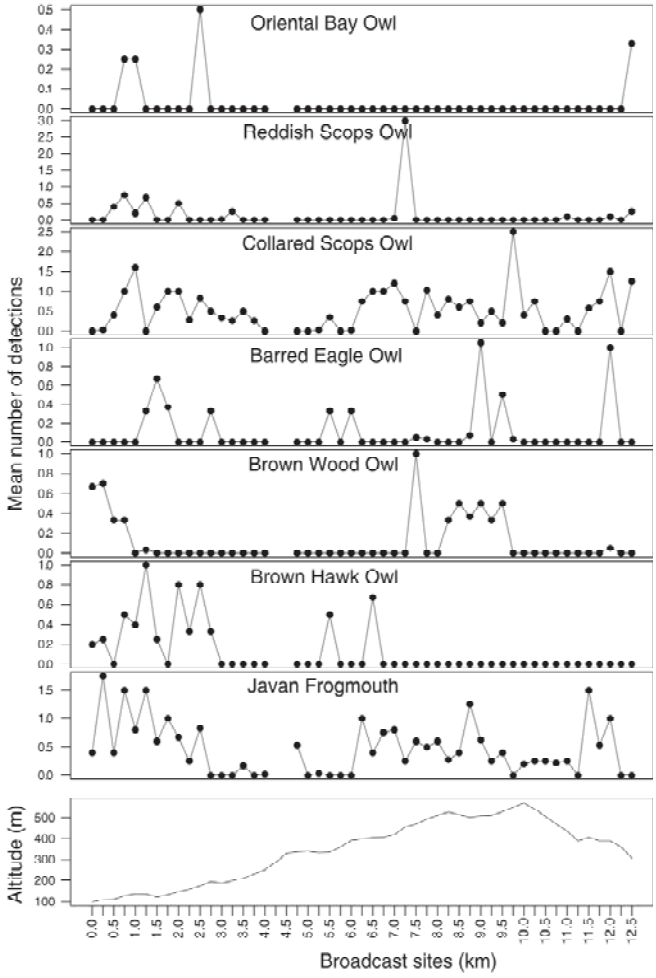

Figure 2. Mean numbers of seven nocturnal bird species detected over 10 lunar months of 2004, plotted at 0.25 km intervals above the altitude gradients along the 12.6 km of road through Bala rainforest, southern Thailand. On any one lunar-monthly survey, we did broadcasts only at locations 0.5 km apart and recorded number of individuals per species within a radius of 250 m. Abbreviations for species as in Table 2.

The mean number of detections per broadcast location also varied spatially, at least with respect to altitude (Figure 2). Two main patterns were evident. For Oriental Bay, Reddish Scops and Brown Hawk Owls, we detected them most frequently below ~300 m asl, although we did detect each species at broadcast locations up to 308 m, 456 m and 404 m asl, respectively. However, the detections made at the two highest locations were in steep terrain and the birds were actually calling from the floor of a deep valley at least 100 m below. After 6 June, we only broadcast calls for these species at altitudes below ~300 m asl, but we still never heard any of these species at higher altitudes during subsequent surveys. We detected all other species across the full range of altitudes, particularly Collared Scops Owl and Javan Frogmouth, while Barred Eagle and Brown Wood Owls were patchy in their distribution along the road.

Density estimates

We estimated densities for each species using the overall mean number of detections per locality from all surveys, as well as the higher values calculated using the highest number detected per location on any one survey (Table 3); we present both estimates separately for surveys conducted at the 0.5-km and 0.25-km markers. We also estimated densities for the same species from elsewhere on the Thai-Malay Peninsula, converting available data into units comparable to our results (see Table 3; Wells 1995).

For Barred Eagle, Brown Wood and Oriental Bay Owls, we also estimated the potential number of pairs along the whole 12.5 km transect. Our detections for these species were clumped around widely separated localities and we assumed that each clump represented a pair that was territorial within a separate home range. This appeared to be accurate for Barred Eagle and Brown Wood Owls, as we sometimes heard neighbouring pairs calling at one another along their adjacent boundaries. For Buffy Fish Owls we also estimated the density of

Table 3. Estimated overall density along 12.5 km of road through Bala rainforest, southern Thailand, for nocturnal species detected within a 0.25-km radius (0.1964 km²) of each broadcast location. We derived separate estimates based on (a) the overall mean of the numbers detected per broadcast at all locations and (b) the overall mean for the highest number detected at each location on any one broadcast, each one separately for the 0.5-km or 0.25-km locations. We also estimated (c), the spacing between apparent territories for larger and more widely separated species. We compared our results with approximate densities converted to similar units from reports elsewhere on the Thai-Malay Peninsula (Wells 1999). Abbreviations of species as in Table 2, with the addition of BFO = Buffy Fish Owl.

	Estimated density as number of individuals detected/km²							
			b) From overall mean for highest no. of individuals/24 lunar-monthly locations				Estimated densities for other areas of Thai-Malay Peninsula	
Nocturnal species	a) From overall mean/ playback location*	Mean density as % of highest density	Surveys at 0.5 km markers	Mean of means at 0.5+0.25 km markers	Surveys at 0.25km markers	c) Estimated territorial spacing at Bala as km/pair**	Nos/km², from no. of pairs x 2	Nos/km², from no./ reserve area
OBO	0.31/0.36*	51/34	0.61/1.27*	0.51/1.06*	0.41/0.85*	4.2 (n =3)	–	–
RSO	0.71/0.87*	79/45	0.90/1.49*	1.20/1.94*	1.49/2.38*	–	2–4	0.15–0.17
CSO	2.65	33	8.57	7.95	7.32	–	4–8	15–17
BEO	0.46	40	1.85	1.16	0.47	2.5/1.8 (n = 5/7)	–	–
BWO	0.56	58	1.24	0.96	0.68	4.2/3.2 (n = 3/4)	2	1.2
BFO	–	–	–	–	–	2.5/1.7 (n = 2/3)	–	–
BHO	0.87/1.17*	56/64	2.04/3.64*	1.55/2.73*	1.06/1.82*	–	–	–
JFM	2.29	41	5.95	5.53	5.11	–	6	0.15

*We calculated two density values for 'lowland' species (OBO, RSO, BHO): the first an overall value across all locations and habitats, the second a value only for locations within their lowland habitat below ~300 m asl.

**See text for details of how number of pairs was determined, with widely separated pairs for OBO, but with lower/upper values for the less clearly separated pairs of BEO, BWO and BFO.

pairs, assuming that all the signs detected were indeed from this species, and that concentrations of signs at locations separated from each other by at least 1 km represented different territorial pairs along the 5 km of river that we surveyed.

DISCUSSION

The eastern end of the road that we surveyed at Bala rose gradually from a wide valley with patchy agriculture, through well-developed lowland rainforest, into submontane rainforest along a higher intervening section with sharp ridges and deep valleys, and then, at the western end, descended steeply into a narrow valley and ended among more cultivation. Across these habitats, and in 10 of the 13 lunar months of 2004, our technique detected most species of nocturnal birds known previously to occur in the Bala section of Hala-Bala Sanctuary. We failed to detect White-fronted Scops Owl, Collared Owlet, Spotted Wood Owl and Large-tailed Nightjar, but added Oriental Bay and Brown Wood Owls to the list.

Our data for the mean numbers recorded per location had sufficient resolution to confirm Oriental Bay, Reddish Scops and Brown Hawk Owls only below ~300 m asl, while Collared Scops, Barred Eagle and Brown Wood Owls, and Javan Frogmouth, occurred across all altitudes sampled. These results are consistent with the altitudinal preferences of these species reported elsewhere (Lekagul and Round 1991, Wells 1999, Robson 2002), and they suggest that our data were precise enough for additional applications, should other such ecological measures become available along the road that delimit topographic features, vegetation types, nest sites or availability of prey.

We probably did not detect some species because we sampled mainly at altitudes or in habitats where they were not common. Uthai Treesucon (pers. comm. 2004) only expected White-fronted Scops Owl in forest below 100 m asl, altitudes similar to where we probably detected Gould's Frogmouth but where it was certainly not common. Collared Owlet were only expected to be common above 600 m asl, and Mountain Scops Owl at even higher altitudes, equivalent to the peaks of the Hala part of the Sanctuary (Robson 2002, Thong-aree 2004), and both above the 590 m asl peak along the Bala road. Spotted Wood Owl and Large-tailed Nightjar were expected in disturbed areas around the forest periphery, habitat only present at the ends of the road (Lekagul and Round 1991, Wells 1999, Robson 2002). Although we recorded Buffy Fish Owl at a low overall density, due to the limited amount of its linear riparian habitat, it was spaced within that habitat at densities equivalent to those of the similar-sized Barred Eagle Owl in the extensive tracts of terrestrial forest.

Variation in the numbers of species and individuals detected at broadcast locations, both within and between lunar months, suggests that our techniques were not consistent in detecting all species or individuals, even for those expected to be resident. The consistently lower values recorded for the mean number per location compared to the highest number per location support this suggestion, but even though we found the mean and highest numbers significantly correlated for all species (Spearman Rank Correlation, $P<0.001$), the difference does suggest that each value provides a slightly different estimate of relative abundance. The percentage difference between these two measures may even be an additional index for how detectable each species was when using our particular broadcast technique (Table 3). The percentage of detections that we scored as responses to our broadcasts also differed between species (27–100%; Table 2), probably indicating specific but undocumented differences in basic biology and communication behaviour, or differences in elicitation of responses for those calls that we chose to broadcast. All such variation contributes to the incidence of 'false absences', which would need to be incorporated into future survey design (Wintle *et al.* 2005).

For some species, seasonal variation in detection was correlated with known migratory tendencies, e.g. the Grey Nightjar (Wells 1999). However, Oriental Bay Owl (detected between July–September) and maybe even Malaysian Eared Nightjar (March–May), which were expected to be residents, may only have been local vagrants or summer visitors to Bala. For other species expected to be resident, variability in detection was probably due to variation in calling intensity at different ages and stages of the reproductive cycle, including variation in detection resulting from seasonality in vocal behaviour and responsiveness as related to territorial and/or courtship behaviour (Table 2). We detected small, mainly insectivorous species (Reddish Scops, Collared Scops and Brown Hawk Owls, and Javan Frogmouth) most often in May–June, coincident with the peak of the dry season when many other bird species were breeding (Table 2, Wells 1999, Kemp and Kemp 2007). We detected large, mainly small-vertebrate feeders (Barred Eagle and Brown Wood Owls) most often in July–September, when several large diurnal raptors were also most active with calls and displays (Kemp and Kemp 2007), and maybe the uncommon medium-sized but large-footed Oriental Bay Owl fits this pattern as well. Barred Eagle Owl was the only species for which we confirmed breeding, when we saw and heard a juvenile begging by day and night south of the 1.25–2.25 km position on the road between 11 June and 24 October, and heard a second juvenile once at 11.0 km in July, suggesting that the species was most vocal after fledging young.

Overall, we consider our survey estimates conservative, including those based on the highest numbers per location. Besides lunar-monthly variation, we know from other non-survey observations that some birds were present during our surveys but undetected. For example, we observed a pair of Barred Eagle Owls several times in one area (6.0–7.0 km) next to the road, by day and at dusk, and even found their regular diurnal roost. Yet we never detected them there on our surveys, and only a single response to broadcasts, by an adult that flew up to perch at a location 1 km away, may have belonged to this pair. We also heard on some nights at the Hala-Bala Research Station more individual Brown Hawk, Reddish Scops and Collared Scops Owls than the highest numbers we ever detected at any of the survey locations (1.75–2.50 km) on the adjacent road.

Our estimates of density are conservative for additional reasons. We assumed that each species was resident, or at least sedentary, when we detected it at Bala, and that we had some probability of repeated detections at or near the localities where we first recorded a species. In support of these assumptions, we detected most of the common

species on all or most months of the survey and some individuals of most species often called from a similar position at a particular location on different lunar months. We had to assume that we detected all individuals within a circle of 250 m radius around each broadcast location, but our estimates of density certainly indicate only minimum values for the habitats surveyed (Table 3). For instance, we assumed that the habitat on either side of the road was uniformly suitable for all species, although roadworks have altered the verges to varying extents and the adjacent forest also showed obvious but undocumented differences in composition, structure, altitude, aspect and slope. For most species, we were also not able to distinguish which sex called and so assumed that it was usually the male (see Wells 1999). Only in the larger owl species (Barred Eagle and Brown Wood Owls) and the commoner small species (Collared Scops Owl and Javan Frogmouth) was it sometimes possible to distinguish the sexes and to hear both members of a pair calling at the same time and location. Our survey therefore failed to include most non-calling adult males, adult females and juveniles of either sex, which would have at least doubled the densities recorded. Our conservative estimates of density appear similar to what little is recorded for the same species, also based on their calling, in other Malesian forests on the Thai-Malay Peninsula (Table 3, Wells 1999), but we found no comparable data for these species from where they occur in other types of Asian forests.

Comparison with other studies of noctural forest-bird communities

Because we did not manage to follow our lunar-monthly protocols exactly, owing to disruptions from vehicle breakdowns, wind, rain, fallen trees and regional security, we ended up with different sample sizes by species, lunar-month and location, and so had to adjust our results accordingly. We also did not control for a variety of factors that may have affected our results. These include changes between lunar months in the type and quality of calls broadcast, the duration of listening intervals, the sequence in which species were broadcast, and the number of species broadcast per location (and hence the length of the total listening/broadcast period both in and between lunar months). However, despite the exploratory nature of our surveys, the assumptions we had to make about uncontrolled factors and the uneven sample sizes, our data did detect temporal and spatial variations consistent with known altitudinal preferences and breeding seasonality, and provide conservative estimates of density.

We found no equivalent nocturnal surveys for other tropical Asian forest-bird communities, only exemplary studies from South America that examined diverse communities of up to six species of tropical forest owls. The latter studies had similar findings to our survey in showing temporal and spatial variation in species abundance and detection, but they also examined additional aspects that we did not consider in our survey design. One survey distinguished how different owl species responded to broadcast of inter- as well as intra-specific calls (Enriquez and Salazar 1997), something we noticed but did not control. Another survey found that two adjacent but distinctive habitat types supported different communities of owl species (Borges *et al.* 2004), suggesting that variation in density with forest type is a factor that requires further study in our region. A third survey alerted us to possible effects of moonlight, finding significantly higher detection around full moon, but only before the moon had risen or when it was obscured by clouds (Enriquez-Rocha and Rangel-Salazar 2001), although a fourth study found no effects of moon phase or cloud-cover (Lloyd 2003). In addition, many other survey techniques and results with relevance to our study are available from surveys of only one or two species in North American, African and Australian forests (e.g. Takatz *et al.* 2001, Delport *et al.* 2002 and Newton *et al.* 2002, respectively, and references therein).

Further surveys at Bala and in other Asian forests are obviously required, with improved techniques and more attention to the spatial, social, habitat and environmental requirements of each species. We offer our preliminary estimates of relative abundance and minimum density as a basis for further ecological studies and conservation planning, with special urgency for White-faced and Reddish Scops Owls whose restricted lowland habitats in Thailand must be of very limited area and quality, including in Bala Sanctuary.

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Alan Kemp+, Meg Kemp and Siriporn Thong-aree, Peat Swamp and Hala-Bala Rain Forest Narathiwat Province Research Unit, National Center for Genetic Engineering and Biotechnology (BIOTEC), c/o Hala-Bala Wildlife Research Station, P. O. Box 3, Waeng Narathiwat 91960, Thailand.*

*Current addresses: + Research Associate, FitzPatrick Institute, University of Cape Town, P.O. Rondebosch, 7000 South Africa. * Naturalists and Nomads, Postnet Suite #38, Private Bag X19, Menlo Park, 0102 South Africa. E-mail: leadbeateri@gmail.com.*

APPENDIX

Details of the 1-min cuts of the loud call of each bird species, and of the intervals between playbacks, that were included on the playback tape routine used during each lunar month for a nocturnal survey along the road through Bala rainforest, southern Thailand. Recordings were copied from Birds of Asia, species cuts 1, 2 or 3 (BoA 1, 2, 3), Birds of Singapore (BoS) and Birds of Thailand (BoT), or supplied by Uthai Treesucon (TR). Abbreviations of species are as in Table 2, with the addition of MSO – Mountain Scops Owl, SWO – Spotted Wood Owl, COW – Collared Owlet, LFM – Large Frogmouth, GFM – Gould's Frogmouth, MEN – Malaysian Eared Nightjar, LTN – Long-tailed Nightjar.

Lunar month and date of full moon	Tape edition	Nocturnal species, acronym of name, number used to indicate position in tape sequence, months in which call(s) broadcast (X), and source of recordings														Silent introduction, min	Silent interval, min	Species sequence by species number for 1-min cuts/separation of highland/lowland spp.	Total tape duration, min
		OBO 1	RSO 2	MSO 3	CSO 4	BEO 5	SWO 6	BWO 7	COW 8	BHO 9	LFM 10	GFM 11	JFM 12	MEN 13	LTN 14				
6 Mar	1.3				x		x						x		x	5.0	5.0	4-12-14-6	29.0
	1.4		x		x	x*				x			x			5.0	5.0	2-4-12-9-5	35.0
5 Apr	2		x	x	x		x			x		x	x			5.0	2.5	6-9-2-3-4-12-11	29.5
4 May	3	x	x		x	x*	x		x	x	x	x	x			2.5	2.5	6-9-2-5-4-12-11-10-8-1	39.5
3 Jun	4.1/2	x	x		x					x	x	x	x	x		5.0	2.5	9-4-12-13/2-1-11-10	**19.0/32.0
2 Jul	5.1/2	x	x		x	TR		x		x	x	x	x			5.0	2.5	5-4-12-7/2-9-11-10-1	19.0/35.5
31 Jul	5.1/3	x	x		x	TR	x	x		x	x	x	x			5.0	2.5	5-4-12-7/2-9-11-10-1-6	19.0/39.0
30 Aug	5.1/3	x	x		x	TR	x	x		x	x	x	x			5.0	2.5	5-4-12-7/2-9-11-10-1-6	19.0/39.0
28 Sep	6.1/2	x	x		x	TR	x	x		x	x	x	x			5.0	2.5	5-4-12-7/2-9-1-6-11-10	19.0/39.0
28 Oct	6.1/2	x	x		x	TR	x	x		x	x	x	x			5.0	2.5	5-4-12-7/2-9-1-6-11-10	19.0/39.0
26 Nov	7.1/2	x	x		x	TR	x	x		x		x	x			5.0	2.5	5-4-12-7/2-9-1-6-11	19.0/35.5
Source for loud calls used in playback		BoT	BoA 1&2	BoA	BoA 1&2	BoA 1-3	BoS	TR	BoA	BoA 1&2	BoA 1-3	BoA 1&2	BoA 1-3	BoS	BoS				

* For BEO, during 6 Mar to 4 May we had only low-quality recordings available.

** From 3 Jun to 26 Nov we did not play calls of the lowland species RSO, BHO and GFM at all sites, hence two times for tape duration are shown here.