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Caption: Malabar Slender Loris *Loris lydekkerianus malabaricus* © Dileep Anthikkad.

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COMMUNICATION

Factors influencing the flush response and flight initiation distance of three owl species in the Andaman Islands

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Abstract: Effects of anthropogenic pressures on birds of the Andaman Islands have been documented to some extent, however studies on the effect of human activities on the behavioural response of these birds are limited. This study assessed the anti-predatory behaviour (flush response - FR and flight initiation distance - FID) of three owl species (*Otus sunia*, *Otus balli*, and *Ninox obscura*) in response to human stimuli and factors influencing it on the Andaman Islands. In total, 63 % of owls flushed from their roost sites in response to approaching human, and such a response varied between species. Similarly, FID varied widely among the species ranging from 4.23 to 6.73 m. The FR of *N. obscura* was influenced by the count of climbers, presence of spine, and branch status, while roost height, ambient temperature, and lower count of climbers contributed to a higher FID. For the two *Otus* species, camouflage and pairing were found to influence their FR while FID of *O. balli* was influenced by roost height, pairing, and presence of spines. Our results indicated that the anti-predatory behaviour of owls on the Andaman Islands was species- and site-specific and prolonged disturbance to their roost sites may affect the survival and reproductive rate of these owls.

Keywords: Anti-predatory behavior, camouflage, human disturbance, predator avoidance, roost site.

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Author contributions: SS, SB & HNK designed the study; SS & NR collected data; SS analyzed and wrote the article with inputs from SB and HNK.

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INTRODUCTION

The presence of people in bird habitats can be considered as a form of disturbance to the birds because they may perceive humans as potential predators, much like their natural predators (Walther 1969). In such situations, birds either flee or show alertness by assessing the level of threat that such human presence poses to them (such as the mode and direction of approach by people) (Grubb & King 1991; Cooper 1997; Sapolsky et al. 2000; Papouchis et al. 2001; Cooper 2003). Alertness and fleeing have been linked to insufficient parental care (Zuberogoitia et al. 2008), lower foraging times (Velando & Munilla 2011) and a lack of attention to other potential predators (Anderson & Keith 1980). When a threat is detected, some birds would not fly immediately but assess the intensity of such a threat by showing extreme alertness. The response (flight) of birds to humans has been evaluated in different ways and the most common measures are flush responses (FR) and flight initiation distance (FID), the distance at which the bird decides to flee in response to an approaching human.

Diurnal roost sites play an important role in determining the fitness and survival of owls, and hence the selection of a roost plays an important role in the birds' life history characteristics (Ganey et al. 2000). Suitable roost sites may provide owls with the required microclimate which may reduce the energetic costs of thermoregulation (Barrows 1981), provide protection from predators (Bradsworth et al. 2021) and also help avoid parasites to increase their fitness (Rohner et al. 2000; Solheim et al. 2013). To certain extent, a species' social behaviour such as pair bonding (Collins et al. 2019), camouflage and plumage (Møller et al. 2019) also found to have an influence on their predator avoidance tactics. There have been many studies on the effects of human disturbance on the nesting of various bird species (Watson 1993; Dowling & Bonier 2018; Collins et al. 2019) but, except for one study, research on the effect of human activities on roosting owls is limited.

The Andaman & Nicobar Islands has been recognized as an endemic bird area due to the high number of endemic birds. These islands (and in turn, birds found on the islands) have been facing severe anthropogenic pressures including the impacts of selective logging, extraction of climbers (canes), invasive species, tourism, and collection of non-timber forest products. While the effects of these threats on birds have been documented to a certain extent, research on the effect of human activities on endemic birds, especially nocturnal animals, are limited. Out of three species selected for this study, two (*Otus balli* and *Ninox obscura*) are endemic to Andaman Islands. Hence, this study assessed the FID and FR of three species of owls, *i.e. Otus balli*, *Otus sunia*, and *Ninox obscura*, in the Andaman Islands, and examined the factors influencing the FID and FR of these species.

MATERIALS AND METHODS

Study site

This study was conducted on the four large islands of the Andaman archipelago (North, Middle, Baratang, and South Andaman Islands), which covers an area of about 3,447km^2. The land is an uplifted earth surface (Malik et al. 2006) and the altitude of Andaman Islands ranges from 0m to 731m (in Saddle Peak). The Andaman forests can be classified into 11 different forest types based on floral composition. This study was conducted only in three forest types, namely, evergreen, moist deciduous, and secondary moist deciduous. The evergreen forests are dominated with large trees of evergreen with dense understory vegetation, mostly climbers. Having irregular canopy, the moist deciduous forest stands are distinguishable by large deciduous trees with the understory stratum dominated by cane and other climbers. The secondary moist deciduous forests are selectively felled areas and thus with reduced structural complexity (Champion & Seth 1968). Other than the wood-based industry, tourism, fishery and agriculture are the major option to maintain the socio-economic balance on the Andaman Islands.

Study species

The Andaman archipelago supports five owl species namely the Andaman Scops-owl *Otus balli*, Oriental Scops-owl *Otus sunia*, Hume's Boobook *Ninox obscura*, Andaman Boobook *Ninox affinis*, and Andaman Barn Owl *Tyto deroepstorffi* (Rasmussen & Anderton 2005). Among them, we selected only three species namely *O. balli, O. sunia*, and *N. obscura* for this study (Image 1–3) as we had sufficient roost locations for these species. *N.obscura* and *O. balli* are endemic to these islands, whereas *O. sunia* is found throughout the tropical countries of central Asia as well as eastern Asia from Japan to the Malay Peninsula. *Otus balli* was considered as stenotopic in habitat use whereas the other two species are found to be eurytopic (Babu et al. 2019).

Image 1. Andaman Scops-owl *Otus balli*

Image 2. Oriental Scops-owl *Otus sunia*

Image 3. Hume's Boobook *Ninox obscura*

Data collection

All the experiments were conducted on roosting owls of the three species during summer season (February–May) for three consecutive years (2014–2017). We selected this season because of the accessibility to all forest types and feasibility to conduct the experiments on roosting owls. Since this period is coinciding with the breeding season of these owls, we made sure that none of the experiments were conducted on breeding owls by avoiding experiments on owls that were roosting in tree holes. In general, Andaman owls are known to utilize tree holes during breeding season. Prior to the experiments, we located roosting owls by tracing their last vocalization locations during the early morning hours. After marking roost location, we visited the same site around noon (1100–1200 h) and conducted our experiments. Roosting owls, which were detectable from around 10m distance were considered for the experiment. We located roosting of all owls from a approximate distance of 10m because in some roost sites, we could not see the owls at 10m distance from their roost site due to the thick vegetative cover around the roost site and smaller size of the owls. In the selected sites, the experiment was conducted by a single observer with the same dress by walking directly

Table 1. Factors hypothesized to influence the flight initiation distance and flush responses in owls from the day-time roost sites in Andaman Islands.

	Descriptions of factors	Abbreviation	Coding in the analysis	Unit
1	Roosting as pair either with or without physical contact but on the same tree	PAIR	1	Binary
	Solitary		2	
2	Displaying camouflage behaviour when observer approach (for example: closing eyes, elongating body)	CAMFG	1	Binary
	Staring at the observer without any physical changes		2	
3	Presence of spines at the roosting branch	SPINE	1	Binary
	Absence of spines at the roosting branch		2	
4	Number of climbers on the roosted plant	CLIMB		Count
5	Status of the roosting branch - alive	STATUS	1	Binary
	Status of the roosting branch - dead		2	
6	Roost height of owls (*i.e.* from the ground)	HEIGHT	Continuous	Meters (m)
7	Distance at which the observer started to walk towards the roosted owl	BENNG	Continuous	Meters (m)
8	Temperature at the roost site	TEMP	Continuous	Degree Celsius (°C)
9	Relative humidity at the roost site	HUMI	Continuous	Percentage (%)

towards roosting owls with a minimum speed of one step per second and recorded the response behaviour of the owls. If the owl was flushed from the roost site, then the observer stopped to proceed further and measured the distance from the roost site with the digital range finder. In case of a pair, even one bird being flushed from the roost was considered as FR. If the owl did not flee at all even at 1 m distance, it was categorized as not-flushed. While conducting the experiment, we recorded all camouflage behaviours of owls such as elongating its body, erecting their ear tufts and sliding to an angle. We measured all habitat and climatic variables at the roost sites regardless if birds were flushed or otherwise. The detailed description of the variables and method of measuring and coding are given in Table 1.

Statistical analysis

Since the roost site selection of the owls may vary across the habitat (unpublished data), to maintain the uniformity in the experiment, we retained only the experiments conducted in evergreen forest and moist deciduous forests for *O. balli* and *O. sunia*, respectively. However, roosts of *N. obscura* were mostly found along the edges of the evergreen and moist deciduous forests. To know whether the FID and FR of *N. obscura* vary between habitat types, we ran univariate t tests for FID and chi-square test for FR of *N. obscura*. We found no difference in the FID (t= -0.959, df= 51, p= 0.342) and FR (X^2= 0.02, df= 1, p= 0.886) between the habitat types and hence we pooled our data for *N. obscura*.

We arranged the data species-wise and checked for normality by Shapiro-Wilk statistic for continuous variables and examined the histogram and boxplots to identify outliers and residuals (Miles 2014). Since the starting distance was not normally distributed, it was $\log_{10}$ transformed to meet the normality assumption beforehand. One-way ANOVA was applied to find out the difference in FID and FR between species. We ran logistic regression analysis for each species separately to predict the most important variable(s) that influence FR in owls. We applied multiple linear regression analysis to assess the importance of variables' contribution to FID. For both analyses, we generated global model by including all predictor variables (temperature, humidity, starting distance, number of climbers, branch, presence of spines, species camouflage behaviour, roost height and pair. Later, we removed variables that were not statistically significant (p ≥0.05) from the model using backward selection. We used R^2 values for linear regressions and drop-in-deviance test for the logistic regression to assess goodness-of-fit of each resulted model (Swarthout & Steidl 2001).

RESULTS

In total, 180 experiments with an average starting distance of 11.99 ± 3.18 m for *O. balli,* 21.52 ± 2.47 m for *N. obscura*, and 13.94 ± 4.57 m for *O. sunia* were used for analysis. Of these, owls were flushed from their roost during 133 attempts (63 %) (Table 2). We found significant difference in FR ($F_{2,\ 177}$= 7.472, p <0.001) among the three species. *N. obscura* (x^2= 12.262, df= 1, *p* <0.001) and *O. sunia* (x^2= 9.779, df= 1, *p* <0.05) were more likely to be flushed than did *O. balli*. However, *N. obscura* and *O. sunia* were not significantly different in terms of FR (x^2= 0.163, df= 1, p >0.05).

When looking into the variable that influence the FR of all three species, the negative influence of pairing (β= -2.248 ± 1.0725, *p* <0.05), and camouflage behaviour (β= -2.723 ± 1.3687, *p* <0.05) of *O. balli* were found to be the reason for their tolerance to approaching human, compared to the other two species (Table 3). However, the FR of *N. obscura* was largely influenced by the roost tree characteristics *i.e.* presence of climbers (β= -0.787 ± 0.6963, *p* <0.05), spines (β= -1.623 ± 0.7583, *p* <0.05) and status of the branch (β= -1.660 ± 0.7413, *p* <0.05). The FR of *O. sunia* was influenced by species pairing (β= -1.884 ± 0.8611, *p* <0.05), roost height (β= 0.604 ± 0.2585, *p* <0.05) and camouflage behaviour (β= 1.283 ± 0.6393, *p* <0.05) (Table 3).

We recorded relatively a higher FID for *N. obscura* (6.78 ± 0.22 m) than the other two sympatric owls (*O. sunia*= 5.48 ± 0.3 m and *O. balli*= 4.23 ± 0.42 m). The FID among three species of owls was significantly different ($F_{2,110}$= 13.066, *p* <0.05) and post-hoc test showed significant differences in FID between *O.balli* and *N. obscura* (*p* <0.001), and *O. sunia* and *N. obscura* (*p* <0.001). But there was no significant difference in FID between *O. balli* and *O. sunia* (*p* >0.05). Ninety-five percent of *O. balli* flew at a distance of 8 m in response to approaching human while the distance was around 11 m for both *O. sunia* and *N. obscura* (Figure 1). The maximum FR was observed at a distance of 3 to 6 m for *O. balli* and *O. sunia* while it was 6 to 9 m distance for *N. obscura* (Figure 02). Roost height, pairing and presence of spine were the important predictors for the FID of *O. balli* while it was roost height, temperature and count of climbers for *N. obscura* (Table 4). None of the quantified variables contributed significantly to the FID of *O. sunia*.

DISCUSSION

In 63% of the trials, owls were flushed out from their roost sites when humans approached. Several factors such as the predator's approaching direction, speed and mode have been reported to influence flush response in birds (Spaul & Heath 2017). Though we did not test the effect of different approaching methods on the FR of owls, Grubb & King (1991) reported that birds perceive a higher threat from humans on foot than any other mode of approach. Our observation also corroborated with Holmes et al. (1993) where grassland raptors in Colorado were reported to be flushed out more frequently in response to human on foot (97%)

Table 2. Mean flight initiation distances and percent of flush responses of three owl species to approaching human in Andaman Islands.

Species	*n*	Number of owls flushed (%)	Flight Initiation Distance (m)		
			$\bar{x}$	SE	Range
O. balli	38	14 (37)	4.23	0.42	1.36 – 07.30
O. sunia	69	47 (68)	5.48	0.30	1.42 – 11.25
N. obscura	73	52 (71)	6.78	0.22	3.05 – 10.36
Total	180	113 (63)	5.93	0.19	1.36 – 11.25

Table 3. Factors influencing the flush response of three owl species to approaching human in Andaman Islands.

Species	*n*	Factors [a]	β	SE	Wald's X^2	*p*	Odds ratio
O.sunia	69	PAIR	-1.884	0.8611	-2.188	0.028	0.123
		HEIGHT	0.604	0.2585	2.339	0.019	0.448
		CAMFG	1.283	0.6393	2.008	0.044	5.761
O.balli	38	PAIR	-2.248	1.0725	-2.096	0.036	0.106
		CAMFG	-2.723	1.3687	-1.990	0.046	0.066
N.obscura	73	CLIMB	-0.787	0.6963	-1.130	0.037	0.455
		SPINE	-1.623	0.7583	-2.141	0.032	5.071
		STATUS	-1.660	0.7413	-2.239	0.025	0.190

[a]—Refer Table 1 for description of variables.

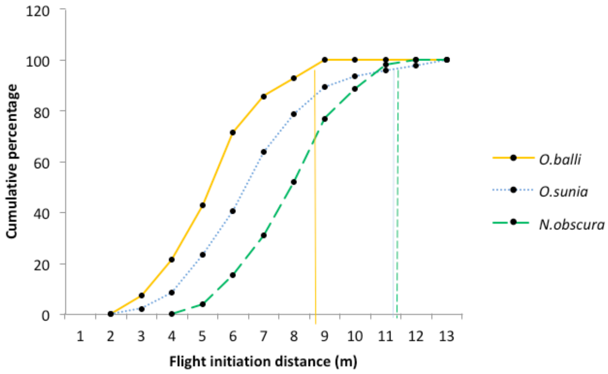

Figure 1. Flight initiation distance of flushed owls in response to approaching human and the straight line indicates the 95 % of sampled flushes occurred at the distance from the human.

Table 4. Factors influencing flight initiation distance of *O. balli* and *N. obscura* to approaching human in Andaman Islands.

Species	*n*	Factors [a]	Estimate	SE	*t*	*P*
O. balli	14	Intercept	19.40	9.25	2.098	0.081
		HEIGHT	-1.312	0.43	-3.031	0.023
		PAIR	2.305	0.89	2.588	0.041
		SPINE	-3.526	0.96	-3.642	0.011
N. obscura	52	Intercept	-17.65	9.45	-1.867	0.068
		HEIGHT	-0.413	0.13	-2.984	0.004
		TEMP	0.898	0.32	2.779	0.007
		CLIMB	-1.697	0.78	-2.158	0.036

[a]—Refer Table 1 for description of variables.

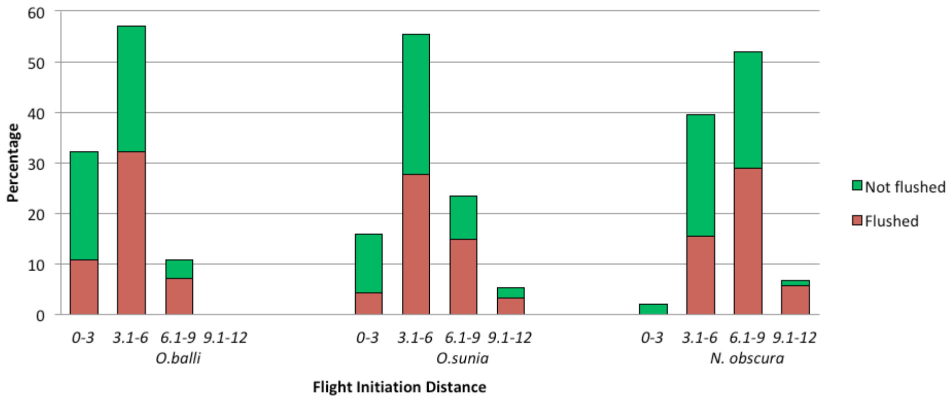

Figure 2. Closest distance (in m) an observer approached three owl species at their roost sites and the percentage of the responses.

than vehicular ones (38%).

The average FID of all three species in the Andamans (Table 2) was very low compared to the Mexican Spotted Owl (≥24 m) (*Strix occidentalis lucida*; Swarthout & Steidl 2001), and this might be due to the availability of potential refuge sites and the size of the owl. The FID of Mexican spotted owls was studied in open canyons that have limited refuge sites in the vicinity of roosts. In contrast, the availability of refuge sites around the roosting sites of three owls were higher (unpublished data). The Mexican spotted owls are relatively larger (wing span 302–328 mm) compared with our study species *O. balli* (wing span 133–143 mm), *O. sunia* (wing span 137–145 mm) and *N. obscura* (wing span 197–220 mm) (König et al. 1999).

We also found species-specific FID and FR, which corroborated with other studies (Burger & Gochfeld 1998; Blumstein et al. 2003; Braimoh et al. 2018). Previous studies demonstrated species-specific responses that are driven by several factors such as previous exposure to humans (Sproat et al. 2020), individual experiences (Martín & López 2015), hunting pressure (Stankowich 2008; Sproat et al. 2020) and life history strategies (Bennett & Owens 2002). In this study, *N. obscura* showed a higher FR and FID compared to the other two species. Possible explanations for a higher FR and FID in *N. obscura* could be its larger body size and dark plumage, as well as the poaching pressure on the islands. Among the three species, the body size of *N. obscura* is relatively larger. It has been widely recognized that body size is an important factor to elicit higher FRs in many organisms (Gotanda et al. 2009). The darker plumage of *N. obscura* also attracts more attention from humans as it is more visible against the green surroundings of its habitat, which could result in a higher FR. Similarly, Holmes et al. (1993) observed higher FRs and FIDs in the dark morphs of Rough-legged Hawks *Buteo lagopus* and Ferruginous Hawks *Buteo regalis* than in light morph birds. Our unpublished data on perceptions about owls among the residents of the Andamans revealed that

N. obscura and *O. sunia* are highly susceptible to being poached on the basis of various myths and superstitious beliefs that surround these species. On the islands, *O. balli* occupies undisturbed evergreen forest stands leading to minimal interactions with human and hence it showed a lower FID in this study. This observation corroborated with the results of a study on the FID of Capercaillie *Tetrao urogallus* in central Europe (Thiel et al. 2007), where a low hunting pressure and the occupancy of an undisturbed habitat by the species had been found to reduce its FID.

The count of climbers, presence of thorny vegetation and status of the branch (whether they were dead or live) influenced the FR of *N. obscura* (Table 3) while the count of climbers, roost height and temperature influenced its FID (Table 4). Higher number of climbers in a roost tree could influence the FR & FID in two ways; first, climbers on the roost tree may provide better concealment by increasing vegetative complexity around the roosting substratum, thus providing good hiding spots from predators. Secondly, dense climbers around the roost site may provide a more favorable microclimate by breaking down hot gusts of wind and providing insulation against the diurnal heat (Walsberg 1985). The presence of spines in the roost branch decreased the FR nearly fivefold (Table 3) because spines could physically impede predators from reaching the roosting owl. The positive association of atmospheric temperature with species' FIDs implies that an increase in temperature increases the FID and it is also evident that *N. obscura* initiated flight quickly in response to the approaching predator when the temperature of roost site was unbearable (Table 4). An experimental study on the captive Mexican Spotted Owls found that the birds initiated flight swiftly when temperature was higher (Ganey et al. 1993). At higher temperatures, an owl could be in heat-related stress.

Unlike *Ninox obscura*, the FR and FIDs of the two sympatric *Otus* species were largely determined by the species' behavioural mechanisms rather than their selection of roosting microhabitats. We found that pairing and camouflage behaviour influenced the FR of both species. Pair status negatively influenced the FR of both *Otus* species. Owls roosting solitarily were flushed out faster in response to an approaching human than those roosted in pair. The reason for a lower FR while in pair is to increase their reproductive fitness. In such cases, such birds use camouflage as a defensive behaviour to avoid detection and secure breeding opportunities.

In our study, the camouflage mechanisms of species were identified as a possible influencing factor in the FR of *O. balli* and *O. sunia* but their relationship was opposite. Camouflage behaviour might work in two different ways for the two owl species. When a predator approaches, usually prey species would move immediately to a safer place, whereas a cryptic species like owls are flushed out slowly (Hemmingsen 1951). Their late department is an unusual response that is expected to scare and startle the predator, which is termed close-quadrat effect (Nishiumi & Mori 2015). Another advantage of using camouflage behaviour prior to a FR is to maximize energy by freezing before initiating an energy-intensive escape flight (Samia et al. 2016). In *O. sunia*, individuals showing camouflage behaviour are likely to be flushed out more than individuals not showing any response to the approaching human. In this study, habituation might be an important reason for the observed responses from *O. sunia.*

Roost height influenced the FID of *O. balli* and *N. obscura*. In both species, roost height was negatively associated with their FID, which could be due to the decrease in predation risk at a higher roost (Tables 3 & 4). A similar relationship has also been reported in other raptors (Holmes et al. 1993; Steidl & Anthony 1996). Higher perches afford greater visibility of approaching disturbances, which has been shown to increase the FR rate and FID of Bald Eagles *Haliaeetus leucocephalus* (Steidl & Antony 1996). In Utah and Arizona, the female Mexican Spotted Owls that nested at higher locations changed their activity budgets in response to hikers more so than females that nested at lower locations (Swarthout 1999). Higher perches are considered safer and are also likely to facilitate the display of aggression to other group members (Portugal et al. 2017).

Both the FID and FR of *N. obscura* are negatively influenced by the count of climbers, and in particular, canes. Therefore, the extraction of canes on the islands may affect the roosting habitat and behaviour of this species compared to other two *Otus* species. Further studies focusing on the effect of cane extraction and selective logging on the roost selection of these endemic owl species is warranted. Our results indicated that the anti-predatory behaviour of the owls on the Andaman Islands was species and site specific and prolonged disturbance to their roost sites may affect the survival and reproductive rate of these owls.

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