



The diet of Indian Eagle Owl *Bubo bengalensis* and its agronomic significance

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Author Contribution: SP laid the foundations of the work and collected field data. ND performed statistical analysis. Both SP and ND wrote the paper.

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Abstract: If the importance of wildlife in agricultural pest control through predation can be conveyed, it can play an important role in the conservation of wildlife. However, such a strategy needs to be backed with convincing data. We studied the habitat preference, diet and reproductive behavior of the Indian Eagle Owl (IEO) *Bubo bengalensis* in order to understand its role in agricultural pest control. The Owls preferred landscapes with a higher percentage of agriculture and fed on rodents, birds, reptiles, arachnids, insects and other prey species. Despite being a generalist feeder, its diet was dominated by agricultural pests, which contributed 88% of the total prey biomass. Out of the 13 rodent prey species, which comprised a major part of the diet, seven were identified as major agricultural pests and were 98% of the total rodent biomass in the diet of the IEO. The dependence of the IEO on rodent pests was further reflected by positive correlation between rodent biomass consumed and the breeding success of the owl. The IEO, therefore, plays a positive role in the biological control of crop pests. However, owls spent a longer duration of time in agricultural habitats, where they also had higher productivity. Thus IEO may be subjected to anthropogenic activities, human contact and interference. Since this owl is still hunted due to superstitious beliefs, scientific evidence elucidating the importance of the IEO in agricultural pest control can be used for its conservation by educating the farming community.

Keywords: Agronomic significance, *Bubo bengalensis*, crop pests, Indian Eagle Owl, rodent control.

INTRODUCTION

Agriculture is a major source of livelihood in India. Indian agriculture is rapidly shifting from natural subsistence type farming to a managed intensive agricultural practice. Despite the developments in the infrastructure for production and storage of agricultural produce, it is estimated that rodents damage between 2–15 % of the crops annually throughout the country; while severe damage can escalate to 100% (Parshad 1999). As a result, agricultural pest control is a major concern. Chemical control using pesticides and biological control through predators and pathogens have been suggested for pest control (Howard 1976; Parshad 1999). However, chemical pesticides and control of pests using pathogens often affect the environment and human health adversely (Hearn 1973; Wodzicki 1973; Kaukeinen 1982; Littrell 1990; Gillies & Pierce 1999). Hence, utilization of natural predators is an environment friendly solution to pest control (Wodzicki 1973; Singleton 1994; Johnson et al. 1996).

A number of natural predators of the agricultural pests have been identified for their use in pest control. While some of them, such as cats, can be domesticated (Wodzicki 1973), even wildlife can be considered as natural enemies of crop pests (Johnson et al. 1996). If the importance of wildlife in pest control can be backed up with convincing data it will

serve two purposes. First, predation by wildlife can be promoted as an environment friendly pest control method and second, if the importance of wildlife in pest control is conveyed to the farmers, it can be used as a step towards conflict resolution and conservation of wildlife. This is especially true for predators like owls, which are often killed as they are considered as bad omens and also for their demand for use in black magic (Kasambe et al. 2004; Devkar 2009).

Owls are important for controlling agricultural pests as their diet is dominated with rodents (Neelananarayanan et al. 1999, 2007; Pande et al. 2004, 2007). Even though the potential of owls in agricultural pest management has been suggested earlier (Wodzicki 1973) and the possible importance of natural predators in integrated pest management programs is also recognized (Jain et al. 1993) a strong argument supported by relevant data is still missing.

In this study we elucidate the importance of the Indian Eagle Owl (IEO) *Bubo bengalensis* as a potential predator of agricultural pests by studying its reproductive output in relation to diet and habitat selection. We propose that such scientific findings based on first hand field data could be used to promote conservation awareness and the eradication of superstition about these biological controllers of agricultural pests.

METHODS

Study Area

The study was conducted around Pune (18°32'N & 72°51'E) on the Deccan Plateau, and around Alibag (18°28'52"N & 73°14'52"E) and Chiplun (17°0'2"N & 73°18'57"E) in the coastal region of Maharashtra State, India. The average annual precipitation in the study area, which is derived from the southwest monsoon, ranges from 250–1250 mm in the Deccan Plateau and 1500–3500 mm in the coastal region. The temperature ranges between 6°C and 40°C during winter and summer respectively. Agricultural cropland consists of seasonal *Triticum aestivum*, *Zea mays*, *Sorghum vulgare*, *Panicum miliaceum*, *Oryza sativa*, and open type of cultivation of lentils, pods, leafy vegetables, fruit orchards of figs (*Ficus* sp.), pomegranate (*Punica granatum*), custard apple (*Annona reticulata*) and guava (*Psidium* sp.) (an open

type of cropland with better visibility). The perennial grassland community in the study area is Sehima-Dichanthium type arrested in sub-climatic seral stage of succession due to grazing, grass cutting and burning (Roychoudhary 1966; Murthy & Sanjappa 2001). The grasses are *Aristida setacea*, *Aristida adscensionis* and *Heteropogon contortus* with a presence of bush *Xanthium strumarium* that has spiny seeds.

Data collection

During the breeding season (October–March) of 2004–05 and 2005–06, we identified 44 occupied nest sites. The Eurasian Eagle Owls are known to nest near their preferred hunting areas (Frey 1973; Olsson 1979; Leditznig 1992) and their breeding success depends on the distance between the nest and foraging area. Hence, we selected an area of 1000m radius centered around the nest in order to analyze the landscape features in all of the nest territories. Following Donázar (1987), Penteriani et al. (2001) and Pande et al. (2007) we categorized each circular plot into six habitat categories: (a) agriculture, (b) scrub, (c) grassland, (d) water body (perennial or seasonal), (e) hills, and (f) rural habitat around human habitation, using 'look down' visual surveys conducted from high vantage points and estimated the percentage occurrences of each category (Bibby et al. 1998).

At least five visits were made to each of the nest sites each year during the breeding seasons. Owl pellets and prey remains were collected from all nest sites and were separately analyzed for each nest for every breeding season. Pellets were dried in an oven, dissected and all identifiable prey remains were scrutinized (Penteriani et al. 2002). To avoid duplication, items found in pellets were used only when not found as prey remains in the same visit (Penteriani 1997). We did not encounter separate prey remains that were not found in pellets. Prey in pellets were identified to orders, families, genera or species by using published literature (Tikader & Bastawade 1983; Tikader & Sharma 1992; Daniels 2002; Ramanujam 2004) or by comparing with specimens in the collections of the Zoological Survey of India, Pune. Pellet contents were grouped into six categories, namely insects, reptiles, birds, rodents, bats and other prey species. The number of individuals in each diet category was considered as the abundance for that category. The fresh masses of prey species were

estimated by weighing specimens in the field using Pesola scales (least count 0.1g) or by using published data (Spillet 1966; Khajuria 1968; Ranade 1989, 1992; Kanakasabai et al. 1998; Pande et al. 2004, 2007). This was used for calculating the biomass of each prey type in the diet of the owl. Percent biomass for each diet category was calculated by estimating the relative percent contribution of each category to the overall diet.

Breeding time and nest site occupation were monitored to record the dates of egg-laying, to monitor the number of hatchlings and count the number of fledglings (Frank & Lutz 1997; Penteriani et al. 2002). We considered the date of laying of the first egg as the date for the onset of the breeding season. The incubation period or duration of breeding was calculated as first egg laid till last egg hatched based on the observation that the hatching is asynchronous in IEO (Ramanujam & Murugavel 2009). We determined breeding success or productivity as the number of fledglings per nest.

Statistical analysis

We performed the Kruskal-Wallis test and multiple pairwise comparisons using the Mann-Witney U test with Bonferroni correction (Bonferroni corrected significance level used was $\alpha = 0.0033$) to see if the preference for different habitats was different. Associations between prey items, habitat preference and breeding success were analyzed using Redundancy Analysis (RDA) assuming that these are interdependent variables. RDA was performed in the freeware Biplot 1.1 (Smith & Lipkovich 2002). To see if the dependent variables were linearly dependent on the independent variables we performed permutation tests with a null hypothesis that dependent and independent variables are not linearly related to each other (Legendre & Legendre 1998).

RESULTS AND DISCUSSION

IEO builds terrestrial nests on hill slopes, earth cuttings, rocky outcrops and under bushes, where the surrounding areas, which are its hunting grounds, consisted of agriculture, scrub, grassland, water body, hills and rural habitats. IEO preferred to nest in landscapes with a high percentage of agriculture followed by grassland and scrubs (Fig. 1). Preference

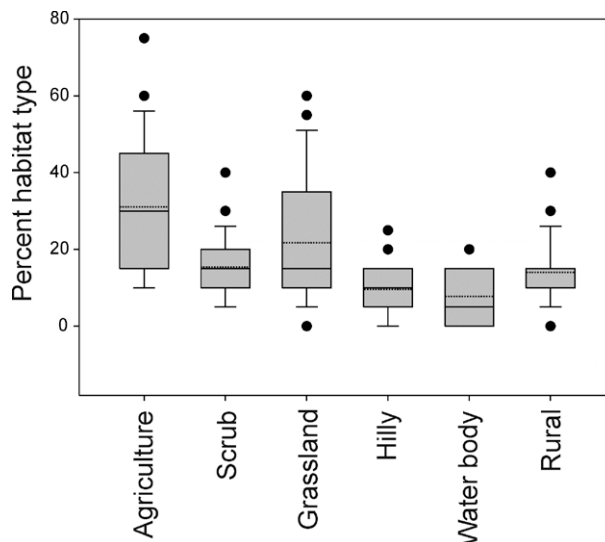


Figure 1. Percentage habitat type of breeding sites of Indian Eagle Owl. Agriculture is a dominant habitat followed by grassland and scrub habitats. Solid line inside the box denotes median and dashed line the mean.

Table 1. Abundance and total biomass of different prey in the diet of the Indian Eagle Owl in the study area.

Prey item	Abundance (%)	Total biomass in g (%)
Rodents	1503 (54.69)	277830 (85.05)
Bats	124 (4.51)	9418 (2.88)
Birds	367 (13.36)	37558 (11.49)
Reptiles	20 (0.73)	42 (0.01)
Insects	712 (25.91)	712 (0.22)
Other unidentified prey	22 (0.80)	1117 (0.34)

for different habitats was significantly different (Kruskal-Wallis $K = 141.199$, $p < 0.0001$), with a preference for agriculture dominated habitats than the second most dominant grassland habitat (Mann-Witney $U = 5075.000$, $p < 0.0001$).

The IEO showed high versatility in the choice of food depicting its feeding habit as a dietary generalist (Table 1). It fed on rodents, birds, reptiles, arachnids, insects and other prey species. Rodent prey included Lesser Bandicoot Rat (*Bandicota bengalensis*), Large Bandicoot Rat (*B. indica*), Indian Bush Rat (*Golunda ellioti*), Soft-furred Field Rat (*Millardia meltada*), House Mouse (*Mus musculus*), Field Mouse (*M. booduga*), Elliot’s Spiny Mouse (*M. saxicola*), House Rat (*Rattus rattus*), Indian Gerbil (*Tatera indica*), Long-tailed Tree Mouse (*Vandellura olivacea*), Common House Shrew (*Suncus murinus*), Pigmy Shrew (*S.*

etruscus) and Anderson's Shrew (*S. stolizcanus*). Bat prey included Indian Fulvus Fruit Bat (*Rousettus lesheanaulti*) and Lesser Dog-faced Bat (*Cynopterus sphinx*). Bird prey included Ashy-crowned Sparrow-Lark (*Eremopterix grisea*), Rufous-tailed Sparrow-Lark (*Ammomanes phoenicura*), Blue Rock Pigeon (*Columba livia*), Common Myna (*Acridotheres tristis*), Jungle Myna (*A. fuscus*), Egret species (*Egretta* sp.), Asian Koel (*Eudynamys scolopacea*), Large Grey Babbler (*Turdoides malcolmi*), Painted Francolin (*Francolinus pictus*), Quail species (*Coturnix* sp.), Eurasian Collared Dove (*Streptopelia decaocto*), Common Kingfisher (*Alcedo atthis*), Little Green Bee-eater (*Merops orientalis*), House Sparrow (*Passer domesticus*), Sunbird species and House Crow (*Corvus splendens*). Reptiles included lizards (*Calotes* sp.), geckos, skinks and snake (*Coelognathus helena*). Arachnids included *Mesobuthus tamulus*, *Heterometrus xanthopus*, *Heterometrus granulomanus*, *Galeodius orientalis* and *Galeodius indica*. Insect prey included Rhinoceros Beetle (*Oryctes rhinoceros*), Long-horned Beetle (*Batocera rufomaculata*), Stag Beetle (*Lucanus cervus*) and Grasshoppers and Mantids. Other unidentified prey items included juveniles of Felidae and Leporidae (*Lepus nigricolis*) and amphibians.

Even though our analysis of the diet suggests that the Indian Eagle Owl is a dietary generalist, which concurs with published literature (Ali & Ripley 1969; Ramanujam 2006), the abundance and total biomass of different groups of prey in the diet showed that rodents were the most important prey followed by birds and bats (Table 1). Abundance of insect prey was also very high but the biomass of insect diet was minute. Of all prey items, 73% of relative abundance and 81% of prey biomass was of pests of agricultural significance (Table 2). Thus, the IEO is an important predator of agricultural crop pests, particularly rodents. Owls also feed on a variety of other agricultural pests like insects and bats and venomous organisms like snakes and scorpions (Table 2).

Of 13 species of rodent prey, which formed the major part of the diet of the IEO (55% relative abundance and 85% total biomass), seven were agriculturally important pests (Jain et al. 1993; Parshad 1999). Agriculturally important rodent pests contributed 88% of the abundance and 98% of the biomass of the total rodent in the owl diet. To understand whether the rodents actually came from the agriculture dominated

Table 2. Abundance and total biomass of agriculturally important pests and other prey venomous for man in the diet of the Indian Eagle Owl.

Prey item	Abundance (%)*	Total biomass (%)*
Agriculturally important pest		
Lesser Bandicoot Rat <i>Bandicota bengalensis</i>	397 (14.5)	108,381 (33.100)
Large Bandicoot Rat <i>Bandicota indica</i>	207 (7.5)	72,450 (22.100)
Indian Bush Rat <i>Golunda ellioti</i>	153 (5.6)	11,475 (3.500)
Soft-furred Field Rat <i>Millardia meltada</i>	154 (5.6)	15,400 (0.050)
House Mouse <i>Mus musculus</i>	8 (0.3)	120 (0.040)
House Rat <i>Rattus rattus</i>	208 (7.5)	33,280 (10.200)
Indian Gerbil <i>Tatera indica</i>	196 (7.1)	31,752 (9.700)
Indian Fulvus Fruit Bat <i>Rousettus lesheanaulti</i>	88 (3.2)	6,336 (1.900)
Rhinoceros Beetle <i>Oryctes rhinoceros</i>	328 (11.9)	328 (0.100)
Long-horned Beetle <i>Batocera rufomaculata</i>	21 (0.8)	21 (0.008)
Grasshoppers and Mantids	249 (9.1)	249 (0.080)
Venomous prey		
Snake: <i>Coelognathus helena</i>	2 (0.1)	550 (0.170)
Scorpion: <i>Mesobuthus tamulus</i>	10 (0.4)	20 (0.007)
Scorpion: <i>Heterometrus xanthopus</i>	3 (0.1)	9 (0.003)
Scorpion: <i>Heterometrus granulomanus</i>	2 (0.1)	6 (0.002)

* Percentage is calculated considering all the prey items encountered during the study.

habitats we performed Redundancy Analysis (RDA) with relative abundance of different prey items as dependent variables and percent habitat types as the independent variables (Fig. 2). There was a significant relationship between dependent and independent variables (permutation test pseudo-F = 0.380, $p < 0.0001$). The relative abundance of rodents in the diet was significantly correlated with increase in the agricultural habitat (correlation coefficient $r = 0.3996$, $p = 0.0001$). Although bats and birds were also positively correlated with the agricultural habitat, they were more strongly correlated with the increase in rural and scrub habitats respectively (Fig. 2).

We also performed RDA to understand how habitats and relative abundance and percent biomass of different prey types affected the productivity and duration of

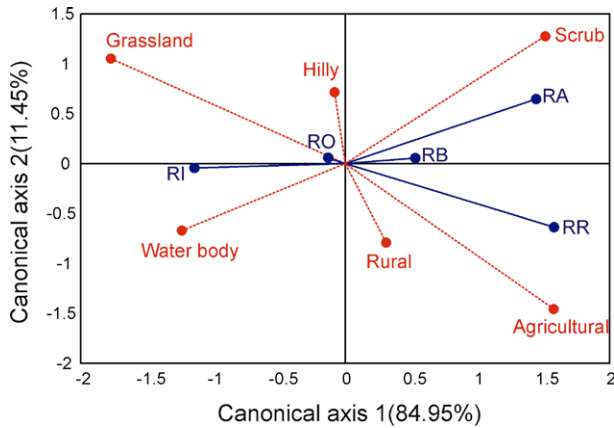


Figure 2. Redundancy analysis (RDA) depicting the canonical correlations between relative abundance of prey and habitat types. Percentage in parenthesis is the percentage variation explained by each canonical axis. Key: RR, relative abundance of rodents; RA, birds; RB, bats; RI, insects; and RO, other prey items.

breeding in the IEO (Fig. 3). Our analysis suggests that both productivity and duration of the breeding of IEO was high in agriculture and scrub dominated habitats (Fig. 3a, permutation test pseudo-F = 0.166, $p = 0.006$). Productivity was strongly correlated to the high relative abundance (Fig. 3b, permutation test pseudo-F = 0.309, $p < 0.0001$) and percentage biomass (Fig. 3c, permutation test pseudo-F = 0.302, $p < 0.0001$) of rodents and birds followed by bats.

Our findings of RDA point to two important outcomes. First, owls have a high productivity in the agriculture habitat (Fig. 3a), which could be attributed to the increased access to rodents (Fig. 2) which alleviates their productivity (Fig. 3b and 3c). As a result, owls are not just the predators of rodents, important agricultural pests, but are in turn dependent on them to increase their productivity. Therefore, there appears to be a delicate interdependence between owls and rodent populations. However, this interdependence points to another alarming threat to the owls. Chemical pesticides are used for rodent pest control which can affect the non-targeted wildlife (Kaukeinen 1982; Littrell 1990; Gillies & Pierce 1999; Newton & Wyllie 2002). Because the IEO has shown a dependence on the rodents, use of these rodent pesticides could affect IEO populations because of secondary poisoning. Second, since the productivity of owls is higher in the agricultural lands, the duration of breeding in the agricultural land is greater (Fig. 3a). As a result, owls may be prone to detection and anthropogenic activities

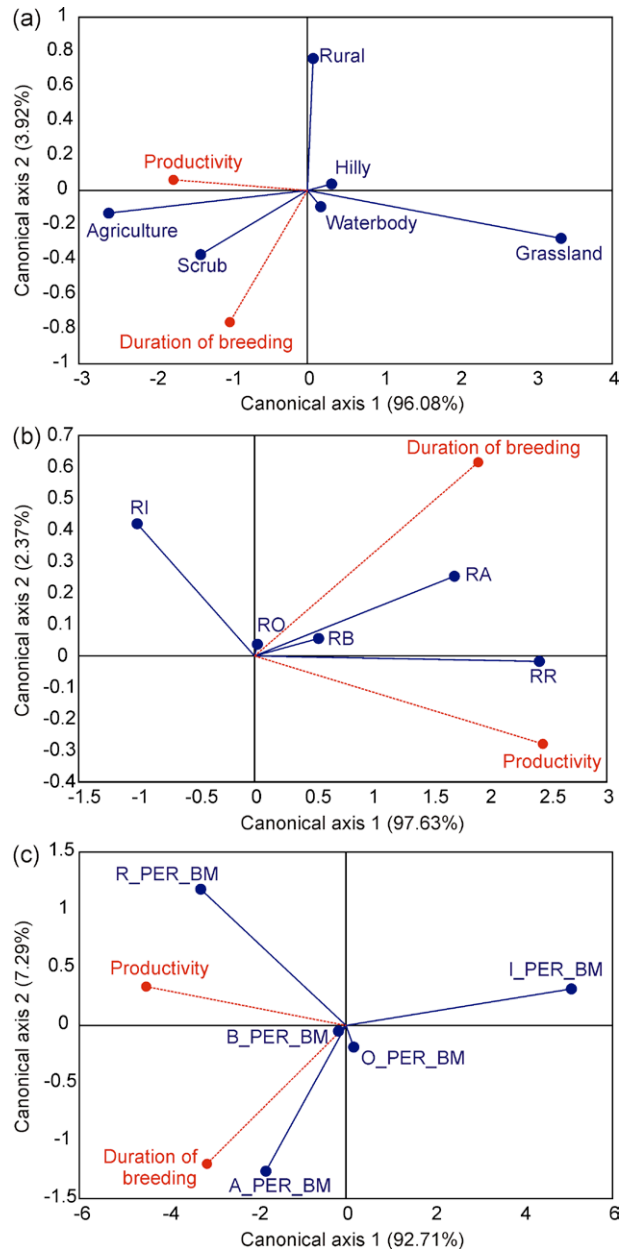


Figure 3. Redundancy analysis (RDA) depicting the canonical correlations between productivity and duration of breeding of the owls and (a) habitat, (b) relative abundance of prey and (c) percent biomass of different prey items. Percentage in parenthesis is the percentage variation explained by each canonical axis. Key: R_PER_BM, percentage biomass of rodents; A_PER_BM, birds; B_PER_BM, bats; I_PER_BM, insects; O_PER_BM, other prey items. Other abbreviations are as per Figure 3.

including persecution and interference.

Unfortunately, the IEO is often subject to indiscriminate hunting, out of superstition or fear (Pande et al. 2005) or trapping for use in black magic (Kasambe et al. 2004; Devkar 2009). If we can promote the importance of owls in the control of agricultural

pests, especially rodents, then such a strategy will help reduce human persecution of the owls. We believe that interactive educational programs based on scientific data, like this study, can be used to remove superstitions and further owl conservation.

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