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An Overview of Vertebrate Pests in India

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ABSTRACT: A billion-plus human population, agriculture, and development are shrinking and degrading the habitat of many of the 1,200 bird and 500 mammal species of India. With humans and herbivores competing for the same resources, many of them are becoming pests on crops. The granivorous birds depredate on selected cereals, sunflower, groundnut, and oil palm. Guava, grape, apple, sapota, pecan, pomegranate, and pineapple are damaged significantly by frugivore birds. Amongst vertebrate pests, rodents are the most destructive. A dozen species, viz. *Rattus rattus*, *Bandicota bengalensis*, *B. indica*, *Millardia melitana*, *Mus booduga*, *M. platythrix*, *Mus musculus*, *Tatera indica*, *Meriones hurrianae*, *Funambulus pennanti*, *F. palmarum*, *F. tristriatus*, and *Hystrix indica* are serious pests. Cereals, pulses, oil seeds, vegetables, fruits, and plantation crops are damaged considerably. Sown seeds, seedlings of maize, sorghum, sunflower, groundnut, red gram, tender coconut, oil palm, cardamom, and cocoa are depredated much more. Other vertebrate pests of significance are *Pteropus giganteus*, *Cynopterus sphinx*, *Rousettus leschenaulti* (bats), *Boselaphus tragocamelus* (Nilgai), *Elephas maximus* (elephant), *Macaca mulatta*, and *Semnopithecus entellus* (monkeys). Sporadically, other langurs, sloth bear, wild boar, hare, golden jackal, and peacock become pests. This paper reviews the lethal and non-lethal methods of managing this wide array of vertebrate pests.

KEY WORDS: bird pests, blue bull, elephant, frugivore bats, hare, India, lethal control, monkeys, non-lethal methods, peacock, rodents, sloth bear, wild boar

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INTRODUCTION

If resources become limited and if there is competition between humans and wild herbivores for the same resources, either in natural or cultivated fields, the latter become pests or predators. Elephants, wild pigs, bison, monkeys, langurs, bears, bats, porcupines, and several species of seed-eating and omnivorous birds were not habitual crop raiders in the past on the Indian subcontinent. But currently, these animals are devouring cultivated crops, putting the subsistence farmers to enormous losses and affecting government's policies to protect them. As most of these pests are either endangered or threatened, the issue becomes controversial. A section of society insists on conservation at any cost. On the other hand, the affected farmer becomes agitated and angry, as he is helpless to take any action against these protected animals. He expects hefty monetary compensation or suitable action by the government to ameliorate the problem. But such a plan can be formulated only after recognizing the damage patterns and the species responsible, which in turn is based on understanding the biology of pest species causing damage, evaluation of methods of management, and awareness about local laws about pest control and wildlife protection. This overview summarises the damage pattern, species involved, and existing methods of management of major vertebrate pests in India.

BIRDS

There are about 1,200 species of birds representing 20 orders in India. A total of 63 species of birds belonging to 19 families have been found damaging several crops, mostly grain-yielding and fruit-bearing ones.

Grainivorous Birds

The important depredatory birds are *Pavo cristatus* (common peafowl), *Grus antigone* (Sarus crane),

Anthropoides virgo (Demoiselle crane), *Columba livia* (blue rock pigeon), *Streptopelia decaocto* (ring dove), *Psittacula krameri* (rose ringed parakeet), *Psittacula himalayana* (slaty headed parakeet), *Megalaima viridis* (small green barbet), *Sturnus roseus* (rosy pastor), *Acridotheres tristis* (common myna), *Acridotheres gignianus* (bank myna), *Corvus splendens* (house crow), *Macrorhynchus* (jungle crow), *Pycnonotus cafer* (red-vented bulbul), *Turdoides striatus* (jungle babbler), *Passer domesticus* (house sparrow), *Ploceus philippinus* (Baya weaver), *Ploceus bengalensis* (black throated weaver bird), *Lonchura malabarica* (white throated munia), and *Lonchura punctulata* (spotted munia).

Crop Losses

Crop losses from depredatory birds (Rao and Dubey 2006) can occur either due to single species as in sunflower (parakeet), or a community of bird complex as in pearl millet, sorghum, paddy, and groundnut. Almost all cereals, pulses, oilseeds, and several vegetable crops are susceptible to bird damage during the sowing, seedling, and ripening stages. Cereals are vulnerable at dough stage, with smaller grains such as pearl millet and sorghum being more damaged than large sized grains like maize. Both smaller and larger birds feed on smaller grains, whereas maize is depredated primarily by larger species such as parakeets and crows. Isolated fields and fields with either early- or late-maturing varieties are highly susceptible to bird damage.

Cereals

Rose ringed parakeet, rosy pastor, ring dove, bank myna, house sparrow, and Baya weaver damaged cereals, which ranged 0.3 to 60% in pearl millet, 0.2 to 41% in wheat, 0.1 to 6.5% in paddy, 0.4 to 48% in sorghum, and 0.3 to 20% in maize (Rao and Dubey 2006).

Oil seeds

Bird damage was maximum in sunflower (10 to 90%) and was by rose ringed parakeet and house crow. Ten species of birds caused 3 to 33% damage at sowing and sprouting stages of groundnut. Oil palm was damaged at 3.3 to 30% by common crow, jungle crow, rose ringed parakeet, and common myna (Rao and Dubey 2006).

Management of Granivorous Birds

Only non-lethal methods of bird pest management are in vogue. These include suggestions to reverse the trends in crop cultivation by resorting to growing the original crops that were not attractive to birds. For instance, before the introduction of sunflower cultivation in Punjab, parakeets fed on seeds of mulberry and weeds like *Crotalaria medicaginea*, in spite of availability of mature wheat in the fields. Once sunflower cultivation spread, its seeds became very attractive (Saini *et al.* 1992). By reversing the cropping pattern, the bird damage is expected to be stopped. But such a change is difficult to adapt, as economic and dietary habits of people dictate the choice of sunflower cultivation. A second method is to prevent access to preferred food by wrapping with leaves, as in corn cobs (Dhindsa *et al.* 1993).

Tannins (Feare *et al.* 1988), and extracts of leaves of *Azardicta indicus*, *Mormoidia foetida*, *Veronica amygdaline*, tobacco, and *Gliricidia sepium* are known to repel bird pests (Rao and Dubey 2006). Treating seeds with Thiram and copper oxychloride at 0.5% before sowing reduced seedling losses to birds in maize, chickpea, soybean, sunflower, and groundnut (Chakravorthy 1993). However, such repellents are known to become ineffective in the absence of alternate foods (Feare *et al.* 1988).

Planting seeds deeper to prevent damage to germinating seeds (Dolbeer *et al.* 1979), growing maize instead of small-seeded cereals, avoiding early and late sowing varieties (Feare *et al.* 1988), and growing cucumber along with bottle gourd and creepers in raised basins (Srihari and Chakravorthy 1998) are some of the farming practices to reduce bird damage. Destroying perches and roost sites and denying water can also mitigate the damage.

Lure crops, if combined with scares, work more effectively than either of the methods alone (Feare *et al.* 1988). Planting of fodder sorghum and fodder maize reduced parakeet damage to maize (Rao and Dubey 2006). Scares include pyrotechnics and scarecrows. Growing crops in large blocks also prevented damage by parakeets to sunflower (Rao and Dubey 2006).

Frugivorous Birds

Several species of parakeets, bulbuls, crows, mynas, and one species of koel are frugivorous. Recorded damage was 20% in apple, peach, and apricot by red billed magpie, red vented bulbul, white cheeked bulbul, and slaty headed parakeet; 14-33% in guava by rose ringed parakeet and small green barbet in Karnataka (Chakravorthy 1993); and considerable damage was caused by bulbuls in Punjab (Toor 1982, Simwat and Sidhu 1973). Losses to grape ranged 19% to 60% in

Punjab by bank myna and Indian myna (Toor 1982, Sandhu and Dhindsa 1995), and 36% in Karnataka by jungle crow, common crow, and barbet (Prasad and Verghese 1985). An estimated damage of 21.2% was seen in peach by rose ringed parakeet, common crow, and sparrow (Toor and Ramzan 1974, Mann 1986), and up to 80% damage in apple by blossom headed parakeet (Narang and Chandel 1995). Jungle crow and golden fronted chloropsis caused considerable damage to orange (Chakravorthy 1993), while common crow was a pest on sapota (Verghese 2006). Rose ringed parakeet (Sridhara 1999), small green barbet, myna spp., and coppersmith (Chakravorthy 1993) damaged pomegranate (10-30%). Reported losses to pineapple due to depredation by jungle crow was 22% (Chakravorthy 1993). Damage to papaya by green barbet (Chakravorthy 1993) and to mango by rose ringed parakeet (Toor 1982) are also reported.

As in the management of grainivorous birds, lethal approaches to prevent damage by frugivore birds are avoided. Popular management techniques include netting entire trees, if the trees are large, and blocks of vineyards and smaller fruit trees. Other measures are covering canopy with dried twigs and thatches, shooting to scare, visual scares, and destruction of roosts and nests of birds.

RODENTS

Species

Of the 128 species of rodents belonging to 46 genera, 12 are serious pests (Table 1). *Rattus rattus* and *Mus musculus* are the commensals, also occurring in warehouses, godowns, and poultry and livestock facilities. *Bandicota bengalensis* is becoming commensal, replacing *R. rattus* across the country. There are 3 species of arboreal squirrels, namely *Funambulus pennanti*, *F. palmarum*, and *F. tristriatus*. These, along with 2 species of *Rattus*, *R. rattus wroughtonii* and *R. r. blanfordi*, are serious pests of coconut, cocoa, cashew, cardamom, and coffee in south-western and western coastal areas. The arid areas of Rajasthan and north-western Gujarat are infested by 3 xeric species: *Meriones hurrianae*, *Gerbillus gleadowii*, and *Golunda ellioti*. Of these, *M. hurrianae* and *T. indica* cause significant damage. North-east India is a biodiversity hot spot with its own repertoire of indigenous rodent pests, viz. *R. nitidus*, *R. sikkimensis*, *R. r. brunneusculus*, and *Dremomys lokriah*, apart from *B. bengalensis*, *B. indica*, *M. musculus*, and *M. booduga*.

The distribution of mole rat, *Nesokia indica*, is limited to north and eastern India. The porcupine, *Hystrix indica*, is ubiquitous, occurring at the forest edges, adjacent to crop fields, and wilderness throughout the country. At the northern tip, in the states of Jammu and Kashmir, the rodent species composition is unique with temperate species such as marmots, hamsters, voles, and some indigenous squirrels occurring along with the usual pest complex of *B. bengalensis*, *T. indica*, *M. musculus*, and *Rattus* species.

Generally, *B. bengalensis*, *T. indica*, *Millarida meltada*, *Mus platythrix*, *M. booduga*, and *M. musculus* are the agricultural pests throughout the country. Amongst these, *B. bengalensis*, *M. booduga*, and *N. indica* predominantly infest irrigated fields (Sridhara and

Table 1. Rodent pests in Indian agriculture.

Species	Distribution	Pest status
Five-striped northern palm squirrel, <i>Funambulus pennanti</i> (Wroughton 1905)	South of Sikkim to northern districts of Karnataka.	Damage to fruits and vegetables (Prakash <i>et al.</i> 1992, Parshad and Malhi 1994).
Southern palm squirrel, <i>F. palmarum</i> (Linnaeus 1766)	Entire South India.	Common pest of <i>chiku</i> , pomegranate (Sridhara 1999), coconut, cocoa, coffee, areca nut, cashew nut & cardamom (Bhat 1992, Chakravarthy 1993).
Western Ghat squirrel, <i>F. tristriatus</i> (Water house 1792)	Limited area of Western and south-western India from Mumbai to Travancore, west coast & Western ghats.	Major pest on Cocoa, cashew nut and areca nut (Bhat 1992).
The Indian crested porcupine, <i>Hystrix indica</i> (Kerr 1792).	Throughout India up to 2,750 M.	Feeds on tubers, bulbs, tree barks-damage severe at forest edges (Agarwal and Chakravarthy 1992, Sharma 1994, Girish 2005).
The Indian gerbil, <i>Tatera indica</i> (Hardwicke 1807)	Throughout India.	Major pest of rain fed agriculture, consuming almost all crops at every stage (Jain 1992, Sridhara 1999).
The desert gerbil, <i>Meriones hurrianae</i> (Jerdon)	Restricted to north-west Gujarat, Rajasthan desert, parts of Punjab and Haryana.	Serious pest of cereals, vegetables and fodder (Prakash 1981).
The hairy-footed gerbil, <i>Gerbillus gleadowii</i> (Murray 1886)	Rajasthan desert and parts of Gujarat.	Occasionally becomes a serious pest of crops (Tripathi <i>et al.</i> 1992).
The house rat, <i>Rattus rattus</i> (Linnaeus 1758)	Throughout India as a commensal; as a field pest in plantation crops of S. India and crop fields of N.E. India.	Huge losses in godowns, poultry and serious damage in livestock facilities, cocoa, coconut and field crops in N.E. India (Bhat 1992, Sridhara and Krishnamoorthy 1979, Parshad 1999).
Sikkim or Hodgson rat, <i>R. r. brunneusculus</i> (Hodgson 1845)	Restricted to the hill states of N.E. India.	Considerable loss to paddy, maize and vegetables. Population outbreak correlated with bamboo flowering (Chauhan and Saxena 1992, Pathak and Kumar, 2001).
The Himalayan rat, <i>R. nitidus</i> (Hodgson 1845)	North-east India & Kumaon region in Uttar Pradesh.	Damages paddy, maize and pineapple (Singh <i>et al.</i> 1994).
The Wroughton's rat, <i>R. r. wroughtoni</i> (Hinton 1919)	Kerala, Karnataka, Andhra Pradesh, parts of Maharashtra.	Serious pest of coconut, cocoa and oil palm (Bhat <i>et al.</i> 1990).
The Norway rat, <i>R. norvegicus</i> (Berkenhout 1769)	Occurs in only port cities of Mumbai & Kolkatta.	Pest of warehouses (Jain <i>et al.</i> 1993).
The soft furred field rat, <i>Millardia meltdada</i> (Gray 1837)	Throughout India except north-east mountains.	Serious pest of cereals, pulses and oil seeds. Also damages natural grasslands and fodder crops in Rajasthan (Rana 1992).
The Indian bush rat, <i>Gollunda ellioti</i> (Gray 1837)	North-west region of India.	Minor pest of agriculture in Punjab & Rajasthan (Saini and Parshad 1993, Prakash <i>et al.</i> 1995).
The house mouse, <i>Mus musculus</i> (Linnaeus 1758)	Throughout the world.	Nuisance in houses, damage in storage and a pest of sugarcane, groundnut (Rao and Balasubramanyam 1992).
The brown spiny mouse, <i>M. platythrix</i> (Bennet 1832)	Throughout India except the north-east, Jammu & Kashmir.	Pest of paddy, ragi, wheat, oil seeds, pulses and vegetables (Rao and Balasubramanyam 1992, Sridhara 1999).
The Indian field mouse, <i>M. booduga</i> (Gray 1837)	Throughout India.	Pest in paddy, vegetables and groundnut (Rao and Balasubramanyam 1992, Sridhara 1999).
The short-tailed mole rat, <i>Nesokia indica</i> (Gray 1830)	North-western and northern India.	Pest on lawn grass, cereals, groundnut and vegetable crops (Ramesh 1992).
The lesser bandicoot rat, <i>Bandicota bengalensis</i> (Gray 1835)	Throughout India including the semi-arid Rajasthan.	Very serious pest of cereals, pulses, sugarcane, oil seeds, almost all vegetables, selectively commensal in godowns. Burrowing activity affects fruit trees like apples etc. (Chakraborty 1992, Sridhara 1999, Sridhara and Tripathi 2005).
The larger bandicoot rat, <i>B. indica</i> (Bechstein 1800)	From the south of Rajasthan to the southern tip of India, eastwards to W. Bengal and north-east India.	Damage to paddy, wheat, maize and vegetables, also to aquaculture (Chakraborty 1992).

Tripathi 2005).

Rodent Damage to Agricultural Crops

Almost all cultivated crops are vulnerable to rodent depredation at some stage or the other of the crop growth and maturity. The damage caused is extensive and varied and has been extensively summarized by Parshad (1999) and by Sridhara and Tripathi (2005). Amongst cereals, it was 2.7 to 21.3% in wheat, 3.28 to 24.4% in rice, 10.7 to 80% in maize at seedling stage, 1.9 to 24% in maize at cob formation and maturation stage, and 4 to 10% in sorghum. Species inflicting damage are *B. bengalensis*, *M. melitad*, *M. platythrix*, and *T. indica*. In pulses, damage at seedling stage was 50 to 100% in pigeon pea and 10% in green gram. At pod maturation stage, it was 2 to 7% in pigeon pea, 4 to 18% in cow pea, 5 to 6% in green gram, and 0.6 to 3% in soybean. In oil seeds, damage was 30 to 40% in groundnut seedlings and 70% in sunflower seedlings.

Damage was 0.6 to 19% at pod formation and maturation stage of groundnut, which rose to 85% during outbreaks. More than 10% damage was seen in vegetables like tomato, cauliflower, carrot, cucumber, musk melon, bottle gourd, ridge gourd, and chillies. Considerable damage was also seen in knol-khol, potato, pea, cabbage, brinjal, French bean, sweet potato, and sponge gourd. Amongst fruits, rodent damage was 8 to 80% in ber, 2.6 to 44.4% in pineapple, 9 to 19.8% in watermelon, 1.4 to 18.4% in summer squash, 17 to 40% in apple, 1.6 to 17.4% in pecan, 5 to 10% in sapota, and 6 to 12% in pomegranate. Extensive damage was observed in plantation crops: 6.8 to 8% in coconut nursery, 4.5 to 55% losses to tender coconut, 7 to 15% damage in mature nuts, 10.28 to 60% in cocoa, 1.4 to 20% in cardamom, 10 to 45% to seedling of oil palm, and 50 to 57.3% to fruits and nuts of oil palm. However, damage to cashew nut and rubber were negligible.

Strategies of Rodent Pest Management

In spite of various methods of control (Table 2), rodent damage continues to be unabated in India. Not only is pest density high, but there are several species with varying biological traits and behavioural ecology infesting the crop simultaneously or at different stages of its growth, in what appears to be a successful example of resource partitioning, both temporally and spatially. Managing these multiple species of rodent pests, and motivating farmers to adopt crop- and area-specific management techniques, needs evolving appropriate technologies, preferably integrated ones.

The various methods in practice can be categorized into 4 major approaches, namely preventing rodent access to crop fields, discouraging infestation, reducing numbers, and preventing re-infestation and population build-up.

Preventing Access

Preventing access to crop fields is mainly by rendering fields unfit for fresh burrows, reducing vegetation cover so that exposure to predators is increased, and erecting barriers. Changes in tillage practices such as deep tillage, crop rotation, ploughing the vacant bunds and land

around wheat fields (Ramesh and Katiyar 1985, Parshad 1999), and keeping bunds low and narrow (Sharma and Rao 1989) are some of the measures advocated to prevent rodent access.

A smooth aluminium sheet of 0.2 mm thickness, measuring 18 cm, fixed 2-3 m above the ground around the trunk of coconut, was extremely effective in preventing damage due to rodents (Anon. 2004). Similarly, placing screw pine leaves along the edges of paddy fields repelled rats (Subaiah 1978).

Table 2. Strategies for rodent pest management suitable for Indian agriculture.

Sl. No.	Strategy	Steps/Technology to be Adapted
1.	Preventing access to crop fields	(i) Tillage (ii) Bund reduction (iii) Agro forestry (iv) Barriers
2.	Discouraging infestation	(i) Synchronized planting (ii) Clean cultivation (iii) Resistant varieties
3.	Density reduction	(i) Physical control (a) Hunting and killing (b) Trapping (c) Trap barrier system (ii) Chemical control (a) Acute rodenticides (b) Chronic rodenticides (c) Fumigants (d) Timing of control Prophylactic control Symptomatic control (iii) Biological control (a) Predators (b) Pathogens and diseases (iv) Fertility control (a) Steroids (b) Immunocontraception vaccines (c) Predator odours
4.	Integrated pest management of rodents	(i) Understanding pest species (ii) Action threshold (iii) Population dynamics (iv) Management (a) Prevention of infestation (b) Non lethal or weak chemical use (c) Pesticide application

Discouraging Infestation

Discouraging infestation by eliminating or reducing sources of food and harbourage was achieved by synchronized cropping, clean cultivation, and by weed control (Singh *et al.* 1983, Sablok and Pasahan 1985, Pasahan and Singal 1994). But attempts to raise rodent-resistant varieties are non-existent in India.

Density Reduction

Density reduction measures employed are physical (hunting and trapping) and chemical (rodenticide usage). Hunting is by flooding and smoking. The burrows are flooded or smoked to force rats out, which are caught by hand or by using nets, or killed by sticks, or dogs are allowed to hunt them. Several tribes in south India, Bihar, and north-east India catch rats to use as food

(Whitaker 1979). Traps are basically snap and live traps of various types.

Chemical control using rodenticides continues to be the most widely used method for rodent control in India as elsewhere in the world. Seven rodenticides are registered but only 4 are marketed, namely zinc phosphide, aluminium phosphide, coumatetralyl, and bromadiolone.

Zinc phosphide is the most commonly used and popular rodenticide because of its wide efficacy and good acceptance. It is used at 2% in the bait and usually results in 60-70% mortality. Bait shyness resulting from ingestion of sublethal doses, which extends for periods ranging 6-170 days, and lack of specific antidote are the limitation in its use (Idris and Prakash 1992).

Aluminium phosphide tablets (0.4 to 0.5 g) are used to fumigate burrows. Though their small size, easy handling, and the resulting quick death make it popular, the fumigant is banned in many parts of the country and is registered for restricted use because of its extreme toxicity, fire hazard, and lack of antidotes.

Coumatetralyl at 0.075% is used as a tracking powder for commensal rodent control and at 0.0375% in cereal bait against field rodents (Parshad and Malhi 1995). Low toxicity, chronic action, and availability of Vitamin K, the antidote for the poison, have made this anticoagulant practical and sufficient.

Bromadiolone is the only second-generation anticoagulant that is marketed in India. Ready-to-use wax blocks are ideal for residential rodent control, and the powder form at 0.005% in cereal bait is recommended for crop fields. Although resistance to bromadiolone is reported elsewhere in the world, it may not happen in the near future in India because rodent control has not yet attained the status of routine agricultural practice.

Timing of Rodent Control

Prophylactic control in the months of May through June and November through December, which are the fallow periods between summer and winter crops, is advocated. During this period, rodents are confined to reservoir habitats such as bunds, dykes, borders of water channels, uncultivated lands, or inside long-duration crops such as sugarcane, orchards, and plantations. In the absence of adequate natural food resources, rodents are easily attracted to baits, and mortalities are high. Such a control breaks the natural breeding cycle of rodents, preventing population build-up later during the cropping season. Control during May through June is also economical and more effective, as the population is minimum and non-breeding (Sridhara 1999).

There is the possibility of farmers being reluctant to take up rodent control in fallow fields, although they are relatively free of farm activities. However, a well-planned motivational campaign would give optimum reduction in pest population, apart from being cost-effective.

Symptomatic Control

There are definite susceptible stages during crop growth when a symptomatic control can be taken up, such as 30-60 days after transplantation of rice (Rao and Singh 1983, Bhaskaran *et al.* 1995), 80-100 days after

sowing of groundnut (Parshad *et al.* 1987), late tillering stage of wheat (Rao 1992), and July-August and October-November in sugarcane (Parshad *et al.* 1986, Ahmad and Parshad 1991). In cases where seedling damage is significant (i.e., sorghum, maize, sunflower, red gram, and groundnut), rodent control in and around to-be-cultivated fields is suggested during land preparation itself.

Success and Failure of Control Campaigns

Three decades of intense government-backed research on the biology of pest species, rodenticides, and non-chemical approaches to reduce pest populations has contributed significantly towards reducing rodent damage in India. Still, not only is the problem persisting, but there are sudden, unexpected outbreaks of rodent populations here and there.

The reason for this unsatisfactory situation is two-fold: the biology, behaviour, and adaptability of rodents, on one hand; and the socio-economic conditions and farmers' attitudes, on the other hand. Apart from rodents being 'r' strategists and consequently prolific breeders, their extreme adaptability, capacity to detect and colonise newer habitats, genetic resistance to anticoagulants, neophobia, and bait shyness towards acute rodenticides renders rodent control unsuccessful in India, as elsewhere. Added to this, adoption of rodent control by Indian farmers is very poor due to general neglect, lack of awareness of economic losses, small land holdings that make organization and execution of large-scale rodent control operations difficult, low or no education, poverty, earlier failures, and the resigned attitude that rodent control is not only a minor problem but also unmanageable (Parshad 1999).

BATS

Only 3 of the 12 species of fruit bats are common throughout the country, namely the short-nosed fruit bat, *Cynopterus sphinx* (45 g), the fulvous fruit bat, *Rousettus leschenaulti*, and the Indian flying fox, *Pteropus giganteus* (900 g). Studies on bat damage to fruits are limited. *C. sphinx* is reported to damage grapes substantially, which was positively correlated with fruit maturity and was higher if the vineyard had open spaces around it (Verghese 1998). Damage ranged 10-100% (Srinivasalu and Srinivasalu 2001) and yield loss was 1,182 kg/ha by *P. giganteus* and *R. leschenaulti* (Elangovan and Marimuthu 2001). *P. giganteus* damaged 18% of areca nut (*Areca catechu*) and 12.5 to 22.3% of sapota, while *P. giganteus* along with *C. sphinx* damaged 18% guava (Chakravarthy and Girish 2003).

The most practical and harmless method of bat management is netting entire trees with fine-mesh fishing net. In larger orchards, mist nests are used to capture them. Eco-friendly, economical methods include covering grape bunches with dry sprigs of foliage, leaving bat-damaged bunches on the vine intact (Verghese 1998), and using firecrackers (Srinivasalu and Srinivasalu 2001). Block plantation makes it easy to cover fruit-bearing trees and vines with nylon nets or sprigs, dry foliage, thatch, etc. (Chakravarthy and Girish 2003). Growing trap crops like Singapore cherry, *Muntingia calabura*, in and around orchards can divert bats away from commercial fruit

crops (Chakravarthy and Girish 2003, Marimuthu 2004).

BLUE BULL

Blue bull, *Boselaphus tragocamelus* (Artiodactyla: Bovidae) is indigenous to India, with its distribution restricted to western and northern India. It is the biggest antelope in the country (2 m in length and 1.5 m in height), inhabiting areas with open scrub and scarce vegetation in and around wildlife sanctuaries, but avoids dense forests. An adult animal is reported to consume 13-15 kg plant material per day (Goyal and Rajpurohit 2000). Of late, crop depredation by blue bull has become a serious problem in the states of Rajasthan, Haryana, and Punjab. However, such studies are limited to survey-based data collection.

In Haryana (north India), gram, wheat seedlings, and green gram rarely were damaged less than 10%, and often damage reached as high as 58% of total yield (Chauhan and Singh 1990). In Madhya Pradesh (central India), damage was reported for gram, green gram, wheat seedlings, mustard, linseed, groundnut, sugarcane, soybean, gingilly, and jowar. In certain areas, the damage was so severe that cultivation had to be abandoned (Chauhan and Sawarkar 1989). The blue bulls in Rajasthan preferred moth (*Pennisetum aconitifolios*), gawar (*Cyamopsis tetragonoloba*), bajra (*Pennisetum typhoidenum*), moong (*Triticum vulgare*), jeera (*Carum nigrum*), dhania (*Coriandrum sativum*), and several vegetables. In addition, fruits like ber (*Ziziphus maritima*), nimbu (*Citrus medica*), papita (*Carica papaya*), amrud (*Picidium guajava*), and anar (*Punica granatum*) were also devoured.

Several reasons are attributed to the pestiferous activities of blue bull, such as rapid increase in population consequent to a ban on hunting and trapping, protection bestowed by the Wildlife Act of 1972 (Chauhan and Sawarkar 1989), lack of natural predators, deforestation, overgrazing of grasslands by livestock, and religious protection given by a sect of Hindus called *Bishnois* who share the same habitat as blue bull.

The only method of crop protection was the guarding of fields by humans and dogs during vulnerable stages of crop growth. Although culling was suggested, it was strongly opposed by *Bishnois*. In view of strong demands by affected farmers, the governments of Haryana and

Rajasthan have relaxed rules of hunting, even though the animal is a protected species. Other methods, such as containing them in enclosures, fencing crop fields including power fencing, translocation, and sterilization, are not practical and economical for the marginal farmers of India.

ELEPHANTS

The Asian elephant, *Elephas maximus*, with an estimated food requirement of 125 kg green leafy matter and grains per day, in the wild forages extensively on grass, bamboo, barks of various trees, and reed. From time immemorial, reports exist on human-elephant conflict. But the problem has become severe in the recent past throughout the tropics because of reduced, fragmented, and deteriorating habitat. These conflicts are manifested as killing/injuring people, crop raiding, damaging property, and harming livestock. This paper deals only with crop raiding.

Crop Raiding by Elephants

Although elephant damage to crops (Table 3) is known from the past records, the problem has become serious due to continuous loss of habitat as a result of expanding agriculture, industry, mining, and roads inside the forests. Sukumar (1985) found maximum damage to finger millet. After its harvest, paddy, other millets, and sorghum fields were raided. Rachis from coconut tree, fibrous pith of banana, inflorescence or bunches of fruits, sugarcane stalks, flowering branches of mango, and ripe jackfruits also formed the food of raiding elephants. The intake of grains was 5,472.2 kg by herds on 33 nights and 4,450.5 kg by bulls in 77 nights. Cultivated crops formed 9.3% the annual food requirement of bulls and 1.7% of family herds (Sukumar 1990). In Nilgiri Biosphere, 9.1% of the fields visited were raided and 2.1% of the raided fields suffered damage. The damage estimates ranged from 3.45% in paddy to 1.5% in ragi and 1.4% in maize. Ginger was not consumed, but 1.7% losses occurred due to trampling (Balasubramanyam *et al.* 1995).

Studies around Dalma Wildlife Sanctuary in south Bihar (Datye and Bhagawat 1995) revealed initial bull attacks in July, by family herds in August, and by both during September-October. Raiding ceased with their migration to west Bengal in November-December.

Table 3. Foraging behaviour of elephants.

Location	Plants eaten/crop raided & damage	Reference
S. India	<i>Themeda cyambaria</i> , <i>Cymbopogon flexuosus</i> (grasses)	Sukumar 1990
Nilgiri Biosphere	<i>Themlia</i> spp. (grasses)	Sivaganeshan and Johnsingh 1995
S. India	5,472.2 kg crops in 33 nights (Herds) 4,450.5 kg crops in 77 nights (bulls) Mostly finger millet, paddy, sorghum, jowar, coconut rachis, banana pith, sugarcane stalks	Sukumar 1985
Nilgiri Biosphere	Paddy – 3.45% Ragi – 1.5% Maize – 1.4% Ginger – 1.7% (trampled)	Sivaganeshan and Johnsingh 1995
S. Bihar	Paddy worth Rs. 1.8 million	Datye and Bhagawat 1995
S. West Bengal	5.5% cultivated area mostly paddy raided average loss 40% = Rs. 3.2 crores. Paddy>Potato>Vegetables>Wheat>Maize	Singh <i>et al.</i> 2002
Meghalaya	Annual losses of Rs. 24,000/farmer	Williams and Johnsingh 1996

About 150 villages were raided around the sanctuary, all along the migration route as well as in migrated villages. Paddy loss in 10 villages studied was worth 0.16 to 0.18 million rupees (US\$360-400) during 1989-91. However, hay loss ran into thousands of rupees and was meagre compared to grain loss.

On their return migration to Dalma Wildlife Sanctuary, only 5.5% of the total cultivated area in the range of elephant movement was raided (Singh *et al.* 2002). Generally, crop depredation was lower when cultivated areas were larger than forest cover, and vice-versa. Damage was maximum during crop maturity and was greatest for crops grown in *kharif* (September-December). The losses averaged 40% resulting in annual losses of 3.2 crores (US\$ 710,000). The decreasing order of damage severity was paddy (66%) > potato (16%) > vegetable (10%) > wheat (5%) > maize (1%). At provisional and national level, the degree of economic loss is not very significant, but at the local level it is severe, as most affected farmers are marginal and subsistence level cultivators.

In the degraded habitat of West Garo hills in north-east India, the habitat is sub-optimal, and elephants roam more from one patch to another in search of food. During these searches, they raid the newly cultivated jhum fields on the slopes of degraded forests/mountains, causing an estimated loss of Rs. 24,000 (US\$533), compared to annual income of Rs. 11,000 (US\$244) of subsistence farmers (William and Johnsingh 1996).

Reasons for Crop Raiding

Reasons for crop raiding by elephants include proximate factors such as reduction, degradation, and fragmentation of habitat, as well as palatability and nutritive value of cultivated crops. The ultimate factors are the lower energy expenditure involved in crop raiding compared to foraging in open, and the selection pressure to select nutritive food, a case of optimal foraging strategy. Secondly, elephants have to procure more nutritive food from cultivated fields, as their natural

habitat of degraded forests cannot provide an adequately balanced diet to support successful reproduction (Sukumar and Gadgil 1988).

Management of Crop Raiding

Management of crop raiding elephants involves short-term measures to mitigate elephant damage, including use of repellents, deterrents, night vigils, capture, translocation, destruction of "rogue" elephants, wildlife squads, and monetary compensation. Deterrent approach is by guarding and chasing away marauding elephants using sound and noise (Table 4). Long-term measures include preventing farming around and inside forests, illegal cattle grazing, illegal collection of firewood, forest fires, etc., as these improve habitat and mitigate elephant damage to crops and nuisance to humans. Habitat can also be improved by growing fodder crops and bamboo inside the forest, by creating water bodies, conserving water, enriching forest flora, and by protecting swamps and resettling people who are living inside the core area of elephant habitats. Other measures include preventing encroachment of forest for cultivation, disallowing cultivation around their natural habitat, stopping conversion of forests into plantation crops, mining, construction of new roads, railway tracks, and to some extent, tourism too. However, unpredictable and recurring droughts as a result of irregular monsoons worsen the already deteriorated elephant habitat, which in turn is due to depletion of resources inside forest by humans and livestock. In such a habitat, the measures suggested above are likely to encourage human elephant conflicts.

An indirect way of enriching the degraded elephant habitat is by promoting eco development works, which basically aim at reducing the dependency of villagers on forest for grazing, firewood, etc. The measures include using alternate sources of energy instead of firewood, growing enough fodder for livestock, and maintaining elephant corridors. Growing non-edible crops around sanctuaries and changing the schedule of cropping are some other recommendations to reduce crop losses to

Table 4. Existing measures to alleviate crop losses to elephants.

Short Term Measures	Long Term Measures
<ol style="list-style-type: none"> 1. Repellents & Deterrents <ol style="list-style-type: none"> (a) Repellents <ol style="list-style-type: none"> (i) Chemical repellents "HATE-C4", Secretions from temporal gland Pepper spray (<i>Capsicum</i> oleoresin) (b) Deterrents <ol style="list-style-type: none"> (i) Passive deterrents Trenches Electric fencing Non-electric fencing (ii) Active deterrents Guarding Driving away using sound or light (iii) Integrated approach using sound & light 2. Capture of elephants 3. Capture & Translocation 4. Use of trained elephants (<i>Koonkie</i>) 5. Wildlife squads 6. Monetary compensation 	<ol style="list-style-type: none"> 1. Habitat improvement <ol style="list-style-type: none"> (a) Preventing encroachment (b) Preventing deforestation (c) Preventing conversion of forests into monocultures (d) Growing fodder grass inside elephant habitat (e) Swamp protection 2. Eco-development works <ol style="list-style-type: none"> (a) Use of alternatives to firewood (b) Preventing illegal grazing (c) Resettlement of tribals 3. Elephant corridors 4. Agro-forestry as a buffer between forests and villages 5. Changed land use (cultivating non-edible crops)

elephants. However, in the absence of long-term studies on elephant damage to agriculture, it is difficult to categorize elephants as pests.

MONKEYS

In dealing with the rich primate fauna of India, we face the dilemma of conserving rare and endangered species of primates (such as Assamese pig-tailed and stump tailed macaques; capped, golden, and Phayre's langurs; slow loris and Hoolock gibbon in north-east India; and lion tailed macaque, Nilgiri, langur, and slender loris in south India) on one hand, and managing the pestiferous activities of monkeys on the other hand.

Three species of monkeys, viz. rhesus monkey (*Macaca mulatta*), bonnet monkey (*M. radiata*), and Hanuman langur (*Semnopithecus entellus*), although living in forest edges, are almost totally dependent on the human environment for food, and they become pests in the process. Long-term studies on rhesus macaques have revealed vigorous population growth by prolific breeding and efficient utilization of commensal habitat, thus qualifying them for 'r' selection. They are also termed "weed macaques" because of their aggressive commensalism.

Hanuman langur (*Semnopithecus entellus*), in spite of being a successful commensal, has a lower birth rate and high infant mortality. In the wild, they subsist on natural vegetation such as seeds, nuts, fruits, grasses, leaves, roots, occasionally insects, and rarely raid crops. As they are considered as the incarnation of Hindu Monkey God, Hanuman, devout Hindus feed them reverentially. It is only at the fringes of some forests, protected areas, and sanctuaries that they become pests, raiding cultivated foods, eating everything that is palatable (i.e., sown seeds, sprouting seedlings, young plants, maturing green vegetables, and fruits). Their crop raiding behaviour has been studied in detail in Kumbalgarh Wildlife Sanctuary (KWS) and Jodhpur city, which are both in the desert state of Rajasthan (Chhangani and Mohnot 2004). At KWS, they are reported to consume 184 types of food items, inclusive of natural food, cultivated plant parts, and cooked food. Damage was found to be 27% of total yield, which is equivalent to US\$900 annually from a troop of 102 monkeys. This apart, there was significant loss due to consumption of flowers and fruits, and by way of damage to vegetative parts of trees.

Sixty percent of the farmers guarded the crop fields to prevent langur damage during season. Twenty percent used a device of throwing stones, 15% employed dogs to chase monkeys, while the remaining 5% used lethal approaches such as shotgun, potash bomb, and high voltage electric current.

Rhesus monkey (*Macaca mulatta*) lives close to human beings in villages, towns, cities, temple sites, parks, gardens, orchards, etc. Out of 0.3 million monkeys reported to live in India, around 48.5% are *M. mulatta*, which are true commensals (Southwick and Siddiqui 1994). The problems associated with rhesus monkeys are three-fold, namely possible transmission of fatal diseases, nuisance to people, and pestiferous activities.

Monkeys are susceptible to viral diseases (*Herpes simiae*, *H. hominis*, *Yaba virus*, monkey pox, and rabies),

bacterial diseases (*Mycobacteria*, *Shigellosis*, *Salmonellosis*, and *Camphyl bacteria*), and parasitic diseases (*Giardia* and *Entamoeba histolytica*), and potentially are transmitters to humans (Tiwari and Shukla 1984).

With their natural habitat destroyed, fragmented, or shrunk, rhesus monkeys are forced to raid human habitat to procure food and water. They invade crop fields and settlements, damaging property, gardens, household items, etc. They are over-abundant in temples, hospital premises, and schools. Irrate citizens threaten nuisance monkeys, hit them with stones, and sometimes even shoot at them, which makes monkeys defensive and over-aggressive. In response, they threaten human beings with snarls, snatch food boxes, handbags, umbrellas, and spectacles. Frequently, they bite; bites have increased alarmingly to 100 bites a day in New Delhi alone (Malik 2001). In the temple town of Vrindavan, they entered homes stealthily, stole food, uprooted seedlings and tuberous vegetables, pulled out electric wires and TV antennae, threatened and attacked people, and often bit viciously (Malik and Johnson 1994).

Management of Nuisance Monkeys

With religious sentiments associated with monkeys, managing them is a sensitive issue. Southwick and Siddiqui (2001) suggested 3 measures to reduce monkey menace: reducing supplemental feedings, translocation, and fertility control. However, supplemental feeding by religious Hindus will never stop in India, and fertility control is yet to find a safe, successful technology. Thus, translocating becomes the only feasible and practical method to manage problem monkeys (Siddiqui and Southwick 1993, Imam and Malik 1997).

UNCONVENTIONAL AND SPORADIC VERTEBRATE PESTS

There are a few herbivorous and omnivorous mammals that become sporadic pests. These include some species of monkeys, bears, wild boar, jackal, hare, and peacock.

Langurs

Three species of indigenous langurs, viz. Phayre's leaf monkey (*Presbytis pharyrei*), capped langur (*Presbytis pileatus*), and golden langur (*Presbytis geei*), which normally live in dense forests of north-east India, have learnt to raid crops. They have started feeding on ripe fruits, green twigs, green leaves, flowers, pods, seeds, fleshy fruits of mango, pigeon-pea, *Zizyphus*, *Brassica* spp. (cabbage), citrus, guava, banana, jackfruit, and gooseberry (*Embelica*), resulting in considerable losses in orchards (Bhattacharjee and Chakravathy 1992).

Sloth Bear

The sloth bear, *Melurus ursinus* (Carnivora: Ursidae), is indigenous to India. In the natural habitat, the sloth bear's diet consists of fruits of banyan, wild figs, mangoes, jamoon, ber, honey, and termites. In several places, particularly Karnataka in the south, changes in forest type from dense forests to plantation and scrub jungle, and encroachment of agriculture up to forest edge/ foothills, have reduced food availability and the range of

bears, forcing them to depredate on agricultural crops. Ishwaraiah (1984) reported that 50% of the sloth bear's nutritional requirements are met from crop fields because of non-availability of natural food in their habitat. Apart from crop losses, bear-man conflicts are also on the rise. There are no studies on bear management so far.

Wild Boar

Wild boar, *Sus scrofa* (Artiodactyla: Suidae), found throughout India, is an unrecognized pest of crops wherever wilderness borders cultivation, moreso around national parks and hilly regions. A total of 44 species of edible plants in Kerala were reported to be destroyed by wild vertebrates such as elephant, wild bison, sambar, wild boar, bonnet macaque, common langur, black napped hare, and pea fowl, with wild boar causing the maximum damage (Jayson 1999).

Wild boar damage also occurred in crop fields around national parks of Sariska (Sekhar 1998), Nandadevi Biosphere (Rao *et al.* 2002), and Kumbalgarh Wildlife Sanctuary (Chhangani and Mohnot 2004). It is a pest on cardamom and rice in Karnataka, causing 12% loss in the latter when grown along forest fringes (Chakravarthy and Srihari 2002, Chakravarthy 1994), with taller varieties being damaged more than dwarf varieties (Thomas and Naidu 1995). Hanging polythene bags containing thimet granules and sand along the edges of rice fields (Chakravarthy and Srihari 2002), growing dwarf rice with long auricles on panicles (Thomas and Naidu 1995), guarding fields (Chhangani and Mohnot 2004), and cultivating non-edible crops (Rao *et al.* 2002) are some of the measures adopted to contain wild boar damage.

Golden Jackal

The golden jackal, *Canis aureus* (Carnivora: Canidae), lives close to towns, villages, and cultivated areas at the fringe of forests. Although they feed on crops such as corn, sugarcane, melon, and vegetables, their role in scavenging is far greater and as pests is negligible (Prater 1986). They caused 4.5% damage to cocoa and also to pineapple in western Ghats and coastal Karnataka (Chakravarthy 1994).

Hare

The hare, *Lepus nigricollis* (Lagomorpha: Leporidae), is capable of damaging crops adjacent to forests. Although there are no published accounts, farmers and agricultural field workers are aware of hare damage to sprouting grains (rice and cow pea), pulses, and bamboo (Chakravarthy 1994). Ten percent thimet mixed with dry sand and suspended in perforated polythene bags, when hung around the fields, repelled hares from bamboo seedlings (Chakravarthy 1994).

Indian Peacock

The Indian peacock, *Pavo cristatus* (Galliformes: Phasianidae), is generally omnivorous, consuming seeds, grains, lentils, tender shoots of crops, flower buds, berries, insects, worms, and grubs in and around villages (Ali and Ripley 1987). They were found feeding on paddy grains, panicles, buds/flowers/tender fruits of cucurbits, brinjal, cow pea, and pods/seeds of pulses

(Chakravarthy 1994). Due to religious sentiments and the protected status of the peacock, which is also the national bird, no measures are taken to discourage peacocks from foraging in cultivated fields.

CONCLUSIONS

The management of vertebrate pests in India is besotted with diverse opinions and pressures. In many situations, methods to deal with vertebrate pest problems are limited. Local, national, or international regulations and laws interfere with implementation of management of their pestiferous activities. Research and concern has resulted in several recommendations to prevent damage. However, the choice of method is riddled with controversy and is susceptible to social, economical, and political pressures. Those suffering damage insist on the traditional methods of hunting, trapping, and poisoning. But these age-old practices are considered cruel and inhumane by conservationists and the emerging animal rights/welfare activists. But when planning management, it is important to bear in mind that usually these protesters are not victims of vertebrate damage, directly or indirectly. In the end, an Integrated Vertebrate Pest Management is the best approach for resolving the problems with avoidance of lethal methods as much as possible.

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