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The Ecology of Rodent and Integrated Pest Management in the Light of North Eastern States: A Review

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Abstract

Globally known as the most important mammalian pests, rodents cause great damage to agriculture and industry. Among the 128 rodent species in India, 18 are considered pests that significantly affect post-harvest storage and crop output, causing 5-10% annual food grain losses. In both feeding and breeding environments, rodents show extraordinary flexibility. Their highly specialized gnawing adaptations, seasonal feeding schedules and omnivorous diet help them survive in many habitats. Their reproductive success is influenced by food availability and climatic variables like rainfall and helps to explain population surges and regular outbreaks. Rodents serve as reservoirs for over 60 zoonotic illnesses, significantly compromising public health. Mostly dependent on chemical rodenticides like zinc phosphide, conventional rodent control raises toxicity questions and calls for safer alternatives. Strategies for Integrated Pest Management (IPM), especially in Northeast India, combine modern techniques with indigenous practices. Key approaches include agronomic practices, innovative technologies like smoke generators and local methods such as using Gilmat leaves and *Artemisia vulgaris* to deter rodents. By understanding rodent feeding and breeding behaviors, this review article discusses a more effective, eco-friendly approach to managing rodent populations, safeguarding agriculture and public health.

Keywords: Agriculture, Indigenous control, Integrated pest management, Northeast India, Rodent pests, Zoonotic diseases

Introduction

Arguably, rodents are the most significant mammalian pests on a worldwide scale (Grist and Lever, 1969). They have a pair of chisel-shaped incisors in each jaw, ideal for gnawing. It comprises of rats, mice, bandicoots, gerbils, voles, squirrels *etc*. Out of 128 species recorded in India, 18 species are categorized under pest (Roonwal, 1987; Pradhan and Talmale, 2011). Because they inflict significant harm to crops in fields and ruin harvests after harvest by consuming stored grain and vegetables, rodents are significant agricultural pests (Elango *et al.*, 2022). They account for 5-10% of food grain loss yearly during production, processing, storage and transportation. They are often omnivores, primarily consuming plant matter, animal tissue, insects, snails and other invertebrates for their survival. They survive in diverse natural habitats. Therefore, controlling rodent pests in agricultural areas is crucial to lower poverty. They threaten agricultural products in the Northeastern states, particularly when bamboo is in bloom. Their population is growing rapidly, which causes significant losses and occasionally even starvation (Kumawat *et al.*, 2016). Singh (1995) has reported 15 species of rodent pests from Northeast India comprising of *Bandicota bengalensis*, *Rattus nitidus nitidus* and *Mus musculus* (Pathak and Kumar, 2001). The lesser bandicoot, *Bandicota bengalensis*, is predominant in irrigated crops throughout the country. The Indian gerbil, *Tatera indica*, soft furred field rat, *Millardia meltada* and field mouse, *Mus booduga*, are widespread in both irrigated dryland and dryland crops in the country, except in the north eastern states (Mariadoss *et al.*, 2020).

Compared to other pests, rodents generate a far greater amount of economic harm. From planting to storage, it

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causes significant harm to all kinds of crops at every step. Furthermore, over 60 zoonotic diseases, including typhus, plague and trichinosis are transmitted by rodents and can have a major negative impact on human health mostly by bloodsucking parasites including fleas, mites and ticks (Khatoon *et al.*, 2004; Meerburg *et al.*, 2009). According to Parshad (1999), the most popular and prevalent method of rodent management is the use of chemical rodenticides (such as zinc phosphide), mostly anticoagulants which have led to a lot of harmful effects. Upon a lot of observation, it has been derived that the combined use of several management practices is more effective and it primarily reduces the use of pesticides (Smith and van den Bosch, 1967). The tribal communities of North Eastern region of India have adapted their own indigenous methods to control rodents along with the conventional methods (Thakur *et al.*, 2013). To implement control measures at a suitable moment, accurate identification and extensive knowledge of the biology, ecology and behavioral characteristics of rodents are necessary (Lawton *et al.*, 2022).

Over the last twenty-five years, Ecologically Based Rodent Management (EBRM) has solidified its role as a cornerstone of sustainable rodent suppression. EBRM integrates comprehensive insights into rodent population biology, encompassing life-history traits, reproductive rhythms and resource utilization, with targeted habitat modifications and the strategic application of species-specific toxicants. This multifaceted strategy not only delivers robust outbreak control but also significantly reduces non-target exposure and environmental residues. Economic analyses estimate that rodents inflict more than US $23 billion in annual global losses, spanning agricultural yield deficits and urban infrastructure damage (Massei *et al.*, 2024).

Longitudinal ecological studies have documented that rodent population peaks are closely synchronized with plant resource pulses, with small-rodent outbreaks linked to vegetation phenology over the past seventy years (Soininen and Neby, 2024). In response to these cyclical dynamics, contemporary syntheses advocate for EBRM's shift away from blanket chemical treatments toward integrated programs that emphasize habitat management, real-time monitoring and judicious toxicant deployment, thereby optimizing long-term effectiveness while minimizing ecological disruption (Singleton *et al.*, 2024).

To apply successful integrated pest control in North Eastern Hill, this study aims to combine the information and research done to comprehend the ecology of rodent feeding and reproduction ecology.

Feeding Ecology

In terms of their feeding systems, rodents are among the most specialized animals. The order is distinguished by the enormously expanded pair of incisors, which possess open roots and continue to develop throughout life in both the upper and lower jaws (Nowak, 1999). Although they can chew on their molars and gnaw on their incisors, rodents cannot achieve simultaneous occlusion of molars and incisors due to a discrepancy in cranial and mandibular lengths. In order to perform both of these functions, the mandible need to be shifted anteriorly and posteriorly in relation to the skull (propaliny), as the two feeding modalities are mutually incompatible (Becht, 1953; Hiiemae and Ardran, 1968). The proportion of food items and feeding habits vary from species to species in different season. They mostly feed on plant parts (roots, leaves, seeds and grasses) (Geleta *et al.*, 2011; Getachew *et al.*, 2016). Because of their opportunistic feeding habits, rodents alter their feeding strategies according to the types of food that are available throughout different seasons. Research on *B. bengalensis* behaviour by Gogoi and Borah (2013) between 2009-10 and 2010-11 found that the species gathered food during the off-season @ 170.78 g per burrow. In boro and sali rice respectively, the mean density of *B. bengalensis* dug burrows are 20.33 ha^{-1} and 27.40 ha^{-1}. The average number of brood chambers recorded was 1.41, with 2.97 food chambers and 5.47 surface openings (Gogoi and Borah, 2012). The maximum damage rates of 4.14% and 5.78% for cut tillers were recorded at the ripening stage (Gogoi and Borah, 2013), indicating that the harm inflicted by *B. bengalensis* escalated with crop growth in the rice ecosystems of Assam. Borah (2016) also noted that at the harvesting stage, the maximum counts of living burrows was 44.91, the trapping index was 8.11% and rodent damage shown as cut tillers amounted to 8.1%. The key to rodents' successful species diversity and richness lies in their wide variety of eating behaviors in light of the planet's changing environmental conditions (Gebresilassie *et al.*, 2004; Datiko and Bekele, 2013). The intensity and frequency of both natural and anthropogenic disturbances, as well as their interactions, drive changes in rangeland vegetation. Natural disturbances could include drought, flood, wildfire and wildlife grazing or browsing. Human-related disturbances could include chemical or mechanical habitat treatments, regulated burning, artificial revegetation and livestock grazing or browsing (Augustine *et al.*, 2023). The key to rodents' successful species diversity and richness lies in their wide variety of eating habits in response to the planet's changing environmental conditions. The rainy season increases the number of worms and arthropods, which provide sustenance for rodents and avian species (Geleta *et al.*, 2011).

In agro-ecosystems, intentional food-supplementation experiments have demonstrated that increased resource availability can substantially modify rodent population dynamics. For example, supplemental feeding of *Microtus pennsylvanicus* has been linked to better overwinter survival and an earlier start of spring breeding, hence stressing the importance of bottom-up regulating mechanisms in determining population paths. The triggering of plant defenses, such silica buildup in grasses, also affects herbivore population by lowering palatability and nutrient absorption, hence generating feedback systems that could disrupt population cycles.

A recent systematic review of plant-rodent interactions (Soininen and Neby, 2024) revealed that while rodents can significantly reduce plant biomass, particularly during winter months, the rapid compensatory growth of vegetation typically prevents the long-term suppression of rodent populations. This result implies that multi-annual mouse population cycles are affected not only by resource depletion but also by complicated interactions including seasonal variation and habitat heterogeneity.

In the Upper Brahmaputra Valley of Assam (2015-2017), five rodent species were recorded: *Bandicota bengalensis*, *Bandicota bengalensis indica*, *Mus booduga*, *Rattus sikkimensis* and *Dremomys lokriah macmillani*. Among these, *B. bengalensis* made up more than 80% of catches in both rice and vegetable growing areas (Phukon and Borah, 2019), suggesting its dominance in local agro-ecosystems.

In arid rangeland ecosystems, overgrazing has been shown to reduce functional diversity, compelling rodent species to broaden their dietary niches to include bark and invertebrates. This shift exemplifies how habitat disturbance can reshape trophic structures (Zhu *et al.*, 2024). Moreover, overgrazing acts as an ecological filter on rodent functional traits, favouring generalist species capable of exploiting lower-quality resources. This not only alters community composition but also impacts broader ecosystem processes and functions.

Breeding Ecology

Numerous rodent species have adaptable mating behaviours that range from promiscuity to polygyny to monogamy (Waterman, 2007). Female rodents have an active part in selecting mates. Female choice may be influenced by the male's size, dominance and spatial abilities (Wolff and Sherman, 2008). Rodent outbreaks occur due to increased reproduction, with natural death playing a minimal role in rapidly rising populations. High cropping intensities that produce quality food, such as rice during the generative stage, can enhance the incidence of rodent epidemics by allowing females to mate for extended periods of time annually. These findings support the agricultural management strategies that address variables limiting rodent reproductive output and create techniques to interrupt pest species reproduction.

Under laboratory conditions, 88% of breeding attempts were successful between 21 and 24 days of gestation. Females reached sexual maturity at 3 to 4 months (Sandhu and Singla, 2020). From March to May was found to be *Tatera indica*'s peak breeding season in the field (Singh, 1961). Where *B. bengalensis* discovered in Bangalore, Karnataka's rice ecosystems, the mean litter count was 7.1. The peak reproductive period fell between September and November. Generally speaking, the reproductive activity began in August and continued through late April, with an anoestrous period occurring from March to July. Fascinatingly, the glands in charge of reproduction showed weight changes that matched seasonal fluctuations. The observed reduction in summer body weight corresponded precisely with the crop maturation and peak breeding season (Srihari and Raj, 1988). During a single oestrous cycle, *T. indica* exhibits typical durations of 0.61 days in pro-estrous, 0.38 days in estrous, 0.62 days in met-estrous and 1.37 days in di-estrous stages, respectively. Rodents' reproduction rates vary depending on habitat and climate. It has been shown that different habitats and climatic conditions affect rodents' rates of reproduction. Any change in rangeland plant community structure or species composition simultaneously favours some wildlife species and disfavors others. Consequently, habitat management commonly seeks to: (i) provide sufficient variability in vegetation conditions to sustain diverse wildlife and (ii) make limiting habitat factors for desired species less limiting (Augustine *et al.*, 2023). Rainfall was one abiotic factor that significantly impacted female gestation and maturity. Rainfall and rodent productivity have been linked in earlier research (Sluydts *et al.*, 2007; Previtali *et al.*, 2009).

Experimental trials involving a neem-andrographolide-based bait on *Rattus rattus* have demonstrated its potential as an eco-friendly fertility control agent. Following a 15-day exposure period, surviving female rats exhibited significant and irreversible reductions in ovarian mass, follicular counts and estrous cycle duration, with these effects persisting for a minimum of 30 days post-treatment (Verma *et al.*, 2025). These findings underscore the compound's promise as a sustainable, non-lethal strategy for rodent population management.

High Reproductive Potential

Tropical field rats, such as *Tatera indica*, exhibit high reproductive potential, with females capable of producing up to five litters annually; each comprises approximately 4-6 offspring. Sexual maturity is typically attained within 6 to 8 weeks, a life-history strategy that facilitates rapid population recovery following conventional control measures (Sandhu and Singla, 2020). Seasonal bamboo mast events in Northeast India, where large-scale rat infestations are often noticed after gregarious bamboo flowering, help to amplify this reproductive resilience even further. These occurrences create nutrient-rich pulses in the environment that coordinate and promote reproductive activity among rodent populations. The species' prolific breeding capacity, marked by multiple litters and early maturity, underscores the limitations of reactive, toxin-based control methods. As such, there is an urgent need to develop and implement integrated fertility management approaches that are both humane and economically sustainable, offering long-term population regulation without the ecological drawbacks associated with acute chemical interventions (Verma *et al.*, 2025).

In the Northeastern hills, supra-annual bamboo mast events, especially of *Melocanna baccifera*, trigger explosive rodent irruptions: *Rattus niviventer*, *R. brunneusculus* and *R. rattus* females may produce up to 800 young during a single flowering season, driving rice field trap indices from ~5.8% in non mast years to 12.9-15.4% during mast years (Chauhan, 2003; Kumawat *et al.*, 2014; Bhairavi *et al.*, 2024).

Integrated Pest Management of Rodents

Several agronomic practices raise crops that subsequently decrease rodent populations. Land preparation procedures such as deep plowing and bund pruning can lower rodent habitat capacity. Farmers removing weeds from fields reduce rats' access to housing and nutritional resources.

Sharma and Rao (1989) indicated that a decrease in bund dimensions showed a reduction in rodent infestation in rice fields. According to Christopher *et al.* (1984), the systematic clearance of rubbish and nesting materials from animal and human habitats, as well as storage facilities on a regular basis reduces rodent activity. Alley cultivation of rice also mitigates rat damage. Acharya N.G. Ranga Agricultural University in Hyderabad has invented a smoke generator that effectively controls burrowing rodents. Burning paddy straw produces smoke, which is then blown into the burrow tunnel using a blower (Rana and Tripathi, 1999). Salmonella and murine typhus bacteria are effective against *R. rattus* and *B. bengalensis* in India (Deoras, 1964). Bindra and Mann (1975) found that the murine typhus bacteria caused less than 40% mortality in *M. musculus* and *T. indica*. Rodents have a hearing range that extends above 20 kHz and includes ultrasonic frequencies. Although ultrasound devices are used for baiting rodents, data suggests they are ineffective. Rodenticides are the most commonly used strategy to address the country's rodent problem. Zinc phosphide is one of the predominantly employed acute rodenticide. Utilized at a concentration of 2% in cereal baits, it quickly detoxifies both corpses and baits, making it both safe and cost-effective. ICAR suggests the using of zinc phosphide in rice, wheat, pulses, oilseeds, jowar, millets, sugarcane and vegetable crops. Nonetheless, owing to toxicity concerns in non-target species, its usage is recommended mainly in conditions with large rodent infestations, specifically 50 active burrows per hectare. Initiatives are under progress to develop a ready-to-use formulation of this rodenticide for effective application in diverse environments (Prakash and Mathur, 1992).

A systematic, evidence-based practice called Integrated Pest Management (IPM) combines cultural, mechanical, biological, chemical and indigenous techniques with socio-behavioral strategies to form a coherent framework for sustainable rodent control. IPM aims to reduce non-target effects and enhance community involvement and infrastructure resilience, balance quick population decline with long-term prevention and strengthen these qualities.

A. Cultural Control

1. Sanitation and Waste Management: Effective sanitation entails prompt refuse removal, scheduled waste collection and storage of bulk grains in sealed, rodent-proof containers. By denying commensal rodents access to alternative feeds and hiding sites, sanitation both prevents initial infestation and increases the detectability of incipient populations. While sanitation cannot wholly eliminate mice, given their capacity to survive on <1 g of food daily, clean environments significantly improve the success of subsequent trapping and baiting (Phukon and Borah, 2019).

2. Deep Ploughing: Repeated deep tillage (≥20 cm depth) collapses subterranean burrow networks, forces rodent dispersal and reduces *in situ* breeding success. Field experiments demonstrated a 45% reduction in burrow density after two consecutive ploughing cycles within a season (Phukon and Borah, 2019).

3. Bund Size Reduction: Narrowing field embankments (bunds) from 1.0 m to 0.5 m eliminates prime burrowing substrata. Trials in paddy systems reveal a 30% decrease in burrow initiation along reduced bund perimeters (Phukon and Borah, 2019).

4. Weed Control: Continuous removal of weeds around crop margins and water channels deprives rodents of cover and alternative feed. Weed-free fringes show up to 60% lower capture rates in standardized monitoring grids (Phukon and Borah, 2019).

5. Farmer Knowledge and Attitudes: Surveys in Taiwan indicate that 75% of farmers apply rodenticides only reactively, upon visible crop damage, rather than proactively as part of an IPM schedule. This underscores the necessity for targeted education campaigns to shift behaviours toward anticipatory, preventative rodent management (Best *et al.*, 2022).

B. Mechanical Control

1. Snap Traps and Kill Devices: High-density deployment of snap traps along runways and burrow entrances can secure trap-indices of 5-12% per session. When integrated post-poisoning, traps capture survivors and enable continual population monitoring, effectively reducing rebound risk (Phukon and Borah, 2019).

2. Glue Boards and Breakback Traps: These devices yield immediate mortality, but should be restricted to confirmed rodent pathways to minimize non-target captures. Placement beneath pallets and along dark corridors optimizes catch efficiency.

3. Live Traps: Sherman, Wonder and box traps facilitate live capture for species identification, ecological research and potential translocation. Captured specimens can be incorporated into controlled fertility-inhibition trials, linking mechanical control with reproductive strategies.

C. Biological Control

Potential biocontrol options include bacterial pathogens (*Salmonella typhimurium*, *S. enteritidis*), protozoa (*Trypanosoma evansi*) and helminth nematodes (*Capillaria* spp.). Indian field trials report only 15-20% mortality in *R. rattus* and *B. bengalensis* with Salmonella strains and public health risks currently limit operational deployment (Kumawat *et al.*, 2016).

D. Chemical Control

Chemical control of rodents involves:

1. Chemical-Infrastructure Synergy: In Brazilian urban slums, pairing chemical baits with infrastructural upgrades (*e.g.*, closed sewer systems, systematic waste removal) reduced rodent activity from 70% to 28% and delayed population rebound for nearly one year, illustrating the power of integrated interventions (Awoniyi *et al.*, 2022).

2. Acute Toxicants: Compounds such as zinc phosphide (2%) and barium chloride cause rapid onset mortality but may induce bait aversion. Formulations typically blend 2% active ingredient, 96% cereal grain and 2% edible oil to enhance palatability and uptake (Kumawat *et al.*, 2016).

3. Chronic Anticoagulants: First-generation anticoagulants (*e.g.*, coumatetralyl at 0.075% powder, 0.0375% cereal bait) and second-generation formulations (bromadiolone wax blocks) require multiple feedings to induce lethal coagulopathy. Daily bait replenishment over 21 days ensures >90% population knockdown, while the availability of Vitamin K antidote mitigates non-target risks (Kumawat *et al.*, 2016).

4. Fumigation: Phosphine (aluminum phosphide 0.6 g pellets) and cyanogas (calcium cyanide 10-20 g per active burrow) deliver >95% efficacy in targeted burrow fumigation. Sealing burrows post-application and reinspecting after 24 hr ensures complete treatment (Kumawat *et al.*, 2016).

E. Indigenous and Ethnoecological Methods

Ethnoecological surveys in Assam documented 33 traditional rice-ecosystem practices, of which 21 were validated as scientifically rational and none were irrelevant. Key methods include:

1. Gilmat Leaf Baiting: Boiling *Dendronide sinuata* leaves within rice transfers plant toxins into the bait. Field trials report up to 80% efficacy in burrow trials with minimal non-target impact (Sinha, 2014; Barman *et al.*, 2024).

2. Smoke-Flooding of Burrows: Tribal farmers use smoke generators to suffocate rodents, achieving ~80% reduction in localized populations. This practice is employed by >35% of indigenous communities (Sinha, 2014).

3. Artemisia Branch Repellency: Placement of *Artemisia vulgaris* branches in paddy fields or granaries releases volatile oils that repel rodents. Adoption rates exceed one-third among Mao and Garo farmers, with recorded deterrence of >70% in choice trials (Barman *et al.*, 2024).

4. Raised Granaries with Inverted Barriers: Elevated stores surrounded by inverted metal rings prevent rodent access without chemical intervention. Over 30% of Jaintia and Garo communities use this method, reporting near-complete protection of stored grains (Kumawat *et al.*, 2016).

5. Scurrula parasitica Gum Traps: Natural adhesives harvested from epiphytic mistletoe applied to bamboo stakes capture rodents along runways, integrating seamlessly into farm architectures.

6. Predator Attraction: Installation of bamboo perches and scarecrow devices encourages owl and raptor predation, reinforcing top-down biocontrol.

F. Reproductive Inhibition Strategies

1. Modeling Proactive Sterilization: Simulation studies indicate that sterilizing >50% of female rice-field rats, or combining short-term culling with fertility inhibitors in grey squirrels, achieves population suppression equivalent to culling alone but at 35% lower cost (Massei *et al.*, 2024).

2. Neem-Andrographolide Dual-Action Bait: Laboratory feeding trials of a neem (*Azadirachta indica*) and andrographolide formulation in *R. rattus* yielded >50% mortality over 15 days. Surviving females exhibited irreversible infertility for at least one month post-treatment, highlighting its potential as a humane, cost-effective IPM component (Verma *et al.*, 2025).

Conclusion

Particularly in the Northeastern areas of India, efficient rodent control in agricultural environments calls for a multidisciplinary approach combining thorough ecological study, modern agronomic techniques and time-honoured traditional practices. Using an Integrated Pest Management (IPM) or Ecologically Based Rodent Management (EBRM) approach, stakeholders can reduce zoonotic disease hazards as well as financial losses by means of environmental preservation and assistance of sustainable livelihoods.

Emerging technologies for real-time monitoring of crop nutritional status and rodent reproductive metrics, coupled with sophisticated population-cycle models, are poised to enhance the precision and timing of interventions and reduce reliance on traditional rodenticides (Soininen and Neby, 2024). The integration of chemical controls, infrastructural improvements, strategic trapping, fertility-inhibition agents and ethnobiologically validated methods within an EBRM/IPM strategy offers the most adaptive and cost-effective solution for Northeast Indian agro-ecosystems.

Future research should prioritize the calibration of control schedules through dynamic modelling of rodent population cycles; the scaling of participatory training programs to transition communities from reactive to proactive management; and the continued empirical validation of plant-derived repellents and contraceptives to minimise environmental impacts while safeguarding crop yields and public health.

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