

Gregarious Bamboo Flowering and Rodent Outbreaks – An Overview

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ABSTRACT: At least 137 species of common bamboos of India and rest of Asia seed synchronously at long and supra-annual intervals. These include species belonging to the genera *Phyllostachys*, *Arundinaria*, *Bambusa*, *Dendrocalamus*, *Gigantochloapus*, *Malocanna*, *Guadua*, *Nechouzeaua*, *Ochlandra*, and *Thyrostachys*. The enormous quantity of seeds shed by these bamboos affect the population dynamics of several vertebrates, including mostly birds, rodents, and wild pigs. The rodents, as generalist seed predators, exhibit a very complex response to the sudden spurt in the availability of nutritious bamboo seeds. In North-east India, the popular saying and belief “when bamboo flowers, famine follows” refers to the phenomenon of gregarious bamboo flowering, massive seed fall, and irruptions in rodent populations, which, after exhausting the bamboo seeds, invade and devour the entire crop fields and stored foods, leading to famine. Such events have been occurring approximately every 40 - 45 years since 1880, the latest being 2005 - 2007 sans any famine. Although 14 species of rodents occur in North-east India, until now there is no strong evidence to identify the species exhibiting population outbreaks. The species suspected to irrupt are *Rattus rattus*, *R. r. brunneusculus*, *R. bowersi*, *R. niviventer*, and *Canomys badius*. Similar irruptions of rodent populations in South America has been documented since 1800. These eruptions, termed *ratadas*, were seen in *Oligoryzomys longicaudatus* and *Abothrix longipilis* consequent to flowering of *Chusquea quilla*. Comparable density increases are seen consequent to masting in trees other than bamboo. Although the mechanism of seed masting is attributed to several hypotheses, predation satiation is the most accepted theory. In this paper, rodent response to masting is discussed in relation to this theory. The non-occurrence of famine in North-east India consequent to 2005-2007 bamboo flowering is mainly due to the effective strategies formulated by the government of India to prevent population buildup of rodents. This seems to be a fine instance of prophylactic approach to rodent management in large areas encompassing several states.

KEY WORDS: bamboo, famines, gregarious flowering, North-east India, predator satiation, *ratadas*, rodent outbreaks, seed mast

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INTRODUCTION

The life cycle of most species of bamboos may range 3 - 120 years and comprise of vegetative growth by rhizome and branch production. They produce wind-pollinated flowers, shed large quantities of seed, and die. The phenomenon of death of the parent plant after flowering and setting seeds only once in its life cycle is termed ‘monocarpy’ or ‘semelparous flowering’. Many of the more common bamboo species in India and Asia (at least 137) have seed synchronously at long and supra-annual intervals. These include several species of *Phyllostachys* and a single species each of *Arundinaria*, *Bambusa*, *Dendrocalamus*, *Gigantochloapus*, *Melaconna*, *Guadua*, *Nechouzeaua*, *Ochlandra*, and *Thyrostachys*. In contrast, the iteroparous bamboos species and do not exhibit the conspicuous, synchronized seeding at intervals greater than one year; after attaining maturity, they continue to flower annually for many years. This pattern is seen in *Bambusa forbesii*, *Arundinaria wightiana*, *A. elegans*, *A. glomerulata*, *Ochlandra rheedei*, *O. stridula*, *Shibataea kumasaca*, and *Bambusa lineata* in Asia, and in a few other neotropical species. The trigger for the former is attributed to an internal physiological clock, and for the latter it is reported to be due to weather (Janzen 1976).

DISTRIBUTION OF MASTING BAMBOOS

Of the nearly 1,000 species of bamboo, only woody species occurring in subtropical and temperate evergreen or deciduous forests are semelparous. Gregarious species occur in Japan, Eastern China, lowland Malaysia, India, Indonesia, South America, and Europe (Figure 1). India has one of the highest concentrations of mast-flowering species, i.e., 70 out of 72 (Gadgil and Prasad 1984).

Bamboo species recorded to flower gregariously in India are: *B. arundinacea* throughout the country; *B. nutans* in sub-Himalayas; *B. tulda*, which flowers sporadically; *B. vulgaris*, *D. hamiltonii*, *D. longispathus*, *D. sikkimensis*, and *D. giganteus* in Uttaranchal; *M. baccifera* in North-east India; *M. compactiflorus*, *M. bambusoides*, and *O. monostigma* in the Western Ghats; and *P. polymorphum* (Sridhara and Rajendran 2009).

INTERMAST PERIODS

Although precise data about presence and length of intermast period for a particular bamboo species is very little, adequate circumstantial evidence exists. Collection of specific information is difficult because the time to flowering in most semelparous bamboos is so long that it becomes practically impossible for a single person to study it during his/her life span. Still, by merging

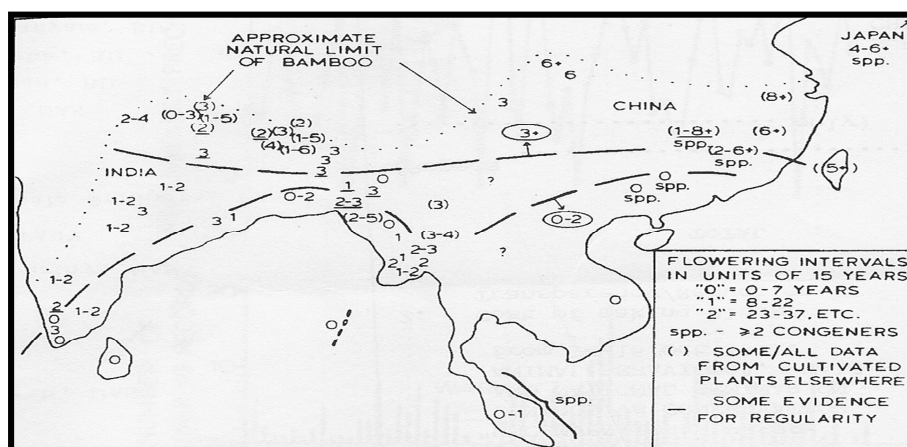


Figure 1. Geographic trends in flowering intervals of Asian bamboos (units of 15 years) (Campbell 1985).

Table 2. Gregarious flowering of bamboos in recent times in North-east India (Rajendran et al. 2006).

Bamboo Species	Year of Flowering	Area of Flowering
<i>D. hamiltonii</i>	1994-1995	Nagaland-Assam border
	1996-1997	Assam-Arunchal Pradesh border
	1997-1998	North Cachar hills of Assam, Meghalaya
	2000-2001	Deopahar (Assam)
	2003-2004	Tamanglong, Chura Chandpur & Tribam (Manipur)
	2004-2005	Arunachal Pradesh
<i>M. baccifera</i>	2000-2001	Tripura
	2002-2003	Karbi-Anglong & Haflong (Assam)
<i>Schizostachyus fuchsium, S. polymorphus</i>	2004-2005	Arunachal Pradesh

recorded data of earlier years with the current information, intermast periods have been calculated for several species of bamboo. These calculations indicated a period of 30 - 34 years for *Chusquea abietifolia* in Jamaica (Seifrizz 1950), 15 - 16 years for *C. tenella*, and 32 years for *Bambusa riograndensis* in Brazil (Dutra 1938). For *D. strictus* in Assam, it is variously reported to be 43 - 44 years, 39 - 44 years, and 42 - 45 years (Janzen 1976). For *M. bambusoides* in Chittagong (Bangladesh), it was reported to be 46 - 51 years. *B. arundinacea* exhibited an intermast period of 45 years in India and of 31 - 32 years when introduced into Brazil. *P. bambusoides* introduced into Japan from China showed an intermast period of 120 years. In addition, there are numerous instances of synchronous flowering in bamboos introduced into greenhouses and botanical gardens, which was always in pace with their parental cohorts in their native habitat. The cyclicity of flowering of bamboos species in North-east India is given in Tables 1 and 2 (Janzen 1976).

Table 1. Cyclicity of flowering in some species of bamboo in North-east India.

Bamboo species	Cyclicity (Years)
<i>Dendrocaamus longispathus</i>	16-17
<i>D. strictus</i>	25-65
<i>D. hamiltonii</i>	30-40
<i>Bambusa tulda</i>	30-60
<i>B. polymorpha</i>	35-60
<i>Melaconna baccifera</i>	40-45
<i>B. bambusoides</i>	40-45
<i>Pseudostachyum polymorphum</i>	48
<i>Phyllostachys bambusoides</i>	60

MECHANISM OF SEED MASTING

Various hypotheses and theories have been put forward to explain seed masting in bamboos. These include the resource hypothesis, predator satiation theory, enhanced wind pollination theory, seed hypothesis, bamboo fire cycle hypothesis, plant competition theory, and the endogenous mechanism theory (also called biological clock theory). The most widely accepted selective force during evolution of masting in bamboos is predator satiation. This hypothesis suggests that mass flowering and seeding is a means of ensuring survival of at least some seeds. Many herbivores, mostly rodents, eat bamboo seeds. To some extent, wild fowl, some birds, pigs, and elephants also consume these seeds. Flowering and seed-set enhances predator populations, either by increased fecundity or by migration. If only a limited number of seeds are produced, survival of bamboo is very bleak, so it floods predators with massive seed-fall to ensure survival of at least some seeds. The vast cache of seeds, produced intermittently, more than satiates the needs of seed predators. Consequently, some of the seeds escape predation and germinate successfully. Simultaneously, lower input of seeds between mast years succeeds in keeping predators at low densities. Synchronously masting trees are predicted to minimize mortality of both pre- and post-dispersal seeds, which results in higher regeneration of seedlings than non-masting perennials. This theory is also employed to explain masting in many other species and to support intraseasonal and interannual reproductive synchrony in both plants and animals.

VERTEBRATE PREDATORS OF BAMBOO SEEDS

Exhaustive studies on vertebrate responses in general, and rodents in particular, to mast seeding have been documented mostly for oak, beech, and other dipterocarps with comparatively less information on gregariously flowering bamboos. Broadly speaking, bird and mammals depredate on most seeds.

Data on mast-feeding birds seem to indicate that most birds are generalist feeders and are also migrants. Studies on bird foragers of masting reveal influence of such feeding on their reproduction and feeding pattern. For example, about 33 species of Asian pheasants occur in bamboo habitats, and many feed on bamboo seeds and sprouts (Collias and Collias 1967).

Among the variety of mammals known to feed on bamboo seed and bamboo vegetation and dipterocarp seeds, wild pigs have been studied fairly well in the dipterocarp forests of Southeast Asia. Otherwise solitary feeders, bearded pigs traveled in groups during masting, with their density increasing 10-fold.

RODENT RESPONSE TO BAMBOO FLOWERING

Rodents play a critical role in regeneration and demography of many mast-seeding trees, including bamboos. While some species of rodents play an important role in seed dispersal, others are significant as predators of seeds and seedlings. In many masting trees, rodents disperse seeds by their hoarding activity (Vander Wall 2002) and also cause seed and seedling mortality by feeding on them (Hulme and Benkman 2002). Many masting tree species depend on scatter-hoarding rodents for dispersal and produce large seeds. The intermittent production of massive amount of seeds by some trees affects the population of seed predators drastically, with characteristic increases after masting and decreases during low seed-crop years (Ostfeld and Keesing 2000). This fluctuation in the density of rodents, in turn, influences the degree of seed predation and dispersal of some tree species (Vander Wall 2002). Although the evolutionary significance of seed mass and mast seeding are not fully understood, both large-size and mast-seeding are considered as adaptations for increasing seed dispersal and reducing seed predation. In addition, physiology of the rodents is affected adversely by presence of defensive chemicals in seeds such as those of *Quercus* and *Aesulus* (Vander Wall 2002, Shimada and Saitoh 2003).

Although exciting and sensational coverage is given in the media and scientific journals to rodent outbreaks consequent to bamboo flowering (Janzen 1976), studies on interaction between rodents and mast seeding have not been extensive except in dipterocarps (Crawley 2000, Vander Wall 2002, Hulme 2002).

The response of polyphagous and generalist seed predators like rodents is likely to be complex, as a result of variation in seed availability as seen in multi-species forest systems (Hoshizaki and Hulme 2002). The other factors affecting rodent predation of mast seeds are stand, locality, habitat, season, and year (Hulme 2002).

Rodent outbreaks consequent to gregarious bamboo flowering is extensively reported for the following countries:

India

The earliest records on rodent species that responded to bamboo flowering by increasing their density indicated species terrestrial within genera such as *Nesokia*, *Mus*, *Rattus*, *Gohunda*, *Rhizomys*, and *Hystrix* (in Janzen 1976). Later, Chauhan (2003) reported that of the 8 species of rodents captured in Mizoram, *Rattus rattus brunneusculus* constituted the major proportion of the rodent population responding to bamboo flowering. In the states of Manipur and Nagaland, the Himalayan rat, *Rattus nitidus*, was the dominant species. Other species were low in numbers and were found to be *Rattus bowersi mackenziei*, *Bandicota* spp., *Cannomys badius*, *Rattus rattus*, and *Mus musculus*. The first 3 occurred in cultivated fields and the latter 2 were commensals in tribal settlements and granaries.

During flowering of *B. tulda*, large numbers of *R. r. brunneusculus* and *R. nitidus* were found in paddy fields, causing extensive damage. It is likely that after harvest, and even after destruction of forests, these migrate to bamboo forests and re-invade cultivated fields when crops mature the following season. Chauhan (2003) did not observe any migration of rats from cultivated lands to forests where bamboo was flowering and vice versa. Instead, he found a link between rodent population fluctuation and paddy growth cycle, but saw no evidence to correlate rodent population with flowering of *B. tulda*. Only a few rats were seen in bamboo forests. This was attributed to the low level of bamboo flowering consequent to heavy rainfall and high velocity wind during the study. As a result, the expected explosion in rat population was not seen. He concluded that the effect of bamboo seeds and fruits on reproduction of rats and rate of population growth needed further investigation (Chauhan 2003).

In a later study (Pathak and Kumar 2000), 15 species of rodents were reported to be associated with the flowering cycle of *B. tulda*, *Dendrocalamus longispathus*, and *Melocanna bambusoides*, which were linked with cyclical occurrence of the famines, locally termed *Mautam* and *Thingtum*. Rodent species responsible for famine were reported to be *R. rattus* and *R. nitidus*.

South America

'Ratadas' or rodent eruptions/outbreaks have been known in South America since the 16th century. Association between ratadas, bamboo flowering, and masting cycles has been documented since 1800. On reviewing 63 well-documented cases of ratadas, Jaksic and Lima (2003) concluded that ratadas are conclusively associated with bamboo flowering. The reported flowering cyclicity for different species of masting plants was 30 years for *Merostachys fistula*, 14 years for *Mesostachys* spp., 12 years for *Chusquea quilla* and/or *C. valdiviensis*, and 14 years for *C. culeou*. Rodent peaks were also associated with rainfall peaks. These two types of peaks are known to occur in several South American countries, namely Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, and Uruguay. Rainfall-associated ratadas were reported to have been caused by El Niño. Some of the mice implicated in ratadas are also reservoirs of

emerging diseases such as hantavirus (Jaksic and Lima 2003).

In southern Chile, the most recent blooming of *Chusquea valdiviensis* started in 1990, which by 2001 spread to 1.2 million hectares. At this stage, the estimated seed fall was 51 million seeds per hectare. Two years after the flowering, a rodent outbreak, seen only in the rice rat *Oligoryzomys longicaudatus*, occurred as was evident by 80% trapping success. The rodents captured were mainly juveniles and young adults. *Abrothrix longipilis* remained unaffected by gregarious flowering of *C. valdiviensis*, probably due to its grainivorous habit. In temperate forests where an outbreak of *O. longicaudatus* occurred, populations of the other herbivorous rodents such as *A. longipilis*, *A. sanborni*, and *Loxodontomys micropus* did not erupt. Genetic mechanisms other than environmental factors are presumed to be involved in these outbreaks (Gallardo and Mercado 1999).

In coastal rain forests of Chile, the response of *O. longicaudatus* to bamboo flowering was delayed by 2 years. This was found to be due to retention of bamboo seeds within spikelets for 1 year. The outbreak population was composed of only large- and medium-sized juvenile individuals (Gallardo and Mercado 1999).

After monitoring population fluctuation in *O. longicaudatus* for 19 years in southern Chile, Murua et al. (2003) attributed 96% of the population variation to climatic factors, particularly the Antarctic Oscillation Index (AAOI) and Southern Oscillation Index (SOI). They also acknowledged the contribution of cyclic fluctuation and masting of bamboo to rat outbreak. Because of the latter, they suggest that bamboo flowering may be used as a signal for forecasting outbreaks of long-tailed rice rats for effective implementation of health policies, as these rats transmit hantavirus. This measure is expected to reduce human-rodent contacts and the consequent spread of disease (Murua et al. 2003).

Similar response of rodents to gregarious blooming of *Chusquea culeou* was observed in neighbouring Argentina in 2001. Massive seeding produced huge quantities of highly nutritious food that resulted in rodent population explosions. The expanded rodent population spilled on to roads, houses, and lakefronts. The two most abundant species were *O. longicaudatus* and *A. longipilis* (Piudo et al. 2005). Surprisingly, rodent population remained unaffected in the Atlantic forests of Sao Paulo in the neighboring Brazil, despite a dense seed-fall at the rate of 25 kg/ha, after the flowering of *Chusquea aft.*

meyeriana (Olmos 1996).

GREGARIOUS BAMBOO FLOWERING IN NORTH-EAST INDIA

The northeastern region of India comprises the hilly states of Manipur, Meghalaya, Nagaland, Sikkim, Tripura, Arunachal Pradesh, and Mizoram. Situated at various altitudes in the eastern Himalayas, these states are endowed with extensive forest cover and rich vegetation that often exceeds 50% of the total land area. The forests of North-east India range from the alpine to the tropical type and have natural bamboo vegetation. The bamboo species naturally growing and cultivated are *Dendrocalamus hamiltonii*, *Bambusa pallida*, *Schizostachyus polymorphum*, *Melaconna baccifera*, *D. hamiltonii*, *Arundinaria maling*, *Phyllostachys* spp., *Chimonobambusa* spp., and *Bambusa tulda*. In addition, several species of bamboo such as *B. tulda*, *B. nutans*, *B. balcooa*, *B. pallida*, *B. longispiculata*, *D. giganteus*, *Oxytenanthera abyssinica*, and *O. albociliata* are cultivated in homesteads, community lands, crop fields, streams, river banks, etc.

RODENTS OF NORTH-EAST INDIA

North-east India has among the richest rodent diversity in the country, with 9 genera and about 15 species. Their state-wise distribution is given in Table 3. The major species are *Bandicota bengalensis*, *Bandicota indica*, *Cannomys badius badius*, *Mus booduga*, *Mus cervivolour*, *Mus musculus*, *Rattus nitidus nitidus*, *Rattus rattus*, *Rattus rattus brunneusculus*, *Rattus norvegicus*, *Rattus (Berylmys) bowersi*, *Vandeleuria oleracea*, and *Rattus sikkimensis*. The squirrels *Callosiurus pygerythrus* and *Dremomys lokriah*, and rat species *Rattus rattus tistae*, *Rattus rattus khyensis*, and *R. sikkimensis* are also reported (Sridhara and Tripathi 2005).

RODENT OUTBREAKS AND FAMINE: AN HISTORICAL PERSPECTIVE

Rodent outbreaks find mention in religious, historical, and scientific literature throughout the world. Flowering of certain species of bamboo is associated with rodent outbreak in many countries (Troup 1921; Elton 1927, 1942). For centuries, these outbreaks have been observed to be followed by famine in North-east India.

Famines in Mizoram have been categorized into two types, locally called *Mautam* and *Thingtam*. *Mautam* results as a consequence of flowering of *Melaconna*

Table 3. Distribution of rodent pests in the North-east Hill region.

State	Major	Minor
Arunachal Pradesh	<i>Rattus nitidus</i> , <i>R. rattus</i> , <i>Mus musculus</i>	<i>Rattus rattus tistae</i> , <i>Bandicota bengalensis</i> , <i>Vandeleuria oleracea</i>
Manipur	<i>B. bengalensis</i> , <i>M. musculus</i> , <i>R. nitidus</i>	<i>R. rattus</i> , <i>R. r. tistae</i>
Meghalaya	<i>B. bengalensis</i> , <i>R. nitidus</i> , <i>M. musculus</i> , <i>R. rattus</i>	<i>R. norvegicus</i> , <i>R. r. tistae</i> , <i>R. niviventer</i> , <i>B. indica</i>
Mizoram	<i>M. musculus</i> , <i>R. rattus</i>	<i>R. nitidus</i> , <i>M. booduga</i> , <i>B. bengalensis</i> , <i>R. norvegicus</i> , <i>C. pygerythrus</i> , <i>R. r. tistae</i>
Nagaland	<i>R. rattus</i> , <i>B. bengalensis</i> , <i>M. musculus</i>	<i>C. badiusbadius</i> , <i>R. nitidus</i>
Sikkim	<i>R. nitidus</i> , <i>M. musculus</i> , <i>R. rattus</i> , <i>B. bengalensis</i>	<i>R. r. tistae</i> , <i>M. booduga</i>
Tripura	<i>M. musculus</i> , <i>B. bengalensis</i> , <i>R. rattus</i>	<i>R. nitidus</i> , <i>R. r. tistae</i> , <i>C. pygerythrus</i>
Overall	<i>B. bengalensis</i> , <i>R. nitidus</i> , <i>M. musculus</i> , <i>R. rattus</i>	<i>R. nitidus</i> , <i>R. r. tistae</i> , <i>R. niviventer</i> , <i>B. indica</i>

Table 4. Frequency of famine and bamboo flowering in Mizoram.

<i>Thingtam Year</i>	<i>Bamboo Species</i>	<i>Mautam Year</i>	<i>Bamboo Species</i>
1880-1884	<i>B. tulda, D. longispathus</i>	1910-1912	<i>M. bambusoides</i>
1928-1929	<i>B. tulda, D. longispathus</i>	1958-1959	<i>M. bambusoides</i>
1976-1977	<i>B. tulda, D. longispathus</i>	2007 (predicted)	<i>M. bambusoides</i>

bambusoides, called *Mao* by tribals. *Thingtam* famine is associated with the flowering of *Dendrocalamus longispathus* (*Rawnal*, locally) and *Bambusa tulda* (*Rawthing*, locally). *Mautam* is more severe than *Thingtam* and has a cyclicity of 48 ± 2 years. Flowering in *B. tulda* and *D. longispathus*, associated with *Thingtam*, lasted 4 - 5 years during 1924 - 1928 (Pillai 1980). The gap between *Mautam* and *Thingtam* is approximately 18 to 50 years.

The first historical record of *Mautam* followed by famine and human death dates back to 1864, when rat plague was reported (Parry 1931). A similar outbreak of rats following bamboo flowering was reported again in 1911-12 (Pearson 1930). Table 4 lists species of bamboo flowering, duration of their flowering, and famines that have occurred/are going to occur.

In 1958-59, rodent plagues accompanied by famine occurred in about 1,000 acres of North-east Indian states (Anon. 1959). After destroying the paddy crop, the rodents ate away chillies, tobacco, ginger, and other crops (Anon. 1960a). Similar devastation also occurred in the bordering country of Burma (Myanmar) (Anon. 1960b). A little earlier, such outbreaks were reported from Garo Hills and Nagaland in 1920-21 and 1929-1930 (in Pathak and Kumar 2000). The earliest record is found in 1911, which is clearly remembered by many old Mizos even today (Rukuma 1988). The subsequent cycle occurred in 1958-59, in Mizoram State and in 1998 in Manipur State, with subsequent increase in rodent population.

In the state of Arunachal Pradesh, bamboo flowering and the accompanying increase in rodent population occurred in 1991. The rodent outbreak was cyclical, occurring after every 20 years. Bamboo species that flowered at 20-year interval were locally called *Bijali*, and those that flowered at a 45 - 50 year interval were called *Hitac/Kako*. The former condition is ideal for rat infestation, while the latter was not considered favourable (Gupta 1980).

M. baccifera has begun flowering since 2002. Rats have started damaging considerable amount of paddy, followed by eating chillies, areca nut, wild chestnut, etc. Based on past cyclicity, gregarious flowering of bamboo was predicted to occur during 2005 - 07 in an estimated area of 18,000 km² in North-east states of India. The epicenter of bamboo flowering would be Mizoram (Rajendran et al. 2008). Accordingly, *Mautam* famine was predicted to occur in 2007. The Government of Mizoram, in collaboration with the Government of India, initiated several preventive measures to combat the predicted famine. These included surveys of flowering areas and of rodent populations, awareness campaigns, and rodent control. Most of the experienced, old people recommended awareness and training in rodent control using poison baiting, trapping, bounties, and the use of

improved storage bins to contain the rodent menace.

Action Initiated for Rodent Control

1. Research and extension activities on rodent control in the hilly districts of North-east India have been intensified. So far, 20 - 28 rodent species have been identified in the region, of which 2 - 3 may have the potential of reaching alarming densities after bamboo flowering (Anon. 2006).

2. The rodent problem in the North East Hill Region (NEH) assumes special significance, as it is unique with 2 types of rodents attacking crops and stored food, namely, invasive forest-dwelling rodents, and the usual agricultural and commensal rodents. Rodent control programmes and strategies need to be planned with this in mind. The recommended control strategy is an integrated one where the trap barrier system, the traditional rodent control programme, and bait stations are being used.

3. In view of a possible outbreak of rodent-borne diseases and migration of rodents to crop fields and homesteads consequent to bamboo flowering, the Directorate of Health Services, Mizoram, the National Institute of Communicable Diseases, and Human Resource Development have initiated necessary action such as human sero-surveillance and rodent surveillance. Public health consequences of rodent population irruption are potentially serious, as the states border Myanmar, which is an endemic area for plague.

4. As regards biological control, although snakes, owls, egrets, storks, and raptors feed on rodents, only barn owls are potentially effective predators, as their entire food is constituted by rodents. As several species of owls are known to occur in the NEH region, it was recommended that their breeding habits be studied for use in rodent control during population outbreaks.

Future Action for Rodent Pest Management

A regional meeting on rodent pest management for North East Hill Region was held in April 2006 at Aizawl, Mizoram, and suggested the following action plan for rodent management (Anon. 2006):

Research

- Identification of major rodent pests
- Distribution mapping of rodent pests in the region
- Studies on bio-ecology and population dynamics of major pest species in different cropping systems of the NEH region
- Studies on the migrant species *Bandicota bengalensis*
- Evaluation of safer anticoagulants and bait delivery systems
- Evaluation of the Linear Trap Barrier System

- Evaluation of bio-potentiality of owls and other predators for rodent control.

DISCUSSION AND CONCLUSION

Rodent outbreaks following gregarious bamboo flowering and mast seedling of other species is only one step in the response of animal communities to sudden availability of massive amounts of food. According to Ostfeld and Keesing (2000), 10 generalities guide the community responses to masting. These are:

1. Consumers of mast seeds/pulsed resources are generalist feeders. They respond to increased food availability by increasing their population, which lasts till the seed availability is in force.
2. As the populations of consumers increase, food availability gets depleted.
3. Enhanced population of seed consumers seek alternate food: vegetative food in the case of primary consumers, and prey for secondary consumers.
4. The generalist consumer itself becomes a pulsed resource for its predators and parasites. These in turn correspondingly increase in population density. Once the generalist consumer levels are exhausted, the predator/prey shifts to alternate prey/host.
5. In some cases of high-density generalist predators, the alternate prey is heavily predated. In temperate forests, both the seeds consumers, i.e., rodents end their predators (small carnivores and raptors), have exploited the same alternate prey, namely ground-nesting birds.
6. Generalist consumers of most seeds affect the populations of their predator and prey but do not seem to influence the density of alternate prey.
7. The impact of increased density of mast consumers and their predators and/or prey is not immediate; it may take several months after masting to affect the population of alternate prey, and it may take up to 2 years after masting to influence predator numbers.
8. Consumers with low potential to breed may not drastically increase in number in response to pulsed resources. However, they affect the food web through migrating to areas of sudden abundant food availability.
9. In contrast, consumers with low mobility respond by increasing their reproduction.
10. Highly mobile consumers like birds strongly influence the community. Once the food sources are depleted, they migrate to adjacent areas of food availability.

The superabundance of rodent populations in response to gregarious flowering and masting of bamboo in North-east India and several South American countries fits this model very well. They exhibit the following characters:

- Irruption of populations several months after gregarious flowering of bamboos
- Since rodents are fairly mobile, once the bamboo seeds are exhausted, they migrate to adjacent cropping fields.
- The continuous availability of food in turn sustains high density of rodents until the food in crop fields and godowns is completely consumed.
- The depredation of crops and stored food by the super abundant rodents leads to famine. This

happened until the early 1990s in India.

- However, improved methods of rodent pest management, food storage, and stocking of enough food grains have successfully prevented occurrence of famine following the 2005-2007 gregarious flowering of bamboo in India.

The most widely accepted evolutionary advantages of gregarious flowering and seed-masting are the satiation of seed-predating rodents, birds, and insects, and increased seed dispersal by scatter-hoarding rodents. Sometimes herbivore feeding behaviour affects seedling sprouts, but this disadvantage is negligible compared to the benefits. Although masting and seed-predation by rodents and birds is a universal phenomenon, most studies have been carried out by plant evolutionary biologists, more for unlocking the mystery of cyclical mast-seeding than to understand the response of vertebrates in general (and rodents, in particular) to masting. Studies on numerical response to periodic, gregarious bamboo flowering are available for India and some South American countries, with almost no information on other details of rodent population dynamics, during and after the phenomenon. What triggers such outbreaks, the physiology of rodent reproduction during masting, and the role of biotic and abiotic factors during rodent plagues consequent to mast seeding need to be studied. Most importantly, as masting occurs for varied periods, sometimes as long as 120-year intervals, the myth of rodent plagues has to be studied in a continuous, scientific process of investigation spanning several generations of scientists.

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