Ecology of flea-transmitted zoonotic infection in village Mamla, District Beed

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Ecological observations were made in the village Mamla and the area around it in Beed district to (i) gather evidence on ecological support system for natural harbourage of rodent species in domestic, peridomestic and feral situations, and (ii) enumerate ecological factors and situations which may have triggered the 1994 outbreak.

Prior to the Maharashtra earthquake of 1993, the ecosystem of Mamla maintained equilibrium densities of domestic rodent (*Rattus rattus*) and their fleas (*Xenopsylla cheopis*). This prevented fulminating epizootics among domestic rats. However, the impact of the September 1993 earthquake in Maharashtra introduced major changes in human ecology at Mamla village which generated unlimited energy inputs (such as foodgrains) for domestic rodents. As a result, there was a gradual, but persistent, growth of *R. rattus* population in the subsequent 8–10 months quiescent period. In August 1994, the *R. rattus* population overshot its equilibrium density level, which eventually led to a flea-mediated epizootic in rats and an outbreak of a cryptozootic, possibly plague, infection in humans in Mamla.

FLEAS as ectoparasites of rodents are known to be the vectors of human diseases like plague, murine typhus and tularemia. Among the 76 species of fleas recorded from the Indian subcontinent[1], the roles of only 3 species viz. *Xenopsylla astia, X. brasiliensis* and *X. cheopis* are well known in plague transmission. However, evidence also exists on the involvement of these flea species in the transmission of murine typhus (*Rickettsia typhi*), which is widespread even in rural India where climatic conditions favour survival of rats and their ectoparasites; however the disease is grossly underreported[2,3]. These rodent–flea borne infections may remain in enzootic form with rare or accidental human transmission depending upon the extent of man–flea contact. Local ecological factors play a key role in the ectoparasite-mediated spill-over of infection from rodent to man.

During August 1994, the inhabitants of village Mamla in Beed district of Maharashtra State, experienced heavy flea nuisance. Subsequently, a number of cases clinically resembling bubonic plague were reported from the village[4]. During May 1995, field investigations were undertaken in and around village Mamla to (i) examine the ecological support system (ESS) for the natural harbourage of rodents in and around the village and (ii) elucidate ecological conditions which may have triggered flea-borne epizootic infection among rodents and its spill-over to humans.

Extensive geographical reconnaissance was undertaken within 30 km around the village Mamla to obtain information on terrain, soil types, vegetation and cropping pattern in agricultural fields. Meteorological data were obtained from the Meteorology Department at Pune.

Wonder traps were laid in the village in the evening and picked up the next morning. Rats were retrieved from the traps and fleas were combed out of their body. Blood was drawn directly from the heart to collect serum for serology. Later, these animals were dissected to take out their lung, liver and spleen and these organs were transported in Cary Blair medium for isolation of bacilli at the Defence Research Laboratory, Gwalior.

Beed district falls along the dry-deciduous scrub land zone of Deccan Lavas region of north-western peninsular plateau. It has small-sized sparse trees mainly *Acacia* sp., with scattered thorny shrubs. The narrow stretches of grasslands used as pastures generally remain dry and barren from March to June.

The village Mamla is an old, remote village, 32 km away from Beed town and falls under Primary Health Centre at Kuppa. The village has a small population of about 350 people, who are mainly agrarian by occupation. During September 1993 a major earthquake shook the adjoining districts of Osmanabad and Latur, but mild tremors were also experienced in certain parts of Beed district. Consequently the residents of Mamla village abandoned their permanent homes in fear during October 1993 and resettled in temporary tin shelters erected on the southern and western borders of the village (Figure 1). The fear of recurrence of earthquake prevented the villagers from reoccupying their old permanent houses which were being used exclusively for storing food grains (wheat, groundnut, millet, etc.). The villagers occasionally visited these houses, for procuring the stored foodgrains.

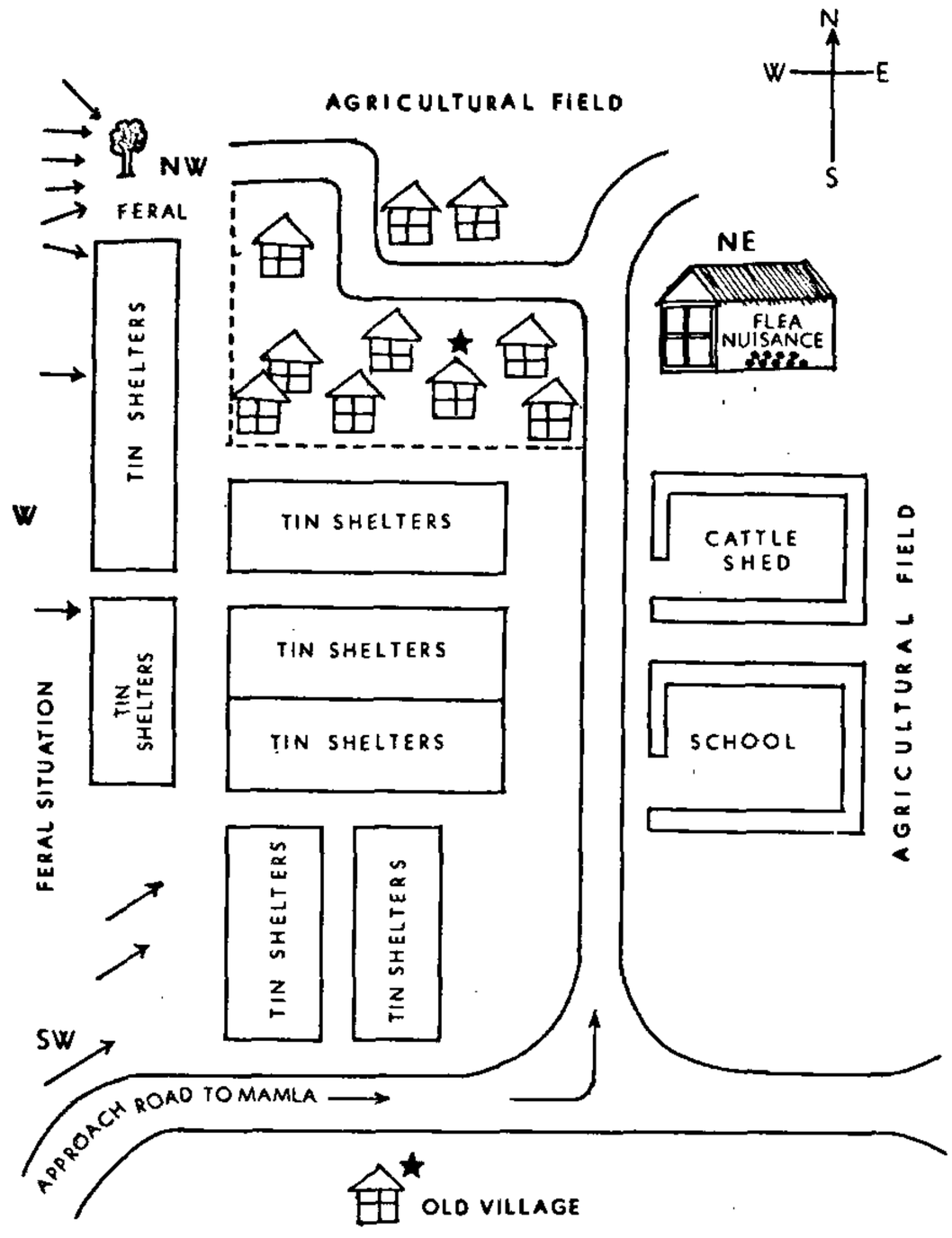

Figure 1. Schematic presentation of village Mamla, Beed.

The village is surrounded on 3 sides, i.e. north, east and south by agricultural fields (agro-climatic zone). However, its western border is contiguous with a small pocket of feral land in the north (Figure 1). The three adjoining borders in the north, east and south of Mamla are cultivated areas, classifiable as a peridomestic agroclimatic zone. The agricultural fields in this zone mainly produce wheat, millet, sugarcane and groundnut. Burrows of the field rodent *Bandicota bengalensis* were found in these agricultural fields mainly in fallow wheat field and a few in the bunds bordering the fields. *B. bengalensis* infestation in the area was relatively poor, though there were some in the fields.

The village has cattle, goat and buffalo populations of about 40, 35 and 18 respectively. Goats are taken every day to open pastures about 1–2 km away for grazing.

The landscape, as observed between Beed city and Mamla village, is a plain and undulating open terrain. The soil is mainly black cotton soil, interspersed with reddish-brown and sandy loose alkaline soil. The black and brown loose soils are mainly used for agriculture but some of the feral areas generally have loose sandy or light red gravelly type of soil. The small discontinuous feral pockets are inhabited by *Tatera indica*.

Dry area crops like millet, cotton, groundnut, maize and wheat are the predominant crops, but in some areas with irrigation facilities sugarcane is also grown.

The maximum temperature during summer touches 44°C in May and the minimum falls to a low of about 5°C in January. However, the monthly mean maximum temperature varies from 29°C to 42°C and the monthly mean minimum temperature varies from 12°C to 25°C. The mean minimum temperature from April to September oscillates between 22°C and 26°C. Beed district is a relatively low rainfall area. An appraisal of monthly rainfall data for the year 1991 indicated that during the monsoon season of 120 days (June to September) there was a total of 20 rainy days, varying from 3 to 9 rainy days per month.

In the domestic biotope of village Mamla, a total of 10 rodents (*Rattus rattus*) was trapped from the peripheral houses of the village and 11 fleas (*Xenopsylla cheopis*) were collected from their bodies. The rodent and parasite indices are as follows:

Trap positivity	16.6%
Flea infestation rate	60.0%
Flea index (*X. cheopis*)	1.1
Intensity of infestation	1.8

These rats were found to be distributed towards the periphery in the old village and tin shelters in the north, west and southern parts of the village. The central and eastern areas of the village had a sparse rat population.

Organs from 10 *R. rattus* specimens which were processed for *Y. pestis* isolation did not reveal presence of the microorganism and serological tests were also negative for antibodies against *Y. pestis*.

The ecological support system was found to be highly conducive for natural harbourage of *Rattus rattus* in the domestic *biotope*; *Tatera indica* in the peridomestic feral biotope and *Bandicota bengalensis* in the peridomestic agroclimatic zone.

The biotope association of village Mamla is of a primitive type[5] wherein the domestic biotope has direct ecological linkages with both the agro-climatic zone and the feral biotope. Such biotope associations are highly favourable for spillover of rodent-borne flea-mediated infection (such as plague) from the wild (feral) directly into the domestic biotope as the (agro-climatic) barrier zone[5–7] is absent between the feral and the domestic biotopes on the western border of Mamla. Another known route of spillover of zoonotic infection from wild to domestic situation which was observed in Mamla is by passive transportation of wild fleas (*Xenopsylla astia*) from pasture land (feral) to the domestic through grazing goats. Such passive transportation of fleas has been reported earlier from Karnataka[6]. From the observations in and around village Mamla and the history of earthquake in the area during 1993 and its impact on human

ecology and other associated ecological features of the village, 4 situations were discernible as far as the dynamics of flea-transmitted zoonotic infections was concerned.

Situation I	(Pre-1993 earthquake)
Situation II	(October 1993; impact of earthquake)
Situation III	(September 1993 – July 1994; quiescent period)
Situation IV	(5 August 1995 onwards; outbreak period).

From situation I standpoint, the biotope-associated ecological linkages of the village Mamla in respect of the rodent and flea populations reveal a state of ecological equilibrium that existed in the rodent–flea relationship during the pre-earthquake period. The natural regulation of host and parasite populations was under density-dependent control factors which presumably prevented the flea population from increasing beyond the level necessary to initiate an epizootic or create pestilence among humans. Density-independent factors like temperature and rainfall in Mamla are not generally inimical to the growth of *R. rattus* and its flea population, as is evident from the minimum and maximum temperature range of the area and poor precipitation.

In situation II, the impact of the September 1993 earthquake in Latur and Osmanabad districts was also noticeable in Mamla village where the inhabitants abandoned their homes in October, 1993, leaving behind large quantities of foodgrains in their homes. The residents shifted to temporary tin shelters thereafter.

In situation III (quiescent period), between October 1993 and July 1994 (for about 10 months), the abandoned homes had ample quantities of stored food grains, for consumption by rodents without human disturbance. This period therefore witnessed on exponential growth of rat populations supported by an abundance and easy accessibility of food in the abandoned homes. This silent period, which promoted unrestricted reproduction and growth of *R. rattus* and *X. cheopis* populations between October 1993 and July 1994 is thus a result of imbalance in ecological equilibria.

In situation IV (August 1994), due to unrestricted growth of *R. rattus* and its flea *X. cheopis* for the previous 10 months, an unusual flea nuisance was seen, having been first detected in one of the peripheral houses in north-eastern corner of the village (Figure 1). It seems probable that the rat population growth which overshot its upper asymptote level sometimes in July–August, 1994 resulted in shortage of space and at this juncture density-dependent population controls, of which disease is a component, operated on the rat population, leading to a rodent epizootic, mediated by the flea *X. cheopis*. A large number of susceptible individuals in the rat population may have suffered mortality which forced their fleas to venture for alternate hosts, including man.

Post-earthquake assessment of Latur and Osmanabad districts revealed an increased vulnerability to vector-borne diseases, including ectoparasite–rodent borne infections in the area[8]. Temporarily vacant houses are also known to produce a sudden abundance of adult fleas upon the return of the tenants and their pets[9], a situation analogous to what was discernible in village Mamla. Population explosion of a domestic rodent *Mus musculus* resulted in outbreaks of murine typhus among farmers[10]. In village Mamla, therefore, a succession of significant ecological events for about an year appears to have led to a flea-transmitted outbreak of a cryptozootic rodent-borne infection in humans, possibly plague.

1. Iyengar, R., *Oriental Insects* (Supplement no. 3), 1973, p. 101.
2. Azad, A. F., *Annu. Rev. Entomol.*, 1990, **35**, 353–369.
3. Traub, R., Wisseman, C. L. Jr and Azad, A. F., *Trop. Dis. Bull.*, 1978, **75**, 237–317.
4. Report of the Technical Advisory Committee on Plague, 1995, p. 79.
5. Saxena, V. K., D Sc Thesis, University of Kanpur, 1992.
6. Saxena, V. K., Kumar, K. and Joshi, G. C., *J. Commun. Dis.*, 1985, **17**, 22–28.
7. Saxena, V. K., *J. Commun. Dis.*, 1987, **19**, 310–316.
8. Saxena, V. K., Khera, A. K. and Bora, D., *J. Basic Appl. Biomed.*, 1994, **2**, 77.
9. Pratt, H. D. and Stark, H. E., US Publ. Hlth. Serv., *DHEW Publ. No.* (CDC) 74-8267, 1973, p. 48.
10. Derrick, E. H. and Pope, J. H., *Med. J. Aust.*, 1960, **2**, 924–928.

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