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EVALUATION OF URBAN RODENT INFESTATIONS—AN APPROACH IN NEPAL

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ABSTRACT: Studies in urban areas have shown that food and shelter are primary environmental factors regulating rodent population growth. These supportive resources can be modified to reduce urban rodent damage; however, widespread adoption of environmental control techniques will require a thorough understanding of rodent-man interrelationships. This study was concerned with what factors should be monitored for making rational ecological decisions on the necessity of rodent management, establishment of priorities, choice of appropriate strategies and evaluation of effectiveness. Guidelines are given for comprehensive monitoring of habitats (social, structural and sanitary factors) and rodent populations (habitat requirements, growth characteristics and zoonosis potential).

INTRODUCTION

It is apparent that some relatively simple environmental alterations can produce substantial changes in sizes of vertebrate populations. Unfortunately, man often provides certain species with abundant supportive resources which allows them to exceed his tolerance limits and, hence, become pests. Geis (1976) has shown that building design and quality of construction can significantly affect the population growth of nuisance birds. We are all familiar with municipal garbage dumps which, unless properly maintained as a sanitary landfill, can serve as a foci for rodent pests.

We must be concerned with pest situations and the particular pest species must be considered in relation to the rest of the environment (Barbehenn, 1973). In urban areas the environment is much the product of man; hence, a basic task in managing urban rodents lies with understanding the interrelationships of man and rodents.

BACKGROUND

When rodents are introduced into an area, the population's growth follows essentially an "S-shaped" curve (Fig. 1, a). There is a slow initial growth rate which increases to a maximum and, then, reduces as it reaches the upper limit of its growth and adjusts to the supportive capacity of the environment. For rodents in urban areas, the environmental carrying capacity can be defined mainly in terms of food and shelter resources. As the limitations of these factors is approached, contact rates between individual rodents increase logarithmically. Under these conditions social organization (dominance hierarchy and/or territorial defense) begins to limit the number of individuals in the population by influencing birth rates, death rates, and immigration/emigration patterns (Davis, 1953 and 1966; Brown, 1968; Southwick, 1969). Much of the regulatory influence is due to a complex socio-physiological feedback mechanism. Once adjusted to carrying capacity, a population continues to fluctuate, at basically the same level indefinitely, or until some management effort is applied.

Conventional poisoning or trapping reduces the number of individuals in a population, but not necessarily the effective breeding population, and does nothing to limit the carrying capacity which can support surviving or immigrant rodents (Fig. 1, b). When such repressive efforts are discontinued, the population once again grows to the capacity of the environment; thus, the control is only temporary.

Most biologists agree that urban rodent populations can be controlled most effectively over time by reducing the food and shelter resources of the environment (Brown, 1968; Cole, 1966; Davis, 1972). When the carrying capacity is reduced, the population reduces its size and stabilizes at the new equilibrium level which can be set below man's injury level (Fig. 1, c). Application of rodenticides has a role in certain circumstances (e.g. a disease outbreak or for initial reduction of a large population), but should generally not be used as the primary management strategy. To avoid reduction of carrying capacity and rely entirely upon other means to reduce rodent damage contravenes the principles of rodent population regulation (Davis, 1972).

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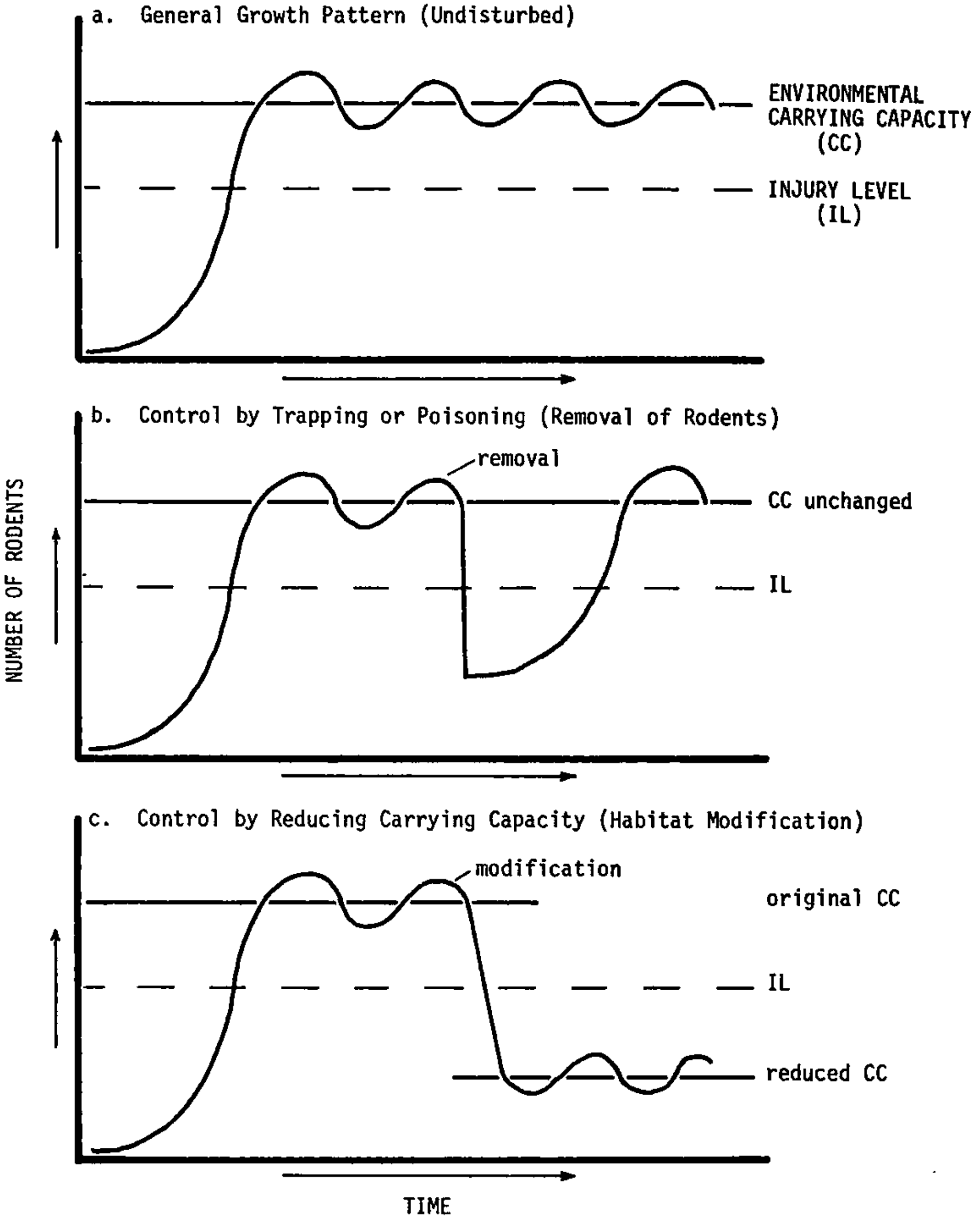

Figure 1. Rodent Population Growth Curves -- Hypothetical

The concept of rodent control through habitat modification was well-proven in Baltimore roughly three decades ago (see Davis, 1953, and Scott and Borom, 1968). A major drawback to the adoption of such practices was the introduction of anticoagulant rodenticides in the late forties. These toxicants have recently lost favor due to the development of widescale resistance in rats and mice and now there may be renewed interest in environmental control practices employing physical, cultural and educational strategies. For this end we need a methodology for assessing a particular habitat's capacity to support particular species of rodents.

Guidelines for evaluating pre- and post-treatment conditions have been given for the U.S. federally funded rat control program (U.S. Dept. HEW, 1974). These guidelines are quite abbreviated, do not consider actual numbers of rodents and are limited to exterior observations; rodent-man interrelationships are not adequately treated.

PURPOSE

The overall purpose of the present study was to design a comprehensive monitoring system for evaluating rodent infestations in areas, including both rodent and human factors. Although still being developed, the broad-scope methodology described has component parts to suit the needs of rodent pest managers or biologists and can be adapted to virtually any rodent habitat situation.

The study occurred in the Kingdom of Nepal which lies on the southern slopes of the Himalayan Mountains, bordered by the Tibetan Region of China (north), Sikkim (east) and India (south and west). Nepal was appropriate for the current work because it has tremendous variations in climate and biota; human habitat and rodent species showed considerable variation within a small range. We worked mostly in the capital city of Kathmandu, in the central valleys at 1302 m above sea level, where conditions were best for developing procedures which were then tested in the lowland and highland regions of the country. This report illustrates the monitoring scheme as it has developed thus far; data on rodent problems in Nepal will be reported elsewhere.

EVALUATION OF HABITAT

Guidelines developed for evaluating urban rodent infestations in Nepal are given in Table 1. Food and harborage are of prime importance in managing urban rodents, but these factors do not exist in isolation and are quite complex themselves. Table 1 has two main sections, evaluation of 1) habitat and 2) rodent population. By monitoring the environment and rodents together, factors may emerge which are important for limiting a particular pest situation and, therefore, enhance the selection of appropriate management strategies.

General information is recorded twice in Table 1 (I-A and II-A) since the work may occur on different days. The various categories are basically objective and self-explanatory. Premises includes a structure and its grounds, essentially the same as in Davis, Casta and Schatz (1974). Premises subdivisions (e.g. individual apartments) are also indicated.

A social-structural-sanitation profile of the community is a basic objective of habitat evaluation. To gain insight into residents' attitudes toward rodents, they are interviewed (Table 1, I-B) for awareness of problem, nature of complaints, and actions taken to reduce problem. Premises ownership is determined to see who is responsible for property maintenance. This knowledge and the number of residents can indicate the probability and complexity of obtaining resident cooperation in a management program. This cooperation is essential if management efforts are to be successful.

Since the interview often occurs indoors, it is then convenient to observe indoor factors (Table 1, I-C). This complements interview data and one learns how people handle food and household goods. Signs of rodents and their location are noted to aid in identifying specific problem areas. Interior structural complexity is indicated by listing all rooms by type (use), number, floor level and size (m^2). These are important features to consider when habitat modification is to be applied.

Next, observe the premises' outdoor features (Table 1, I-D): use, design, construction materials, and grounds. As above, complexity of habitat is defined by listing factors which may be important to rodent infestations; at the same time, complexity of possible management application is assessed. Condition of the structure and rodent entry and stoppage potentials are somewhat subjective categories, but do indicate residents' maintenance efforts. Presence and location of rodent signs are noted, as they were indoors, and help to locate resources utilized by rodents. The importance of some environmental factors can be estimated only after learning what species occur. For example, a defective roof in Kathmandu is not a likely entry point for the lesser bandicoot rat (*B. bengalensis*) which is not a good climber in Nepal.

Evaluation of habitat will enable discovery of environmental deficiencies in terms of human behavior or physical features which might be altered to discourage or prevent rodent infestations. Much of habitat evaluation must be correlated with an evaluation of the rodent population in order to fully understand the pest situation.

Table 1. Monitoring scheme guidelines for evaluating urban rodent pest infestations in Nepal.

I. EVALUATION OF HABITAT

A. General

1. Location

a. city/town
b. census tract
c. block number
d. premises number
e. premises subdivision (if appropriate)
f. total number of premises subdivisions

2. Altitude

3. Visit Number

4. Date

a. day
b. month
c. year

5. Observer(s)

a. number (name)
b. time in
c. time out

B. Interview of Residents

1. Resident's Complaints (note indoors and/or outdoors)

a. pests

1) none
2) shrews
3) mice
4) rats
5) other

b. damage (note where damage is observed)

1) food
2) dry goods
3) structure
4) other

c. bites

2. Rodent Control Used by Residents

a. none
b. rodenticides
c. traps
d. rat-proofing
e. sanitation
f. other

3. Premises Ownership

a. owned
b. rented
c. other

4. Number of People

a. in residence/premises
b. in structure (multiple residence)
c. per square meter of floor space

Comments:

C. Indoor Observations

1. Room Types in Premises (indicate number, floor level and m^2)

a. with food

1) livestock
2) milling
3) kitchen
4) dining
5) storage
6) sitting

7) sleeping
8) all-purpose
9) passage/hall
10) terrace/porch
11) other

b. without food

1) storage
2) sitting
3) sleeping
4) all-purpose
5) passage/hall
6) terrace/porch
7) empty
8) other

2. Indoor Rodent Resources (indicate if rodent signs also observed)

a. exposed food

1) human food
2) animal food
3) water
4) other

b. harborage available

1) wood pile on floor
2) stored dry goods on floor
3) under furniture
4) cluttered shelves
5) rafters/ceiling beams
6) other

3. Indoor Rodent Signs (indicate room type and floor level)

a. feces
b. gnawmarks
c. rubmarks/tracks
d. holes/burrows
e. sounds
f. sightings (dead or alive)

Comments:

D. <u>Outdoor Observations</u>

1. Structure Use

a. residence

1) single
2) multiple

b. residential and commercial
c. commercial

1) food
2) non-food

d. storage (warehouse)

1) food
2) non-food

e. livestock/pets
f. vacant
g. other

2. Architecture of Structure

a. attachment features

1) detached (e.g. single family house)
2) attached (side-by-side; e.g. row house)
3) stacked (vertically contiguous; e.g. apartment building)

b. number of walls touching other structure(s)

c. nearest structure within

1) more than 20m
2) 3-20m
3) less than 3m

3. Construction Materials: Ground Floor Walls Roof

a. concrete

b. burnt brick/tile
c. sun-dried brick/tile
d. sheet metal ---
e. wood
f. soil
g. wattle and daub --- ---
h. thatch --- ---
i. other

4. Condition of Structure

a. good repair
b. deteriorating

5. Rodent Entry Potential into Structure

a. structural defects

1) floor
2) walls
3) roof
4) other

b. maintenance problem

1) unscreened/unglazed window
2) no door
3) carelessness (e.g. open window)
4) other

c. other

6. Rodent Stoppage Potential of Structure

a. rodent-proof (essentially no entries)
b. easily rodent-proofable (requires minor construction)
c. not rodent-proofable (requires major construction)

7. Outdoor Rodent Resources (indicate if rodent signs also observed)

a. exposed food

1) human food
2) animal food
3) garbage
4) vegetable garden
5) agriculture
6) water
7) other

b. Harborage available

1) trash/rubbish
2) large rubbish (including abandoned automobiles)
3) wood/lumber on ground
4) weeds/tall grass/vegetable garden
5) agriculture
6) fence/wall
7) dilapidated outbuilding
8) other

c. sewers

1) none
2) open
3) closed (covered or buried channels)

8. Exterior Rodent Signs (indicate location; e.g. trash pile)

a. feces
b. gnawmarks
c. rubmarks/tracks
d. holes/burrows
e. sounds
f. sightings (dead or alive)

Comments:

II. EVALUATION OF RODENT POPULATION

A. <u>General</u>

1. Location

a. city/town
b. census tract
c. block number

- d. premises number
- e. premises subdivision (if appropriate)
- f. total number of premises subdivisions

2. Altitude
3. Visit Number
4. Date
    - a. day
    - b. month
    - c. year
5. Observer(s)
    - a. number (name)
    - b. time in
    - c. time out
6. Total Number Traps per Premises
    - a. indoors
    - b. outdoors

B. <u>Trap Setting</u>

1. Trap Number
2. Trap Type (note bait formulation)
    - a. wire
    - b. Sherman
3. Trap Position
    - a. floor/ground
    - b. elevated (e.g. bags, shelf)
    - c. rafters/ceiling beams
4. Trap Location
    - a. rooms with food
        - 1) livestock
        - 2) milling
        - 3) kitchen
        - 4) dining
        - 5) storage
        - 6) sitting
        - 7) sleeping
        - 8) all-purpose
        - 9) passage/hall
        - 10) terrace/porch
        - 11) other
    - b. rooms without food
        - 1) storage
        - 2) sitting
        - 3) sleeping
        - 4) all-purpose
        - 5) passage/hall
        - 6) terrace/porch
        - 7) empty
        - 8) other
    - c. outdoors
        - 1) garbage pile
        - 2) trash/rubbish
        - 3) wood/lumber
        - 4) weeds/tall grass/garden
        - 5) agriculture
        - 6) other

C. <u>Trap Collection</u>

1. Trap Condition
    - a. open
        - 1) bait present
        - 2) bait missing
        - 3) capture

D. <u>Captured Animal</u>

1. Animal Number
2. Species
    - a. *Rattus brunneus* (common house rat)
    - b. *Rattus nitidus* (Himalayan rat)
    - c. *Rattus turkestanicus vicerex* (Turkestan rat)

d. *Bandicota bengalensis* (lesser bandicoot rat)
e. *Bandicota indica* (greater bandicoot rat)
f. *Mus musculus castaneus* (city mouse)
g. *Mus musculus homourus* (common house mouse)
h. *Suncus murinus* (common house shrew)
i. other

3. Condition When Collected

    a. healthy
    b. ill (slow moving, lethargic)
    c. dead

4. Sexual Characteristics

    a. sex

        1) male
        2) female

    b. testes position

        1) not applicable
        2) abdominal
        3) scrotal

    c. vaginal orifice

        1) not applicable
        2) closed
        3) open

    d. teats

        1) not applicable
        2) number

            a) left side
            b) right side

        3) lactating

    e. pregnancy

        1) not applicable
        2) no
        3) yes
        4) number embryos

            a) left side
            b) right side

5. Measurements

    a. weight (grams)
    b. length (mm)

        1) head and body
        2) tail
        3) hindfoot (without claw)
        4) ear

6. Disease-related Materials Collected

    a. blood

        1) not taken
        2) number

            a) spots on filter paper
            b) serum aliquots (approx. 0.5 cc each)
            c) smears on micro-slides

    b. ectoparasites

        1) not taken
        2) number

            a) fleas
            b) lice
            c) ticks
            d) mites
            e) other

    c. feces

        1) not taken
        2) number of tubes

d. organs (indicate if pathological and if collected)

1) not observed
2) lungs
3) liver
4) spleen
5) kidneys
6) other

7. Disposition of Body

a. discarded
b. pickled (indicate museum, university, etc.)
c. frozen
d. skin and skull (indicate museum, university, etc.)
e. escaped

Comments:

EVALUATION OF RODENT POPULATION

The second major division of the monitoring scheme involves live-trapping rodents in at least a sample of premises. Selection of sample premises can be made at random (Davis, Casta and Schatz, 1974) or by choosing a systematic sample evenly distributed over the community (we followed the latter procedure in Nepal). Live-trapping allows a wide-spectrum of data to be collected and is necessary for disease-related work. If zoonosis studies are not to be done, snap-trapping may be appropriate if not objectionable to local customs; religious customs in Nepal would not favor trapping which kills rodents.

Two trapping procedures were used in Nepal and are appropriate elsewhere. Survey trapping uses two traps, one Sherman metal box trap (25cm x 8cm x 8cm) and one wire trap (32cm x 16cm x 11cm) in the single room of a structure judged most likely to have rodents. Trapping is done for two successive 24-hour periods with collections made once daily. This is a rapid, though crude technique, suitable for some purposes. Exhaustive trapping also employs two traps (as above), but in every room of a structure. Traps are set for six to eight successive days and collected at twelve-hour intervals (this could be reduced to one collection per day). In Nepal, exhaust-trap criterion was reached when no rodents were captured for two consecutive trapping days. This technique is slow and laborious, but very sensitive. As noted in Table 1.II.B., traps are placed both indoors and outdoors. Exhaustive trapping is rarely possible outdoors, but by standardizing the procedure a useful relative measure of density can be obtained for comparative purposes (e.g. before and after control). Our preference is to use the exhaustive procedure at all times, but when outdoors a time limit criterion (e.g. 8 days) is more practical than lack of captures.

Objectives of monitoring rodent populations include determining major pest species in an area and, through repeated trapping, determining seasonal variations in species composition and detecting interloping species. We used both exhaustive and survey trapping for species composition studies and found no significant (χ^2.05) difference in results from the two procedures.

The rodent species composition partially determines the management strategy for a particular area. In Kathmandu, the ground-dwelling B. bengalensis and the climbing Rattus brunneus (common house rat) are both found in the suburbs; rodent-proofing work would need to be directed at ground-level and elevated potential entry points. Seasonal variations may be found in rodent location because some species tend to move indoors during inclement weather. This information enables the timing of rodent-proofing work to the season with the lowest indoor population.

Level of infestation (average number of rodents per structure) can be determined by preceding exhaustive trapping with marker baiting and then counting marked captures as resident rodents. Rodents and shrews in Kathmandu houses were prebaited for three days (continuous) with bait containing a fat stain, Sudan Black B (1 SBB: 25 bait--by weight). We found that virtually all trapped rats and mice and roughly half of the shrews were marked, indicating that shrews were less sedentary than the rats and mice (this was verified by later movement studies). The average number of pests/structure was four rats, two mice, and six shrews. In management programs, the infestation level is a useful index of control effectiveness even though figures for outdoors will be less accurate than for indoors.

Another trapping objective is to determine where pest rodents are found; this includes an area or neighborhood distribution and on a premises. More rodents will be found where food and harborage are available and along migration routes from these resources. Correlating trapping and habitat data can help to locate foci of rodent infestation which may not otherwise be obvious. Similar data can be obtained for specific premises by carefully-distributed indoor and outdoor trapping.

Percentage of premises infected with rodents, indoors or outdoors, is valuable for comparing different localities and for establishing management priorities. Areas with high indoor infestations would certainly have priority over those areas with primarily outdoor problems. Data from Kathmandu showed that indoor infestation rates for particular pest groups may vary with the trapping procedure. With survey trapping, infestation rates were 43% rats, 16% mice and 52% shrews; with exhaustive trapping the figures were 81% rats, 51% mice and 77% shrews. The percentage of premises infested with rats and with mice differed significantly (χ^2.05) between procedures (conducted simultaneously). This reflects a general difficulty in capturing some animals with short-term survey trapping. At any rate, survey trapping will not give the same infestation rates as exhaustive trapping; the latter should be the most accurate being derived from the concentrated, detailed technique.

Biological characterization of an area's pests is another objective of monitoring rodent populations (Table 1, II-D). Many kinds of standard information (British Museum, 1968; Davis, 1956) are recorded including sex, age, weight, size, and reproductive condition. These data can indicate a rodent population's response to changes in the environment (Davis, 1966 and 1969; Southwick, 1969). When the carrying capacity of the environment is lowered, the percentage of young and of pregnant and lactating females all should decrease; the size at which animals become sexually mature should increase. Such changes indicate a reduction in population growth rate (Fig. 1, c) after carrying capacity has been reduced. When only the population size is reduced, as in poisoning, the above biological factors should show the opposite trends and indicate a growing population (Fig. 1, b) after the removal effort has been discontinued. In order to reveal these trends, the population must be monitored before and after management efforts are applied.

Surveillance of potential zoonosis materials (Table 1, II-D-6) demonstrates the rodent population's disease significance to humans and domestic animals, a sample of collected rodents will suffice for this purpose. From these animals, material can be selected which is related to numerous diseases and is relatively easy to collect, process, and transport to collaborators.

Animals can be transferred from traps into transparent polythene bags for anaesthetization with ethyl ether or chloroform. Blood samples are taken by cardiac puncture while animals are still alive to ensure getting adequate quantities of blood. In Nepal, whole blood spots were taken on antibiotic-treated filter paper; also, blood was taken in tubes for serum collection and freezing. The former is the simplest field procedure (Mosby and Cowan, 1971), but not suitable for all zoonosis studies (e.g. virus isolations).

Ectoparasites are removed from freshly killed or anaesthetized animals by brushing the pelage (with a stiff hairbrush) over a white enameled pan; for accurate counts it is important to also collect those ectoparasites which drop off in the anaesthetizing bag. Collected ectoparasites are stored in 70% ethyl alcohol; in Nepal, we also stored some fleas in 2% saline for plague bacteria isolation attempts. All ectoparasites must be correctly identified as must be the rodent host and trapping location. To simplify this task, we use the host's specimen number to identify all material collected from a specific animal.

Ectoparasite counts as well as species identification are important in assessing disease potentials. For example, the oriental rat flea (Xenopsylla cheopis) is the most efficient vector of plague and was found on domestic rats in Nepal; however, the level of parasitism did not reach the critical transmission index of 2 fleas/animal. Also, no evidence of plague was found in fleas or from serological studies.

Fecal samples can be collected directly from the intestines and stored in merthiolate-iodine-formalin (MIF) for helminth studies. Certain major organs can also be collected if they appear pathological, unusual in size or color or have cysts.

Whenever possible, collaborative disease studies should be established with local public health laboratories. This will enhance the prompt transport and analysis of material and provide rapid feedback to aid future collections. With the Nepal material, we relied on an international network of collaborators and consultants which, though accurate, was (and still is) very slow in generating results. The final disposition of examined animals is noted in case the specimen should be needed at some later date. Reference collections should be prepared and stored with major, local and international museums.

CONCLUSIONS

The many types of data collected in this monitoring scheme may be cross-tabulated and analyzed in various ways in order to clarify where, when, and what kind of rodent management strategies must be used to benefit the most people. Food and harborage are very important environmental factors to consider in managing urban rodent populations. These resources can be altered or limited by physical, cultural and educational strategies, but we must first thoroughly understand them and their origins. In the current study, we are still sometime off from consolidating the data and simplifying the overall evaluation methodology, but this should provide a base for similar studies elsewhere. A comprehensive approach to monitoring urban rodent pest infestations is seriously needed; the guidelines given here are particularly appropriate to developing countries where information on rodent pests and their interrelationships with man is often non-existant.

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