Evaluation of Rodent Infestations in Nepal — A Preliminary Report

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Introduction and purpose

The importance of rodents as reservoirs of disease, despoilers of human food stores and general pests need not be elaborated here. However, it is significant that the rodent fauna of Nepal is rather poorly known and that no attention has previously been focused on rodents of medical and economic import.

The present study is concerned with a wholistic approach to the evaluation of rodent infestations in human settlement areas. The technique employs a number of standard and modified ecological measures in order to: 1) identify the important pest species of rodents; 2) analyze rodent distributions geographically, and vertically or horizontally, within any particular locality; 3) determine infestation rates (% premises with rodents); 4) measure the relative density of each species; 5) survey potential zoonosis material in order to discover zoonoses in the rodent populations as well as estimate the potential for outbreaks of rodent-borne diseases; 6) estimate human food losses; 7) describe the particular human conditions which appear to foster infestations.

The ultimate application of this technique will be in the field of rodent control in human settlement areas, urban or rural.

Population biologists are well aware of the temporary nature of rodent trapping or poisoning campaigns and of the more permanent effect of limiting the food and shelter resources of the rodent pests (Brown, 1967; Davis, 1953; Jackson, 1966). However, in practice, the

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pest control industry has emphasized the use of rodenticides rather than attempting to correct the underlying problems. Part of the reason for their approach may be due to an inadequate understanding of man-rodent interrelationships. Surprisingly, this is a relatively unexplored area of rodent biology.

The survey technique being developed and standardized in this study should provide a practical and economical means of evaluating those parameters which will aid one in deciding if a rodent control campaign is necessary, the appropriate means of control, and the relative effectiveness of any control measures used. The present technique will need to be adapted to the particular environment being investigated, but this will provide a model. At present there is no adequate quantitative method in use by rodent biologists for evaluating infestations (Arata and Gratz, *Pers. Commun.*; *Bur. Community Environ. Manage.*, 1971; Drummond, 1973).

Study Areas

The evaluation technique, in various stages of development, has been used in the three major physical regions of the Kingdom of Nepal, each locality being distinctly separate from the others. Metaura is a town in the inner Terai just south of the Mahabharat Lekh in Chitwan District; the elevation is 421m above sea level. This is a major intersection for both north-south and east-west transport. Kathmandu City is the nation's center for trade, commerce, government and education, and is the largest urban settlement. This is in the east-central Midland region (Kathmandu District) at 1302m elevation; the survey was in the "City Core", an area of roughly 2.5 km² where about 60% of the city's human population is concentrated. In the Himalaya region, surveys have been conducted in Jomosom (Mustang District) at 2743m above sea level and in Nauche (Solokhumbu District) at 3440m. Both of these villages lie along the Nepal-Tibet trade routes, the latter being close to the boundary of the proposed Sagarmatha National Park. Additional miscellaneous trapping has been conducted in Birganj (137m, Patan District / Terai), Kathmandu City and Suburbs (as above), Jharkot (3520m, Mustang District / Himalaya) and Muktinath (3740m, Mustang District / Himalaya). This work was conducted using trapping techniques or in checking species distributions.

Rodent Fauna

Rodents may be divided into four categories based on their general habitat requirements (Baltazard, 1966): domestic — live with man / build nests and live in human dwellings; commensal — live on, but not with man / enter the human habitat to consume man's food, but do

nest there; field -- live on, but away from man in fields where they consume produce/ rarely enter human habitats but may frequent threshing floors, godowns, silos, etc. where they may contact commensal or domestic species wild -- live without man, feeding on wild plants and having little contact with man except on pasture land or in deserts. This classification is by no means rigid for any particular species whose habits may vary from one region to another; however, for any particular locality, the domestic and commensal species are of greatest interest since they pose the greatest threat to man's stored foodstuffs and health. Insectivores (shrews) are also included in the study since they play a similar pestrole to domestic rodents. There have been at least six species of rats, two of mice and one of shrews reported as being domestic or commensal in Nepal (Table 1).

Table 1.

Domestic and commensal rodents (and shrews) reported in Nepal

Scientific Name	Common Name
RATTUS NITIDUS (Hodson, 1845)	Himalayan Rat
RATTUS NIVIVENTER (Hodgson, 1836)	White-bellied Rat
RATTUS TURKESTANICUS VICEREX (Bonhote, 1903)	Turkestan Rat
RATTUS RATTUS BRUNNEUS (Hodgson, 1845)	Common House Rat
RATTUS RATTUS KHUMBUENSIS (Biswas & Khajuria, 1955)	Khumbu House Rat
RATTUS RATTUS RUFESCANS (Gray, 1837)	Common Indian Rat
MUS CERVICOLOR (Hodgson, 1845)	Fawn-colored Mouse
MUS MUSCULUS CASTANEUS (Waterhouse, 1843)	Asian House Mouse
MUS MUSCULUS HOMOURUS (Hodgson, 1845)	Common House Mouse
MUS MUSCULUS URBANUS (Hodgson, 1845)	City Mouse
BANDICOTA BENGALENSIS BENGALENSIS (Gray & Hardwicke, 1835)	Lesser Bandicoot Rat
BANDICOTA INDICA NEMORIVAGA (Hodgson, 1836)	Greater Bandicoot Rat
UNCUS MURINUS MURINUS (Linnaeus, 1766)	Common House Shrew
UNCUS MURINUS SOCCATUS (Hodgson, 1845)	House Shrew

In each locality surveyed in this program, a systematic sample of trapping sites (house godowns, mills, etc.) was chosen from a detailed map or by inspection. Our emphasis was on the "dwelling unit" which is the space occupied by one or more people living under a common roof and sharing a common kitchen (Dep. Hous. Phys. Plan., 1972). Two traps were set in the single, most-likely room to be infested in each site for two successive nights. Rooms were classified as to function and floor level to permit both vertical and horizontal (within a locality) analysis of trapping results.

Table 2 shows the species diversity and composition variation found in four localities within a relatively small compass. It can be seen that *R. R. BRUNNEUS* (38.9%) and *M. M. URBANUS* (44.4%) are dominant species in Hetaura. *B. BENGALENSIS* (11.1%) is probably a commensal/field species which accounts for its low capture rate. In Kathmandu, *R. R. BRUNNEUS* (70.9%) predominates with the house shrew (23.6%), *S. MURINUS* being the second most common house pest. *M. M. HOMOURUS* (83.5%) was most commonly captured in Jomosom, but in Nauche it was *R. T. VERCEREX* (90.9%).

In terms of small mammal distributions, this work has contributed several items. It has provided the first solid evidence that *M. M. HOMOURUS* does inhabit houses (in Jomosom, Jharkot, Muktinath and Nauche); only sketchy evidence existed previously (Hodgson, 1845; Weigel, 1969) and it was generally thought that it was only a commensal/field species. Secondly, *M. M. URBANUS* has been rediscovered in Kathmandu, the first report since its discovery by Hodgson in 1845. We also have the first record of *B. BENGALENSIS* in the Terai (in Hetaura).

Probably the most important result is the first authentic report of *BANDICOOT BENGALENSIS* (Lesser Bandicoot Rat) in the Kathmandu Valley. This is only its second record north of the Terai, the first was in 1855 in Gorkha District by Horsfield (Ellenberg, 1961). Our specimens were captured in lawn/flower gardens in two different areas of east-Kathmandu suburbs. This is the first evidence of *B. BENGALENSIS* as a commensal species in Nepal (in both the Midland and Terai regions); others (Abe 1971; Chesser, 1970) have found it as a Terai field/wild rat. This is particularly important because the Lesser Bandicoot has displaced other species in parts of India to become the dominant urban species. The destructiveness of this rat as a domestic/commensal pest in the grain godowns of West Bengal, India has been well documented (Frantz, 1972a; Spillett, 1968); it also carries a number of human parasites and is highly susceptible to plague. At present it is not known how widespread *B. BENGALENSIS* is in the Kathmandu Valley; this work does indicate that it is not

Table 2

Species composition and numbers of animals trapped in Small-Mammal Surveys in Hetaura (Dec. 1973), Kathmandu (May 1973), Jomoshom (Sept. -Oct. 1973), and Nauche* (Mar. 1974)

Percentage of Captures:	Hetaura/ Terai		Kathmandu/ Midland		Jomoshom/ Himalaya		Nauche/ Himalay	
	%	(No.)	%	(No.)	%	(No.)	%	(No.)
1. RATTUS SP.	0.0	(0)	0.0	(0)	16.7	(1)	0.0	(0)
2. RATTUS RATTUS BRUNNEUS	38.9	(7)	70.9	(105)	0.0	(0)	0.0	(0)
3. RATTUS TURKESTANICUS VICEREX	0.0	(0)	0.0	(0)	0.0	(0)	90.9	(10)
4. BANDICOTA BENGALENSIS BENGALENSIS	11.1	(2)	0.0	(0)	0.0	(0)	0.0	(0)
5. MUS MUSCULUS HOMOURUS	0.0	(0)	0.0	(0)	83.3	(5)	9.1	(1)
6. MUS MUSCULUS URBANUS	44.4	(8)	5.4	(8)	0.0	(0)	0.0	(0)
7. SUNCUS MURINUS	5.6	(1)	23.6	(35)	0.0	(0)	0.0	(5)
Total Rats (1, 2, 3 & 4)	50.0	(9)	70.9	(105)	16.7	(1)	90.9	(10)
Total Mice (5 & 6)	44.4	(8)	5.4	(8)	83.3	(5)	9.1	(1)
Total Shrews (7)	5.6	(1)	23.6	(35)	0.0	(0)	0.0	(0)
Total No. Captures		(18)		(148)		(6)		(11)

*also called Namche Bazar

major commensal pest in the Kathmandu City Core. All of our rodent identifications have been made or confirmed by Dr. J. T. Marshall, SEATO Medical Research Lab, Bangkok.

Small mammal infestations were widespread in the four areas surveyed (Table 3). The overall infestation rate was highest in Hetaura (87.0%), intermediate in Kathmandu (73.6%) and Nauche (69.6%) and lowest in Jomoshom (50.0%). Thus, a mean of 70.0% of ALL properties surveyed in this study were infested indoors with rats, mice and/or shrews. Since a very low profile approach was used, these infestation rates are obviously low estimates. We have

experimented with supplementary trapping and always found the infestation rates to increase. For example, in Hetaura the rate increased to 92% and in Nauche to 74% when extra-survey trapping was done in a few of the original sites. Another factor contributing to low estimates was poor bait acceptance. This problem was marked in Jomosom where infestation signs (fecal pellets, holes in walls, etc.) were greater than that shown by trapping. It was difficult to attract animals away from their regular food resources, and after this a standard, highly acceptable porridge-meat bait was concocted.

Comparative infestation rates for other countries are difficult to find. Drummond (1973) recently reviewed the literature and reported the following statistics: 1.) a mean of 25.7% of properties in over 400 localities surveyed were infested in Lower Saxony, West Germany; 2.) 16% of properties showed 'active exterior rat signs' in poorer areas of some 20 large cities in the United States of America; and 3.) an average of about 1% of all urban properties in Britain are infested at any moment in time. When compared to these figures, the mean of 70% infestation found in four localities in Nepal is outstanding.

Infestations of sites by single species outweighed multiple-species infestations in all areas surveyed. Both the faunal (Table 2) and infestation (Table 3) patterns become more complex as one moves from the Himalaya Regions into the lower Midland and Terai Regions. That is, in a Himalayan village most houses appear to be infested with the same single species whereas in the lower regions some houses have species "X", others species "Y", or combination thereof. It is interesting to note that the house shrew, *SUNCUS MURINUS*, was not found at higher elevations.

Some data have been collected for comparing trap success figures according to species for different floor levels and different room types. Although the data cannot be analysed statistically at this time, we can say that *M. M. URBANUS* was found on more levels and in more room types than any other rodent in Hetaura. Similarly the most ubiquitous pest in Kathmandu was *R. R. BRUNNEUS*, in Jomosom it was *M. M. HOMOURUS*, and in Nauche it was *R. T. VICEREX*.

In Kathmandu where an accurate map of the city was available and the collection data plentiful, Chi-square tests were performed (excluding the limited mouse data) to determine whether the differences in number of captures in different parts of the city were significant (the city core was first divided into 16 equal-sized sectors, see Table 4). In no case were the number of captures between sectors significantly different at the 95% level (for total captures, rats or shrews). In addition when the sectors were grouped into halves (North, South; East, West),

Table 3.

Infestation rates and numbers of sites for Small-Mammal Surveys in Hetaura
(Dec. 1973), Kathmandu (May 1973), Jomosom (Sept-Oct 1973), and Nauche
(Mar. 1974)

Percentage of Sites Infested with:	Hetaura		Kathmandu		Jomosom		Nauche	
	Correct. (No.) Infest. Rate		Correct. (No.) Infest. Rate		Correct. (No.) Infest. Rate		Correct (No.) Infest. Rate	
1. RATTUS SP. only		(0)		(0)	8.3	(1)		(0)
2. RATTUS RATTUS BRUNNEUS only	26.1	(3)	41.8	(38)		(0)		(0)
3. RATTUS TURKES- TANICUS VICEREX only		(0)		(0)		(0)	60.9	(7)
4. BANDICOTA BENGALENSIS only	8.7	(1)		(0)		(0)		(0)
5. MUS MUSCULUS HOMOURUS only		(0)		(0)	41.7	(5)	8.7	(1)
6. MUS MUSCULUS URBANUS only	26.1	(3)	2.2	(2)		(0)		(0)
7. SUNCUS MURI- NUS only		(0)	13.2	(12)		(0)		(0)
8. R. R. BRUNNEUS & M. M. URBANUS	8.7	(1)	5.5	(5)		(0)		(0)
9. R. R. & BRUNNEUS & S. MURINUS		(0)	9.9	(9)		(0)		(0)
10. B. BENGALENSIS & M. M. URBANUS	8.7	(1)		(0)		(0)		(0)
11. M. M. URBANUS & S. MURINUS	8.7	(1)	1.1	(1)		(0)		(0)
Total for Rats: 1,2,3,4,8, 9 & 10	52.2	[6]	57.1	[52]	8.3	[1]	60.9	[7]
Total for Mice: 5,6,8,10 & 11	52.2	[6]	8.8	[8]	41.7	[5]	8.7	[1]
Total for Shrews: 7,9 & 11	8.7	[1]	24.2	[22]	0.0	[0]		[0]
Grand Total: 1 - 11	87.0	[10]	73.6	[67]	50.0	[6]	69.6	[8]

* according to Jackson and Strecker, 1962

Table 4.

Schematic representations of the Kathmandu City Core area with corrected*
trap success figures for each sector division** according to species

- Total -

1	.32	.23	.33	.15
2	.45	.49	.37	.52
3	.28	.52	.33	.56
4	.28	.38	.61	.53
	A	B	C	D

M. MUSCULUS URBANUS

1	.00	.00	.00	.00
2	.00	.06	.03	.00
3	.00	.10	.07	.00
4	.00	.00	.00	.00
	A	B	C	D

R. RATTUS BRUNNEUS

1	.16	.10	.33	.15
2	.18	.34	.30	.33
3	.19	.38	.18	.35
4	.28	.31	.48	.47
	A	B	C	D

S. MURINUS

1	.16	.13	.00	.00
2	.27	.09	.03	.18
3	.09	.03	.07	.22
4	.00	.08	.13	.07
	A	B	C	D

* according to Jackson and Strecker, 1962

** as on a map with North toward the top of the page formula for corrected trap success

$$\text{no. traps} - \left(\frac{\text{no. captures}}{\text{no. disturbed traps}} \right)$$

quarters (NW, NE, SW, SE; four rows; four columns) and tested according to total captures, rat captures, or shrews captures, the differences were not significant with the Chi-square test. Thus, the infestation of the Kathmandu City Core with rats and shrews appears to be rather evenly distributed. The mouse captures, though small in number, were clustered in the center portion of the Core Area. The significance of this can only be made after more animals are captured.

A statistic to be collected in future surveys will be an estimate of the population sizes of the various pest species. Such estimations are always difficult, at best, and are further complicated in the urban situation where Trap Mark-Release programs are not particularly accurate [Emlen, Stocks and Davis, 1949] nor are they ethically desirable. Some form of exhaustive trapping appears to be the best compromise, but in order to reduce errors due to immigration it will be necessary to restrict our trapping to a brief period of about 3 or 4 days [Davis, 1956] especially for attached structures in congested areas. In order to discover what proportion of the population can be collected in the shorter period, census baiting with tracer dyes [Frantz, 1972b; Taylor and Quay, 1972] will be combined with the trapping. This is presently being investigated. More intensive than regular survey trapping, exhaustive trapping employs 2 traps in every room of a site.

From all small-mammal specimens, data is obtained on body weights, length measurements (body, tail, ear and hindfoot), sex ratio, physiological age (sexual maturity), lactation and prevalence of pregnancy and litter size (based on macroscopic embryos in the uterus). This information is particularly useful in estimating the present state in growth of the population under study. For example, Davis (1951) has shown that both increasing and decreasing populations of Norway rats (*R. NORVEGICUS*) have significantly greater prevalences of pregnancy than do stationary populations. The proportion of young animals will be greater in an increasing population than in a decreasing population. Age at sexual maturity (based on weight and/or size at which 50% of the animals have scrotal testes or perforate vaginal orifice) is important because a reduced age at first breeding has a much greater effect on population growth than does a much increased litter size (Davis and Golley, 1963). Comparisons of this sort between different survey areas are necessary in estimating the overall destructive potential of the pest populations. Such data have been collected in this program, but remain to be less analyzed.

Rodent-borne Disease Surveillance

At the present time in Nepal, there are no apparent epidemics or epizootics

related to rodents. However, it is likely that sporadic cases of various diseases but go unnoticed among the usual "fevers" that afflict people here, especially in isolated settlements. The role of the present study in this field can be best described as surveillance of selected potential zoonosis material. The material is collected from trapped animals and distributed to appropriate collaborators for analysis. From heart puncture whole blood specimens are taken as blood spots on filter paper and sera are frozen in a REVCO. The rodent's fur is brushed for ectoparasites which are preserved or kept in an appropriate transport medium. Fecal samples and intestinal worms are preserved in MIF. A sample of diseased organs is preserved in 10% neutral-buffered formalin.

Plague is probably the most outstanding zoonosis reported for Nepal. The first and last reported outbreak was in Oct.-Nov. 1967 in Bajhang District, Western Nepal (Force, et. al., 1971; Stark, Pers. Commun.) Two persons were infected from an acute zootic focus which later resulted in 26 cases, eighteen of which were fatal. No evidence of a rodent epizootic was detected, no survey was apparently made of the rodent population, and no rodent species were identified for the outbreak area. For plague detection in the present study, fleas are taken in 2% saline (with Amphotericin B to discourage mold) and sent to Dr. T.J. Quan (Plague Section, Center for Disease Control, Colorado, U.S.A.) for *YERSINIA PESTIS* isolation attempts. Thus far, bacteriological examinations (by the mouse inoculation test) of all fleas from all specimens collected in Hetaura, Birganj, Kathmandu, Jomosom, and Nauche have proven negative for the plague organism and related agents. Selected blood sera from rats, mice, and shrews of Hetaura, Birganj, Kathmandu and Jharkot have been screened for antibodies to plague; all titres were insignificant.

XENOPSYLLA CHEOPIS (a flea), the most efficient vector of zootic plague has been found on *R. R. BRUNNEUS* in Hetaura and Birganj and on *S. MURINUS* in Birganj. However, in no case was the level of parasitism at the critical transmission index of 2 fleas/animal (Stark, Hudson, and Pittman, 1966) for domestic and commensal rodents. Much of the flea material remains to be identified and has been sent to Dr. R. E. Lewis (Iowa State Univ, U. S. A.), a specialist on fleas. In Worth and Shah (1969), *X. CHEOPIS* was reported from Pokhara (at 910m). *R. R. BRUNNEUS*, *R. T. VICEREX*, and *RATTUS NITIDIS*; on the latter species was also found northeast of Trisuli Bazar (at 1900m). Of the remaining domestic and

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ensal species in Nepal, *M. M. HOMOURUS*, *B. B. BENGALENSIS*, *B. I. NEMORIVAGA* and *S. MURINUS* have been found infected with plague in Asia (Marshall, et. al., 1967; Olson, 1969; Rodenwaldt and Jusatz, 1956). Thus, any of these species may be considered as potential reservoirs for plague in Nepal.

Blood spots of *R. R. BRUNNEUS* and *B. B. BENGALENSIS* from Kathmandu and of *R. T. VICEREX* from Nauche have been analyzed by Dr. D.M. Robinson (U.S. AMRU, Kuala Lumpur) for antibodies to scrub typhus. Six out of fifteen *R. T. VICEREX* had significant, positive titres (IFAT; Gan, Cadigan and Walker, 1972). To our knowledge, this is the first evidence for scrub typhus infection in Nepal. In the Nepal Health Survey, 1965-1966 (Worth and Shah, 1969), the vector for mite-borne typhus, *LEPTOTROMBIDIUM* (*L. DELIENSE*), was widely prevalent at altitudes between 200m and 1450m collected from *SUNCUS* spp. among others; but apparently not from *R. T. VICEREX* or at altitudes of 3440m (Nauche). The vector has been collected from rodents in Sikkim upto an altitude of 3840m (Varma, 1969). Our mite (and tick) specimens remain to be identified and have been forwarded to Dr. H.H. Hoogstraal (U.S. NAMRU-3, CAIRO) for processing. According to Worth and Shah (1969), scrub typhus "would pose a serious threat only to adults (such as tourists without natural immunity acquired in childhood) coming into village areas of high prevalence". Our investigation of this problem continues.

Dr. J. D. Converse (U. S. NAMRU-3, Cairo) has examined, serologically, selected blood spot samples from rats, mice and shrews collected in Kathmandu. Using hemagglutination (HA), hemagglutination inhibition (HI) and complement fixation (CF) tests, these samples have all been found negative for antibody to selected members of the Russian spring-summer encephalitis group viruses, Chobar Gorge virus and Kemerov virus. Additional blood spots and sera are now being processed for these as well as other viruses.

Sera from all of our collections have been given to Dr. S. Pyakural (Central Veterinary Research Lab., Kathmandu) for influenza virus screening. Dr. Anderson (Walter Reed Army Institute of Research, Washington) is screening sera for antibodies to *LEPTOSPIRA ICTEROHEMORRHAGIAE* and other *Leptospira*. No results have been received from these collaborators thus far. A sample of *R. R. BRUNNEUS* sera collected in Kathmandu have been found negative for brucellosis by Dr. D.D. Joshi and Dr. R.R. Shukla of the Central Veterinary Research Lab. in Kathmandu.

Lice preserved in alcohol have been sent to Dr. K.C. Emerson (Dept. Army

Research Washington) for specific identification. Arrangements are also being made for the screening of small mammal fecal samples for helminths or other endoparasites. Preliminary examinations of R.R. BRUNNEUS feces collected in Kathmandu, we have already identified ova of HYMENOLEPIS DIMINUTA (rat tapeworm), H. N. (dwarf tapeworm) and ASCARIS SP. (roundworm). In feces of SUNCUS MURINUS ova of CAPILLARIA SP. and ASCARIS SP. have been found.

As stated earlier, our role in disease work is that of surveillance. Potential zoonosis material has been selected that is relatively easy to collect and process for shipment to collaborators, but that which can also be related to a wide spectrum of diseases. Thus, we will gain some idea of the disease potential of the animals collected and how this might vary between collecting areas. Such data is essential for determining the order of priority for controlling various rodent species. Until now, rodents have not been systematically examined for disease in Nepal.

Study Site Evaluation

In order to evaluate a study area in terms of its active or potential "suitability" for infestation and man/rodent interrelationships, a scheme of inspection and questionnaire is being developed. The structures in both Nauche and Hetaura have been evaluated but the method has recently been revised so these data will be presented in detail at a later date. Basically, an exterior inspection is made for uncovering environmental deficiencies which might be altered, as in environmental rodent control, to improve human living conditions and discourage infestations (Bur. Community Environ. Manage. 1971).

In the Kathmandu City Core, for example, most houses are attached structures. By comparison, only about half of the houses in Nauche are connected to other structures. The attached construction design is probably more conducive (than detached structures) to long-range, protected movements by rodents and could enhance the infestations and the spread of rodent-borne diseases. Structures can also be evaluated from the standpoint of rodent control. The typical house of Nauche is constructed of unmortared stone which provides many rodent entrances between loose-fitting stones. Thus, rat-proofing would probably be more practical and easier in Hetaura where the walls of structures are often made of brick and concrete. In Hetaura, rodents often enter structures through poorly-fitted doors, cracks in foundations, etc.,

of which can be readily altered to prevent rodent passage.

Data from interior inspections further serve the purpose of judging quality of construction and general housing conditions. In addition, it provides information concerning the people's knowledge of their infestation, direct contact between rodents and man (as with rat bites), and relative extent of damage to food and household goods. We also record each study site's approximate size, number of levels and the number and type of rooms. As an example of the kind of data obtained, we can compare people's complaints of pest rodents (from questionnaire) with evidence of infestation (from interior inspection) and capture data (from trapping) in order to learn how accurately people perceive their rodent problems. Data from standard surveys of Hetaura and Nauche are given below:

	<u>Hetaura</u>	<u>Nauche</u>
Complaints	100.0%	84.6%
Corrected Infestation Rate	87.0%	69.6%
Evidence (interior)	83.3%	53.8%

The correlations are relatively good with the estimated infestation rate (based on trapping) being intermediate between the people's complaints (highest estimate) and the indoor evidence (lowest estimate). The latter was particularly difficult to obtain in Nauche because of the complexities of house construction and furnishings, and severe climatic conditions at the time of the survey.

All of these data allow us to give a better estimate of the overall problems with small-mammal pests. Combining these data with that from exhaustive trapping it will be possible to compute the number of rodents per person (or per dwelling unit) which is probably a useful index for comparative evaluations of infestations (Drummond, 1973) on a national or international level. With this information we can make reasonable estimates of the amount of food consumed by the infesting species and, knowing the potential human population in contact with a particular rodent species, some assessment can be made of rodent-borne disease potentials.

It is hoped that this relatively wholistic approach to the study of rodent pest problems will enhance such studies elsewhere in the world, but at the moment we wish to assist Nepal in overcoming the serious depredations attributable to these pests. Our work shows that Nepal already has significant rodent problems and there is a potential for even greater problems because of the rapid expansion of agriculture and

human settlements into former wild habitats in various parts of the country.

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Bibliography

- Abe, H. 1971. Small mammals of central Nepal. J. Fac. Agr. 56 (4): 367-423.
- Arata, A. A., and N.G. Gratz (Pers. Commun.) WHO, Geneva
- Baltazard, M. 1966. Wild and field rodents and their role as vectors and reservoirs of disease, p. 1-8. IN Sem on Rodents and Rodent Ectopar., Geneva 1966. WHO.
- Brown, R.Z. 1967. Biological factors in domestic rodent control. U.S. Dep. Health Educ., Welf., Train. Guide-Rodent Control Ser., Nat. Commun. Div. Cent., Atlanta. 32p.
- Bur. Community Environ. Manage 1971. Status report, urban rat control program 1966-1970 U.S. Dep. Health Educ. Welf/Bur. Community Environ. Manage.
- Chesemore, D.L. 1970. Notes on mammals of southern Nepal. J. Mammal. 51; 166.
- Davis, D.E. 1951. The relation between level of population and pregnancy of Norway rats. Ecology 32 (3): 459 - 461.
- Davis, D.E. 1953. The characteristics of rat populations. Quart. Rev. Biol. 28 (4): 371-401.
- Davis, D.E. 1956. Manual for analysis of rodent populations. Edwards Bros.
- Davis, D.E. and F.B. Golley. 1963. Principles in mammalogy. Reinhold Publ. Corp., New York. 335p.
- Dep. Hous. Phys. Plan 1972. Socio-economic survey -- Kathmandu, Patan, Bhaktapur. HMG Min. Works Transp./Dep. Hous. Phys. Plan Kathmandu. 98p.
- Drummond, D.C. 1973. The role of population ecology in solving urban rodent problems. IN Sci. Group on Ecology and Control of Rodents of Public Health.

- Health Import., Geneva. 1973. WHO.
- Ellerman, J.R. 1961. Rodentia (Part 2), p. 815 - 844, IN M.L. Roonwal (ed.) The fauna of India including Pakistan, Burma and Ceylon Mammalia. Vol. 3. Baptist Miss. Press, Calcutta.
- Emlen, J. T. A.W. Stokes, and D.E. Davis, 1949. Methods for estimating populations of brown rats in urban habitats. Ecology 37 (4): 430 - 442
- Frantz, S.C. 1972a, Behavioral ecology of the Lesser Bandicoot Bat, BANDICOTA BENGALENSIS (Gray) in Calcutta. Ph.D Dissertation, Johns Hopkins Univ., Baltimore. 222p.
- Frantz, S. C. 1972b. Fluorescent pigments for studying movements and home ranges of small mammals. J. Mammal. 53 (1); 219-223.
- Gan, E., F.C. Cadigan, Jr., and J.S. Walker. 1972. Filter paper collection of blood for use in a screening and diagnostic test for scrub typhus using the IFAT. Trans Roy. Soc. Trop. Med. Hyg. 66 (4); 588-593.
- Hodgson, B.H. 1845. On the rats, mice, and shrews of the central region of Nepal. Ann Mag. Natur. Hist. 15; 266-270.
- Jackson, W. B. 1966. Biological and behavioral studies of Norway rat populations as a basis of control, p. 65-67. IN Sem. on Rodents and Rodent Ectoparasites, Geneva. 1966.
- Jackson, W.B., and R.L. Strecker. 1962. Home range studies, p. 113 to 123. IN T.I. Storer (ed.) Pacific island rat ecology. Bernice P. Bishop Mus. Bull. 225: Bernice P. Bishop Mus., Hawaii.
- Laforce, F.M., I L. Acharya, G. Stott, P.S. Brachman, A.F. Kaufman, R.F. Clapp, and N. K. Shah. 1971. Clinical and epidemiological observations on an outbreak of plague in Nepal. Bull. WHO 45; 693 - 706.
- Marshall, J.D., D.V. Quy, F.L. Gibson. T.C. Dung. and D.C. Cavanaugh. 1967. Ecology of plague in Vietnam I. Role of SUNCUS MURINUS. Soc. Exp. Biol. Med., Proc. 124; 1083 - 1086.
- Olson, W.P. 1969. Rat-flea indices, rainfall, and plague outbreaks in Vietnam, with emphasis on the Pleiku area. Amer. J. Trop; Med. Hyg. 18(4): 621- 628.
- Rodenwaldt, E. and H. J. Jusatz (eds.). 1956. World atlas of epidemic diseases. Part III Falk - Verlag, Hamburg. 146p.

- Spillett, J. J. 1968. The ecology of the lesser bandicoot rat in Calcutta. Leaders P. Private Ltd., Bombay 223p.
- Stark, H. E. (Pers. Commun.). Center for Disease Control, Dep. Health, Educ. and W. Ft. Collins, Colo.
- Stark, H. E., B. W. Hudson, and B. Pittman, 1966. Plague epidemiology. U.S. Dep. Health, Educ. and Wel., Atlanta. 115p.
- Taylor, K.D. and R.J. Quay, 1972. An attempt to determine the importance of immigrations in the build-up of a common rat infestation on a farm. Min. Age. Fish. Food (England), Pest Infest. Contr. Lab. Res. Rep. No.2 (ALSO Rodent Res. Rep No. 162). 15p.; 7 tables.
- Varma, R.N. 1969. Survey of the eastern Himalayas for endemicity of scrub typhus. Ind. J. Med. Res. 57(7);1228-1231.
- Weigel, I. 1969. Systematische Übersicht über die Insektenfresser und Nager Nepals. Nebst Bemerkungen zur Tiergeographie. Khambu Himal 3(2): 149-161.
- Worth, R.M. and N.K. Shah. 1969. Nepal health survey 1965-1966. Univ. Hawaii Press, Honolulu. 158p.