MOVEMENT PATTERNS OF THE MONGOOSE IN HAWAII[1]

P. QUENTIN TOMICH, Plague Research Unit, State Department of Health, Honokaa, Hawaii

Abstract: A 3-year study based on 546 small Indian mongooses (*Herpestes auropunctatus*), marked and released in a 30-square mile coastal belt, confirms earlier fragmentary knowledge that this species is highly sedentary. Average moves between successive captures are about 0.25 mile for males and about 0.10 mile for females. Range lengths of males increased with time but seldom exceeded 1.0 mile; those of females seldom exceeded 0.4 mile. Moves as long as 2–5 miles are only rarely detected. These patterns of movement, notably restricted even for a small carnivore, appear to be correlated with an abundance of adequate shelter and a highly omnivorous diet, and suggest a complex social structure that permits extensive overlap of individual ranges.

Studies of movement patterns in the smaller terrestrial mammals have been generally restricted to those on rodents. Carnivores seem to have been neglected because they are difficult to capture and handle and because economic or public health interest in them is generally slight. The small Indian mongoose is locally abundant in the northeastern sector of Hawaii Island, in the Hamakua District, and hence is a favorable subject for intensive study. This species is a generalized viverrid weighing some 350–900 g. It became rapidly adapted to conditions in Hawaii after introduction in 1883, and is of significance in problems of public health, agriculture, and game management (Baldwin et al. 1952, Minette 1964, Meyer et al. 1965, Tomich 1969). The objective of this study was to define several aspects of mongoose movement patterns in order to better understand the relationship of the mongoose to the problem, in the Hamakua District, of plague in fleas, rodents, and man.

Particular thanks are extended to S. Kaaekuahiwi, Jr., for his close attention to details of the field work and for participation in this phase of the study.

METHODS

During a 37-month period from April, 1961, through April, 1964, mongooses were captured, marked with #1 fingerling tags attached to the ears and by a system of clipped toes, and released at the sites of capture. Biological data were obtained from each animal but are not fully considered in this paper. Haas (1966) has reported on collections of the cat flea (*Ctenocephalides felis*) made from these same animals.

The study region extends from the village of Kukuihaele, near the rim of Waipio Valley, for 12 miles southeasterly along the coast to the Kaapahu Homesteads. This region is on the lower slope of Mauna Kea in terrain that supports the cultivation of sugar cane from the precipitous sea cliffs up to an elevation of about 2,000 ft. Pastureland, and some remnant native forest and exotic plantings occur generally above 2,000 ft. Many deep gulches dissect the countryside and some rocky wastelands intermingle with the sugar cane, pastures, and forests. This varied habitat, as well as roadside brush and rank grasses, provides excellent cover for the mongoose.

Seven areas were sampled continuously 4 days each month, for 12–37 months. Traplines were laid out along convenient roads with trap spacing at 0.1-mile intervals, as measured by an automobile odometer. The

[1] Supported in part by Grant AI-02886 from the National Institute of Allergy and Infectious Diseases, C. M. Wheeler, Principal Investigator.

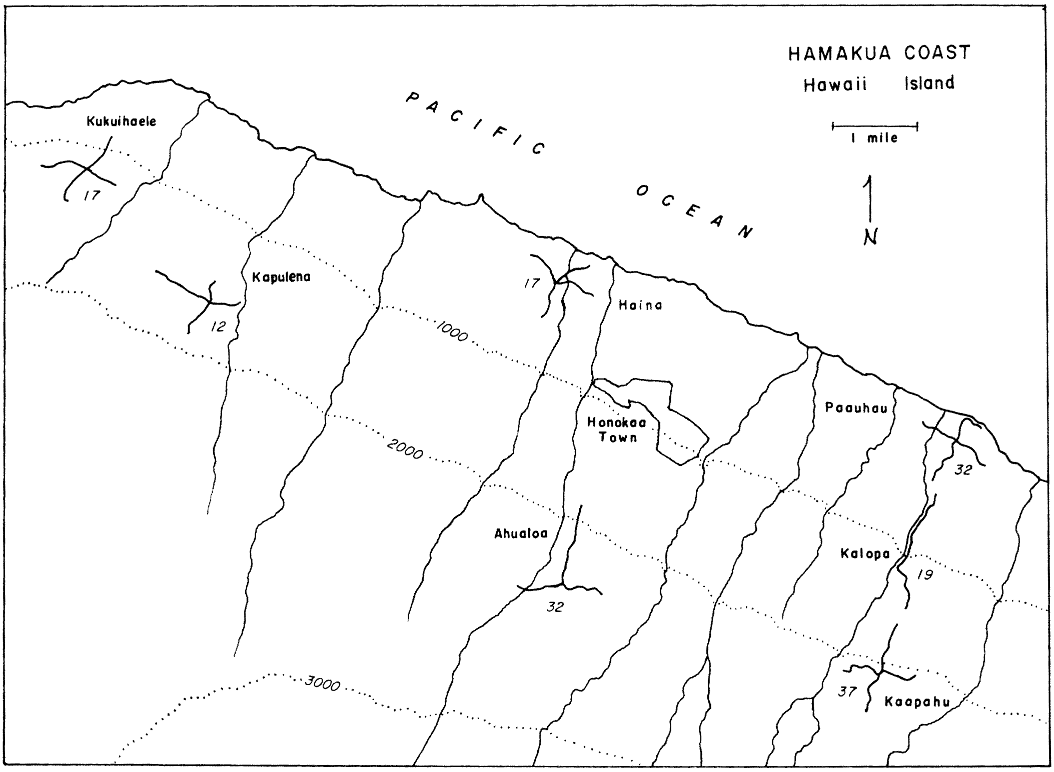

Fig. 1. The study region in Hamakua District, showing topographic features (contour interval is 1,000 ft) and layout of the seven mongoose traplines identified by area or a nearby village. The number near each trapline designates how many months the line was in operation.

plan for each area was to place 21 traps in two 1-mile rows perpendicular to each other and intersecting at the sixth trap. In some areas, road routes dictated a modification of this pattern. However, trap sites were plotted on topographic maps, and this allowed reasonably exact measurement of straight-line distances between traps. Fig. 1 illustrates the character of the study area and the layout of traplines.

Six original lines were 1.6–3.3 miles apart and trap sites ranged in elevation from 120–2,360 ft. The seventh line was laid along Kalopa Gulch to connect the Paauhau and Kaapahu areas when it was realized that few mongooses would move from any one of the six lines to another. Operation of the traps was divided between two crews of two men each. A single trip from the laboratory, at Honokaa near the middle of the region, required 57 miles of driving to reach all 147 traps. We were able to maintain the monthly schedule of trapping, with no interruptions, throughout the period of mark-and-release work.

Traps were of four types: those sold by the National Live Trap Company, which have one or two treadle-released drop doors; a trap we constructed of hardware cloth and wire, with a bait hook and one spring-operated trap-door; and # 0 steel traps. All were satisfactory for capturing the mongoose. Steel traps were used only during removal trapping that followed release trapping. One or two were placed, unbaited, near cage traps to intercept mongooses attempting to reach bait from the side or to dig under.

Several baits were tested, all with similar results, but we soon settled on fresh beef trimmings (chiefly tallow) because these were easily available and kept well in dry as well as wet conditions. Mongooses were handled under light ether anesthesia.

Wilcoxon's rank test was used for all arrays of non-parametric data tested and reported in this paper (Steel and Torrie 1960:402).

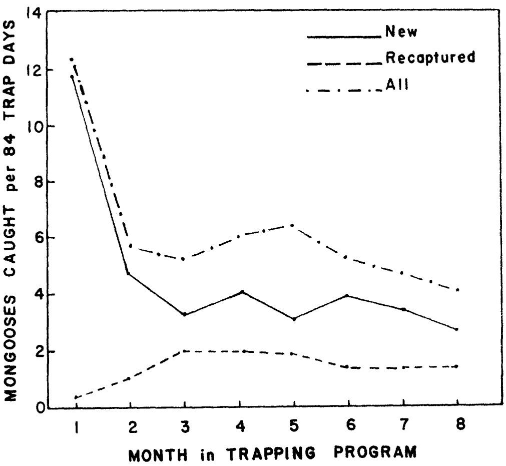

Fig. 2. A composite of trap success in all lines during their first 8 months of operation. Experience in traps is apparently a deterrent to recapture.

RESULTS

Trapping and Handling

Injury or death of mongooses from trapping and handling was slight. None was lost in anesthesia. Five stunted and mangy young animals, each weighing less than 300 g, were found dead or moribund from exposure in traps. Occasional heavy rains that drenched healthy adults, held overnight by traps, appeared to have no ill effect. Another factor causing death or serious injury was entrapment across the cervical or lumbar region by the door of the home-made trap. Five animals died and three others were perhaps fatally injured in this manner. Dogs attacked and killed three mongooses in the traps; one fell on a roadway and was crushed by a motor vehicle. Four, caught by rodent control personnel in their traplines, were killed before it was realized that these were tagged animals.

In the 37 months of regular field operations, 546 mongooses were marked and 861 captures were made during 17,766 trap-days. Thus, one mongoose was caught for each 20.7 trap-days.

It is apparent that some mongooses have little innate wariness toward traps, as reflected in the high rate of trap success in each line established. On our first day in the field, the initial 11 traps examined (at Haina) contained seven mongooses, but this high rate of success was seldom again approached. Wariness is apparently acquired from the experience of being caught. Mongooses frequently scratched and dug the litter and soil about the traps in attempts to reach the bait without entering the traps. The summated data on all lines during their first 8 months of operation (Fig. 2) show that in the first month about one mongoose capture was made for each 7 trap-days, and in the second month this was reduced to one capture for each 14 trap-days. By the eighth month, the figure fell to one capture for each 20 days, which is near the mean for the whole study. It seems likely that many animals in the region encountered the traps more frequently than they were caught. Three lines were begun in April, three in September, and one in October, and this tended to average out seasonal variation in data shown in Fig. 2.

Monthly capture rates are generally unsteady but reveal a pattern that is repeated

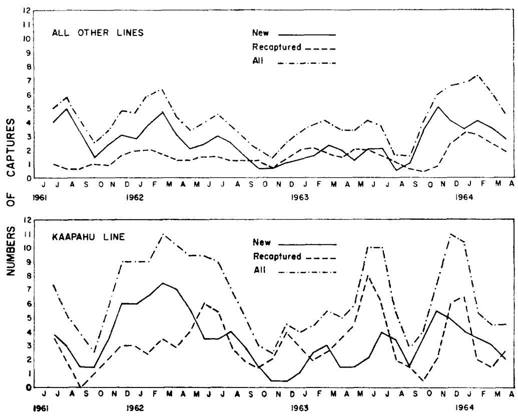

Fig. 3. Seasonal trap success for mongooses during 3 years. Data represent the numbers caught per 84 trap days per month and are smoothed by application of a 2-month moving average. The Kaapahu line was operated 37 months. The six other lines were operated from 12–32 months each and results from them are pooled.

year after year (Fig. 3). The major feature of this pattern is a slump in mongoose captures sometime in the late summer between August and October, in spite of heavy recruitment of young animals fending for themselves. This suggests that such seasonal reduction in catch is behavioral and combines factors in addition to that of avoiding traps. The numbers of new animals caught generally exceeded recaptures. This may result from a long time-lag in the discovery of traps within the individual home range, and from a differential susceptibility to traps in which some mongooses are caught only after a long period, or not at all. There is evidence that the cyclic annual similarities in the patterns of trap success are controlled by factors that affect the mongooses of the entire region. Fig. 3 demonstrates for the Kaapahu area, heavily populated with mongooses, features almost identical to those in the lightly-populated other six areas combined. Synchrony in the curves for new animals is particularly striking. Early summer peaks for recaptures at Kaapahu, however, were more obvious than in other lines. I have been unable to isolate and describe the responsible factors.

The modal class for time between successive captures was 1 month and this class contained 26.4 percent of males and 19.9 percent of females. Animals recaptured within the 4-day trapping period through 3 months made up 62.7 percent of males and 58.0 percent of females. Hence, a large number of animals did contribute to the recapture record within a relatively short time. The mean interval between captures was almost identical in both sexes, 4.5 ± 0.34 months (1 SE) in males ($n = 220$) and 4.5 ± 0.12 months in females ($n = 138$). The maximum interval between successive captures was 31 months for males and 35 months for females, and only 7.7 percent of the males and 5.0 percent of the females were recaptured after 12 or more months.

Of the 546 animals marked, 41.0 percent of the males and 37.8 percent of the females were retaken at least once, and two mongooses were trapped seven times. Nine females and 21 males were repeats (caught more than once in a 4-day period). The returns (caught 1 or more months after the initial capture) consisted of 165 males and 109 females.

The ratio was about six males to four females in all captures, in first captures, in recaptures, and in those caught two or more times in the non-breeding season (Table 1). However, males caught twice or more frequently in the breeding season (January–July) accounted for more than 77 percent of all captures in that period.

Patterns of Movement

The measure of average distance between captures (av. D, Brant 1962) was adopted to express one aspect of mongoose movement, that reflected by successive captures. Zero values ($D = 0$), from recapture in the

Table 1. Sex ratios in various aspects of mongoose-trapping data.

Capture Class	Number and Percent of Captures				
	Males	Percent	Females	Percent	Total
All captures	509	59.1	352	40.9	861
First captures	314	57.5	232	42.5	546
Recaptures	195	61.9	120	38.1	315
More than once in non-breeding season (Aug.–Dec.)	33	57.5	25	43.1	58
More than once in breeding season (Jan.–July)	127	77.4	37	22.6	164

trap of previous capture, are included in the calculations in accordance with Brant's method (1962:126–130). A total of 358 captures supplied measurements of the factor av. *D*. The mean figures of 1,290 ft for males and 484 ft for females indicate a great difference, by sex, in the tendency to move about ($P < 0.01$). The ratio between the sexes in distances moved is 2.7:1. There is a considerable uniformity in av. *D* of each sex, especially for males, by trapline. Although it ranged, for females, from 409–627 ft, none of the pairs was statistically different.

With the lengthening of time between captures, av. *D* tends to increase, and this increase is evident for both sexes (Table 3). The increase is greater for males, as is shown by the generally increasing male/female ratios in the four av. *D* classes ranging from 0–3 months to 15–35 months between captures.

The tendency for a mongoose to return to the trap of previous capture is also marked in both sexes, but is more so in the female (Tables 2 and 3). Of the males, 18.7 percent returned to the trap of previous capture; the figure for females was 41.0 percent. As time increased between captures, fewer males were caught successively in the same trap; the rate of return of females remained about the same regardless of the time factor, which emphasizes attachment of the female to a relatively permanent home area.

For the 21 males and 9 females repeating capture in the 4-day trapping periods, the mean time between captures was 1.67 and 2.33 days, respectively. The males moved an average of 596 ft and the females 518 ft between capture sites. One-third of each sex was caught in the trap of previous capture. No mongoose repeated in August or September when capture rate was generally

Table 2. Average distances between captures (av. *D*)[a] and percentage of recaptures in the trap of previous capture ($D = 0$), for mongooses by trapline and by sex.

Site	Males			Females		
	n	av. *D* (ft)	Percent $D = 0$	*n*	av. *D* (ft)	Percent $D = 0$
Kaapahu	95	1,257	20.2	37	430	55.3
Kalopa	21	1,197	28.6	35	409	40.0
Ahualoa	51	1,395	13.7	24	627	20.8
Paauhau	24	1,412	20.8	22	563	36.4
All Others	29	1,170	13.8	20	460	45.0
Totals	220	1,290	18.7	138	484	41.0

[a] Av. *D* according to Brant 1962.

Table 3. Av. D^a and percentage recapture of mongooses in trap of previous capture ($D = 0$), by sex and by months elapsed between captures.

TIME IN MONTHS	MALES			FEMALES			MALE/FEMALE RATIO OF AV. D
	n	av. D (ft)	Percent $D=0$	n	av. D (ft)	Percent $D=0$	
0–3	139	1,091	22.7	80	474	40.0	2.3:1
4–8	47	1,468	15.6	41	487	47.6	3.0:1
9–14	25	1,540	8.3	12	530	25.0	2.9:1
15–35	9	2,733	0.0	5	612	40.0	4.8:1
Totals	220	1,290	18.7	138	484	41.0	2.7:1

[a] Av. D according to Brant 1962.

low. The fewer female repeats were scattered through much of the year, but 81.0 percent of the males were caught in the 7-month breeding season from January through July. Five male repeats were yearlings, 13 were prime adults, and 3 were aged adults. Hence, these captures appear to be random.

Removal trapping (trap-out), that followed termination of the mark-and-release program, supplemented the information on movement patterns. Mongooses were last marked in the Kaapahu, Paauhau, Ahualoa, and Kalopa lines in April, 1964. During May and June, the first three lines were subjected each to 22 days of removal trapping. The Kalopa line was trapped for a total of 34 days, in April, May, and June, 1964. Ninety-nine marked animals were recovered by this effort. It was anticipated that as mongoose numbers were reduced in the trap-out periods, disruption of the populations might be reflected in the av. D. As no significant differences were found in the trap-out and pre-trap-out figures, all data on av. D were combined for the analyses.

In an attempt to delineate home range in the small Indian mongoose, I have employed the measure, adjusted range length (ARL), proposed by Stickel (1954). This measure is designed to express the individual range by distance between the two most widely separated points of capture. This concept allows for the probability of capture in the next nearest trap as related to the actual site of capture; thus, one-half the distance to the next nearest trap (250 ft in this study) is added to each end of the actual measure. Usual criticisms of this method are that it merely measures responses of the animal to traps in a particular configuration and that it is impossible to adequately compensate for animals taken at the fringes of the trap area compared to those taken near the center of it. In spite of these unpromising limitations, the protracted period of time allowed for this study was a factor highly favorable to reasonable conclusions about the character of home range in this species.

The mean ARL for 128 males, caught two to seven times, was 2,184 ft; for 89 females, caught two to six times, 1,062 ft. Thus, the average range appears to be about 0.40 linear mile for males and 0.20 linear mile for females (Table 4). ARL tended to increase steadily with frequency of capture of males, but such increase was irregular and less for females. The ratio of ARL between sexes also increased with additional captures and demonstrated proportionately increased size of home range, in time, for males.

Only two mongooses were known to have moved between distantly separated traplines. A male, caught in trap 61 at Kaapahu (1,880 ft elevation) in October, 1961, was

Table 4. Adjusted range lengths (ARL)[a] for mongooses, by number of captures and by sex.

No. of captures	Males ($n = 128$)						
	2	3	4	5	6	7	All
n	77	30	12	5	2	2	128
ARL (ft)	1,853	2,484	2,578	2,916	3,609	4,813	2,184
No. of captures	**Females ($n = 89$)**						
	2	3	4	5	6	7	All
n	61	14	11	2	1	0	89
ARL (ft)	975	1,282	1,205	1,236	1,438	–	1,062
Male/female ratio	1.9:1	1.9:1	2.1:1	2.4:1	2.5:1	–	2.1:1

[a] ARL according to Stickel 1954.

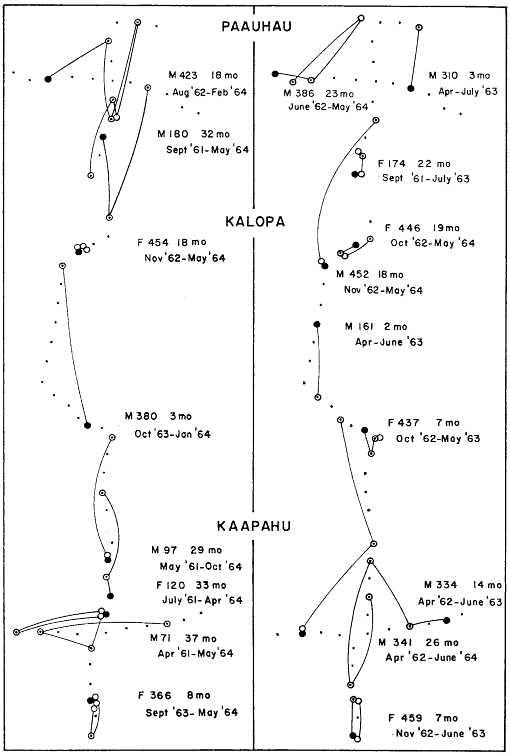

Fig. 4. Examples of mongoose movement and range, as determined by the capture–recapture method, in three of seven areas sampled. Dots represent trap sites; solid circles are sites of first capture, dotted circles represent subsequent captures, except that open circles denote recapture at a site of previous capture (and in one case, a capture outside the regular trapline). Data on each animal appear generally opposite and to the right of the site of first capture. Sex, animal number, length of record in months, and date of first and last capture are given in that order.

retaken after 31 months, in trap 78 at Paauhau, near the sea cliff. The distance between these sites was 2.9 miles. A second male, tagged in the Kapulena line February 13, 1962, was recovered February 27, 1963, at Ahualoa. In 12.5 months, it had moved 5.0 miles to an elevation 800 ft higher than the original site of capture. One of two females caught in June, 1963, at 3,200 ft on the Waimea Plain above Ahualoa (not a part of this study) and released June 28 at Paauhau trap 69, was caught at Ahualoa, July 24, 1963. In the month between release and subsequent capture, it had traveled 4.8 miles in the direction of its original home area. None of these three animals was caught a third time. Fig. 4 illustrates typical patterns of movement obtained during the study.

DISCUSSION

The small Indian mongoose is non-specialized in its feeding habits (Baldwin et al. 1952, Kami 1964), a condition which appears to permit it to thrive in a restricted home area. The male has a body weight 1.4 times that of the female (based on 233 adults from Hamakua District) and this is correlated with the more extensive movement of the male, suggesting that a larger foraging space may be required for its maintenance. It is probable, however, that social as well as nutritional needs contribute to the outline of home range, as they do in other mammals. The apparent overlap of many individual mongoose ranges may preclude a strongly-developed territoriality, although it is uncertain whether or not this species is territorial.

Baldwin et al. (1952:344–345) observed mongooses on Hawaii Island to be sedentary, and that a small group was held at one place for a matter of months by a supplementary food supply. Pimentel (1955: 65–66) summarizes early casual reports of others on range and movement characteristics of *H. auropunctatus* (these were largely speculative) and provides the first substantial field data. He determined in an 18-day mark-and-release program in Puerto Rico, with a grid of traps spaced at 100-ft intervals, that "mean home range diameter" (perhaps the same as "observed range length" of Stickel 1954:4), was 412 ft for males and 267 ft for females. He caught 47 animals a total of 83 times, a high rate of recapture. Continuous exposure of bait and close spacing of traps may have resulted in an underestimate of true home range; yet these data emphasize smallness of the area commonly occupied by this mongoose.

Pimentel's (1955:65–66) data suggest that the 0.1-mile spacing in my work may have been too great for an adequate measure of the female range, and that his 100-ft spacing and grid size of about 1,000 ft on a side, were inadequate for a proper measure of the male range. Clustering of female captures about one, two, or three traps (Fig. 4) during my study tends to support part of this assertion. However, a major value of this project has been the long period worked and the resulting assessment of movement patterns through time. Exposure of the mongooses to baited traps for only 4 days per month almost certainly precluded trap habit, and the mean interval of 4.5 months between captures produced samples of animals that spent generally little time in traps.

Av. D for the 30 mongooses caught twice in the 4-day trapping period (repeats) was 596 ft for 21 males and 518 ft for 9 females. These figures are intermediate between those for animals of each sex recaptured at longer intervals up to 35 months (Table 3). The samples are small and do not permit substantial additional conclusions about av. D.

Adjusted range lengths of males caught three and more times varied from 969–4,981 ft ($n = 21$); range lengths of females with similar trap records varied from 500–2,337 ft ($n = 14$), suggesting that a usual maximum range is approximately 1.0 mile for a male and about 0.4 mile for a female. If one considers the daily range to be about the same as av. D (0.25 mile for a male and 0.10 mile for a female), the maximum range is about four times that of the daily range. Permanent moves from one area to another are probable, and are suggested by some ranges plotted in Fig. 4.

Differences in the patterns of home-range and daily movements are likely in widely divergent ecological settings and could contribute to differences in results of various studies. However, it seems beyond dispute that the small Indian mongoose is generally a sedentary mammal and rarely disperses. Based on the single example of a displaced female, we may surmise that it may have a strong homing instinct. Vagrants are rarely identified; perhaps they are uncommon, else more examples of movement between traplines would have been detected.

The mark-and-release technique for studies of animal movement is currently on the defensive as more sophisticated methods become generally available (Sanderson 1966). Nevertheless, it seems reasonable to conclude that the present study was justified, and that certain data, particularly those accrued from time in years, could have been obtained in no other practical way.

LITERATURE CITED

BALDWIN, P. H., C. W. SCHWARTZ, AND ELIZABETH REEDER SCHWARTZ. 1952. Life history and economic status of the mongoose in Hawaii. J. Mammal. 33(3):335–356.

BRANT, D. H. 1962. Measures of the movements and population densities of small rodents. Univ. California Publ. Zool. 62(2):105–184.

HAAS, G. E. 1966. Cat flea–mongoose relationships in Hawaii. J. Med. Entomol. 2(4):321–326.

KAMI, H. T. 1964. Foods of the mongoose in the Hamakua District, Hawaii. Zoonoses Research 3(3):165–170.

MEYER, K. F., D. MCNEILL, AND C. M. WHEELER. 1965. Results of a preliminary serological survey of small mammal populations for plague on the Island of Hawaii. World Health Organization Bull. 33(6):809–815.

MINETTE, H. P. 1964. Leptospirosis in rodents and mongooses on the Island of Hawaii. Am. J. Trop. Med. and Hyg. 13(6):826–832.

PIMENTEL, D. 1955. Biology of the Indian mongoose in Puerto Rico. J. Mammal. 36(1):62–68.

SANDERSON, G. C. 1966. The study of mammal movements—a review. J. Wildl. Mgmt. 30 (1):215–235.

STEEL, R. G. D., AND J. H. TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481pp.

STICKEL, LUCILLE F. 1954. A comparison of certain methods of measuring ranges of small mammals. J. Mammal. 35(1):1–15.

TOMICH, P. Q. 1969. Mammals in Hawaii: a synopsis and notational bibliography. Bishop Museum Press, Honolulu. 238pp.

Received for publication December 11, 1968.

TIME-SPECIFIC TRACER TO INDICATE BAIT ACCEPTANCE BY SMALL MAMMALS

ROGER D. NASS, Bureau of Sport Fisheries and Wildlife, Denver, Colorado[1]
GLENN A. HOOD, Bureau of Sport Fisheries and Wildlife, Denver, Colorado[1]

Abstract: Tests were conducted to find a tracer that would indicate whether small mammals had eaten treated bait within a 24-hour period. A nontoxic acid-base indicator, Bromcresol Green (3,3′,5,5′-tetrabromo-*m*-cresolsulfonephthalein) was satisfactory. In the laboratory, grain treated with Bromcresol Green was well accepted by *Peromyscus maniculatus*, *Microtus ochrogaster*, and *M. pennsylvanicus*; predictable areas of the animals' gastrointestinal tracts were colored by the tracer during the first 18 hours after ingestion but were devoid of color by 24 hours. In the field, acceptance of dye-treated bait by 729 animals of five species ranged from 88.5 percent on the 3rd day after baiting to 43.8 percent on the 11th day. The apparent decline in acceptance may have been due to fading of the tracer or to a decrease in palatability of the bait. Decomposition of Bromcresol Green on grain from weathering was found to be delayed by overcoating it with Uvinul 490,[2] an ultraviolet filter.

Results of field experiments with baits for small-mammal control are often difficult to interpret because methods are lacking to evaluate the proportion of the population accepting bait, the amount of bait consumed, and the period of time during which feeding occurs from a single baiting. These factors become increasingly important with materials such as reproductive inhibitors and anticoagulants, which require more than one feeding.

[1] Present address: Bureau of Sport Fisheries and Wildlife, Box 244, Hilo, Hawaii.

[2] Antara Chemicals, N.Y. Use of trade names in this publication does not imply government endorsement of commercial products.