

## Movements and Home Ranges of Polynesian Rats in Hawaiian Sugarcane<sup>1</sup>

ROGER D. NASS<sup>2</sup>

**ABSTRACT:** Fifty-seven Polynesian rats (*Rattus exulans*), equipped with transmitters, were monitored in sugarcane fields and neighboring wastelands at various seasons so that a better understanding of crop damage by rats might be obtained. Linear movements for males were longer than for females, longer in winter than in summer, and longer in young sugarcane than in mature sugarcane. Rats with burrows in wastelands moved greater distances than did rats with burrows in sugarcane fields. Estimated home range size (mean, 1845 square meters for males and 607 square meters for females) tended to increase with more observations, and most elliptical home ranges in wastelands were oriented toward the fields. Rats with wasteland burrows were found in fields during 57 percent of the observations, but field residents were found in the wastelands during only 1 percent of the observations.

POLYNESIAN RATS damage sugarcane, macadamia nuts, coffee, and other agricultural products in Hawaii (Pemberton 1925, Doty 1945, Hood 1968) and on many islands of the south Pacific Ocean (Wilson 1968, Wodzicki 1968). Historically, damage-reduction techniques and methodology in these areas have been hampered or misdirected because essential ecological data about the rats were lacking (Tomich and Haas 1966, Smith 1968). As Sanderson (1966) has pointed out, an adequate knowledge of movements is necessary for control programs. I conducted this study of Polynesian rat movements in and around sugarcane fields to obtain some of the basic data necessary to better understand rats in relation to crop damage.

Although movements of Polynesian rats have been investigated by trap-retrap methods (Spencer and Davis 1950, Kartman and Loneragan 1955, Smythe 1967, Tomich 1970, Tamarin and Malecha 1971), the use of radiotelemetry enables the investigator to explore certain parameters that escape detection by conventional means. Biased data from traps and traplines are well known (Hayne 1950, Sealander and James 1958, Sealander

et al. 1958, Justice 1961, Adams and Davis 1967) as is bias from the various attempts by investigators to define movements and home ranges by circles, centers of activity, adjusted range lengths, and other methods (Hayne 1949; Stickel 1954, 1965; Calhoun and Casby 1958; Harrison 1958). Problems also arise with telemetry; Heezen and Tester (1967) listed some of the possible errors involved in triangulation alone. For this study, the disadvantages of radiotelemetry—small sample size, possible location errors, and the risk of faulty transmitters—appeared to be outweighed by the advantages of more telemetric observations per rat, known burrow locations, and known locations of rats in inaccessible terrain.

### METHODS

One field of the Puna Sugar Company, Keaau, Hawaii, and five fields of the Mauna Kea Sugar Company near Hilo, Hawaii, were used during this study. They ranged from 25 to 57 hectares, and all had adjacent waste areas—usually heavily vegetated deep gulches that ran perpendicular to the ocean shoreline. Dominant wasteland vegetation included guava (*Psidium guajava*), banana (*Musa* sp.), melastoma (*Melastoma mala-*

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<sup>2</sup> United States Fish and Wildlife Service, Wildlife Research Station, Post Office Box 593, Twin Falls, Idaho 83301.

*bathrium*), and California grass (*Panicum purpurascens*) as well as wild sugarcane in all stages of growth. Warm weather and high rainfall characterize this semitropical area.

Rats were captured by wire-cage-type live traps in or at the edge of cultivated sugarcane that was 1–22 months old. Rats were taken to the laboratory, fitted with 4-gram transmitters, and released at capture points. Transmitters were attached by soldering the copper antenna ends together around the animals' necks. Transmitter life expectancy was about 35 days, and signals were monitored until batteries failed. The basic circuitry of the transmitters was similar to that reported by Dodge and Church (1965), although antennas and layout were modified as smaller components became available. Signals were monitored with lightweight directional receivers, a Cochran D-11, and a modified Johnson Messenger 350 D/F (use of trade name does not imply endorsement of commercial products by the federal government). I occasionally used a vehicle-mounted R-388/VRR military receiver to search for and verify weak signals. The portable receivers were capable of monitoring signals from the tiny transmitters up to 0.8 kilometer line-of-sight, although practical field ranges were considerably less. Triangulation errors with stationary transmitters were within 1 m at a range of 100 m.

From 6 to 18 rats were monitored during each combination of season and sugarcane age: winter (October–March), summer (April–September), young sugarcane (0–12 months), and mature sugarcane (13–24 months). Rat locations were determined by triangulation from roads, field-edge trails, and paths through the sugarcane fields. These were plotted on suitable map overlays; linear distances from burrows were measured; and home ranges were determined by connecting the outermost points (Storm 1965). Monitoring periods were adjusted to include all hours from dusk to dawn and all conditions from darkness to bright moonlight and from dry weather to torrential downpour. Locations of five to seven rats could usually be plotted within 1 hour. Actual monitoring frequencies were dependent upon distance between rats,

nature of terrain, and layout of roads or trails in a specific field. I made frequent daytime checks to determine diurnal movements and to locate burrows. Precipitation, moon phase, temperature, and wind velocity were recorded for all animal locations.

## RESULTS

In addition to Polynesian rats, roof rats (*Rattus rattus*), and Norway rats (*R. norvegicus*) were caught in all of the fields, and house mice (*Mus musculus*) were caught in three fields. Of 716 rodents trapped, 562 (78 percent) were Polynesian rats, 91 (13 percent) were black rats, 42 (6 percent) were house mice, and 21 (3 percent) were Norway rats. I did not attempt to estimate population densities in the various fields from trap success data, because the sample sizes from several fields were too small for valid comparison. Season and age of sugarcane are two of the principal factors associated with population densities of rats in sugarcane (Hood, Nass, and Lindsey 1970; Tomich 1970).

Of 93 Polynesian rats fitted with transmitters, adequate data for analyses were obtained from 57 rats (40–101 g) that were monitored for periods of 5–22 days. Altogether, 1210 locations (telemetric observations) were determined for these 57 rats, 694 for 29 males (23.9 per rat), and 516 for 28 females (18.4 per rat).

Typically, rats left their burrows at dusk and slowly moved to preferred parts of the field or waste area, where they stayed most of the night. In the early morning hours, they began moving back and by dawn were again underground in their burrows, where they remained inactive during daylight. Diurnal movement was recorded only twice. Preferred areas were not necessarily those closest to home. Rats with gulch burrows immediately adjacent to sugarcane often frequented sugarcane that was several hundred feet farther away. Activity patterns for specific periods between dusk and dawn apparently were not related to rainfall, moon phase, temperature, or wind velocity, even though extreme ranges of these conditions occurred during monitor-

TABLE 1

PERCENTAGE OF POLYNESIAN RAT LOCATIONS OBTAINED BY TELEMETRY AT VARIOUS DISTANCES FROM THE HOME BURROW

SEASON OR BURROW LOCATION	CANE AGE (MONTHS)	N	MALES				DISTANCE FROM BURROW (METERS)				ALL RATS			
			0-15	0-60	0-120		N	0-15	0-60	0-120	N	0-15	0-60	0-120
Summer	0-12	7	21	74	96		11	56	92	100	18	41	84	97
	13-24	2	27	100	100		4	34	100	100	6	31	100	100
	0-24	9	22	79	96		15	50	94	100	24	39	88	98
Winter	0-12	10	13	60	87		7	38	96	100	17	21	71	90
	13-24	10	44	83	94		6	60	98	100	16	49	89	98
	0-24	20	27	70	89		13	48	95	100	33	34	79	94
Year-Round	0-12	17	16	65	89		18	49	94	100	35	31	77	94
	13-24	12	41	85	94		10	49	99	100	22	40	94	97
	0-24	29	26	73	91		28	49	95	100	57	36	83	96
Wasteland Burrows	0-24	14	9	60	87		15	40	92	100	29	23	74	93
Canefield Burrows	0-24	15	46	90	98		13	62	100	100	28	52	93	98

ing of individual rats. Rats monitored during severe weather moved within their preferred areas just as they did under average conditions.

#### *Distances Moved*

Males moved greater distances than did females (Table 1), a characteristic common to many other mammalian species. Male rats were found within 30 m of their burrows 47 percent of the time; females, 76 percent of the time. Maximum movements were 317 m for a male and 99 m for a female. Males tended to move somewhat farther from their burrows in winter than in summer and considerably farther in young sugarcane than in mature sugarcane; females did not show these differences.

In mature sugarcane, 72 percent of all observations were within 30 m of the rats' burrows and only 5 percent were beyond 60 m; in young sugarcane, 52 percent of the observations were within 30 m and 23 percent were beyond 60 m. In mature cane, rats typically stayed close to their burrows. For example, 18 of 22 observations for a 62-g male in 16-month-old cane were within 15 m of his burrow and the other 4 were within

30 m. Heavier males tended to move greater distances; however, one 89-gram male confined his travels to an area within 21.3 m of his burrow.

Typical movement patterns in young cane were strikingly different from those in mature cane. For example, 30 of 37 observations for a 62-g lactating female were beyond 30 m from her gulch burrow; 29 were in 7-month-old sugarcane up to 73.1 m away. Of 72 observations of a 63-gram male, 49 were in young cane 30 m or more from his gulch burrow; he was monitored over 90 m from his burrow on five occasions.

#### *Habitat Preference*

Differences in movement patterns were evident between rats with burrows in waste areas and those with burrows in the sugarcane fields (Table 1). Rats from gulch burrows were monitored within 30 m of their burrows during 43 percent of the observations, but canefield rats were within 30 m during 81 percent of the observations.

Seventy-five percent of all observations occurred in the cane fields, even though rats generally do not have burrows in cane fields for about the first 8 months of the crop cycle.

TABLE 2

AMOUNT OF TIME POLYNESIAN RATS SPENT IN WASTELANDS AND SUGARCANE FIELDS, AS DETERMINED BY TELEMETRY OBSERVATIONS

SEASON OR BURROW LOCATION	CANE AGE (MONTHS)	NUMBER OF RATS	MEAN NUMBER OF OBSERVATIONS PER RAT	% OF OBSERVATIONS IN WASTELAND      CANEFIELD	
Summer	0-12	18	19	34	66
	13-24	6	21	7	93
	0-24	24	19	27	73
Winter	0-12	17	24	34	66
	13-24	16	22	11	89
	0-24	33	23	24	76
Year-Round	0-12	35	21	34	66
	13-24	22	21	10	90
	0-24	57	21	25	75
Wasteland Burrows	0-24	29	24	43	57
Canefield Burrows	0-24	28	19	1	99

Of these field observations, 57 percent were for gulch burrow rats and 99 percent were for canefield rats (Table 2). The rats spent considerable time in the fields, regardless of season or cane age.

A 58-g female with a burrow in 10-month-old cane was monitored in the cane field 30 times during an 8-day period; she was never found in the adjacent gulch area. Although she traveled 48.8 m on one occasion, her activities were usually confined to within 22.9 m of her burrow. Another example of a canefield resident that never left the field was a 72-g male monitored 31 times in 12 days; he was usually found within 57.9 m of his burrow, although he did move a maximum of 115.8 m. Another male had a burrow in the gulch; however, 20 of 30 observations showed extensive movements in the cane field, even though the sugarcane was 16 months old. His maximum movement was 146.3 m, but 70 percent of the observations were within 120 m of his gulch burrow.

Most steep gulches have intermittent or continuous water courses, but rocks, logs, and vegetation provide numerous crossing areas. Nevertheless, rats were never monitored on the opposite side of the gulch bottoms. The interaction between rat populations of opposing slopes of gulches may be

so limited that many gulches may actually contain two distinct populations.

### *Home Ranges*

Even though linear movements and square footage of home range are both used to measure animal travels, these two measurements cannot be indiscriminately interchanged. An animal with its burrow at the midpoint along one side of a square home range, 10 units per side, could show a maximum linear movement of about 11 units. Another animal, its burrow at the midpoint of one end of a rectangular home range,  $5 \times 20$  units, could show a maximum movement of about 20.25 units. Yet both home ranges would encompass the same area (100 square units).

Mean home range size, sexes combined, was 1237 m. Jackson and Strecker (1962) found larger home ranges for Polynesian rats in grassland on Ponape (mean, 1618.2 square m), but Smythe (1967) found considerably smaller home ranges for Polynesian rats in a Hawaiian macadamia orchard (mean, about 279 square m). A 68-g rat had the largest home range for males, and two others (40- and 75-g) had the smallest home range. Mean home range sizes for seven lactating and two pregnant rats were 645 and 619 square m,

TABLE 3  
HOME RANGE SIZES OF POLYNESIAN RATS DETERMINED BY TELEMETRY OBSERVATIONS

BURROW LOCATION	SEX	NUMBER OF RATS	MEAN NUMBER OF OBSERVATIONS PER RAT	MEAN WEIGHT OF RATS (GRAMS)	HOME RANGE SIZE (SQUARE METERS)	
					MEAN	RANGE
Wasteland	Males	14	27.4	66.5	2501	85–12170
	Females	15	20.3	74.3	669	11– 1752
Cane field	Males	15	20.7	75.3	1229	170– 2542
	Females	13	16.3	65.0	532	97– 1825
All locations	Males	29	23.9	70.7	1843	85–12170
	Pregnant females	2	24.0	95.5	619	523– 712
	Lactating females	8	18.5	68.8	645	59– 1752
	All females	28	18.4	70.0	615	11– 182

respectively, suggesting no significant reduction in range with change in reproductive status (Table 3).

To determine if number of observations significantly influenced estimates of home range size, I calculated least-squares regression equations for the number of observations against home range in square meters for the categories of sex and burrow location and made one-tailed tests against the null hypotheses that the regression coefficient was equal to zero. The hypothesis was rejected ( $P < 0.01$ ) for four of the six categories: all males ( $r = 0.67$ ), all females ( $r = 0.59$ ), females with burrows in sugarcane ( $r = 0.82$ ), and males with burrows in gulches ( $r = 0.70$ ). Jackson and Strecker (1962), working with Polynesian rats on Ponape, also found that estimated home range size increased as the number of recaptures increased. Although Tomich's (1970) data related increased movements (average distance between captures) of Hawaiian Polynesian rats to time (subsequent recaptures in succeeding months), my data indicated that the number of observations was more significant than the time period.

Because heavier males appeared to move farther from their burrows than other rats, regression equations also were calculated for weights of rats against square footage of home range. No significant differences were found, either for males or females.

Like linear movements, mean size of home ranges for males and females was considerably different between rats with gulch burrows and rats with canefield burrows (Table 3). However, one-way analysis of variance showed no significant differences ( $P < 0.10$ ) in home range size for gulch males versus canefield males, gulch females versus canefield females, or for all gulch rats versus all canefield rats.

Differences in home range shape occurred between rats with gulch burrows and those with canefield burrows. Of the 57 rats, 17 (30 percent) had circular home ranges and 40 (70 percent) had elliptical home ranges. Fourteen (82 percent) of the circular home ranges belonged to canefield rats and 26 (65 percent) of the elliptical home ranges belonged to gulch rats. Burrows were located at the edges of 11 circular and 37 elliptical home ranges. Burrows were found in the approximate center of the remaining six circular and three elliptical ranges; eight of these nine (89 percent) were in the sugarcane fields.

#### DISCUSSION AND CONCLUSIONS

A sugarcane field is evidently a desirable place for rats to live or to visit for long periods. Even though the adjacent wastelands provide a stable habitat, and thus allow for a population nucleus to invade subsequent

sugarcane crops (Doty 1945; Hood, Nass, and Lindsey 1970; Hood et al. 1971), the wasteland rats appear to prefer the cane fields.

Because rat populations in gulches near young sugarcane usually are relatively low (Tomich 1970; Nass, Hood, and Lindsey 1971a), pressures from an expanding population would not seem to be responsible for these extensive travels into the fields. However, in older sugarcane (midterm or later), after the overall field edge-wasteland population has increased because of the food and cover afforded by the maturing sugarcane, movements may be influenced by population pressures.

The supply of desirable food is probably the major factor influencing rat movements into cane fields, both when the sugarcane is young and when it is mature. In young sugarcane, the plant itself is probably not the attractant. Hood et al. (1971) showed that most fields 6 months old or less have not yet sustained any rat damage, and Nass, Hood, and Lindsey (1971b) and Lindsey et al. (1973) found rats traveling in young sugarcane where damage was minor or absent. This has also been found in unpublished studies at this station through the use of live traps, snap traps, activity boards, and radio tracking in young sugarcane. Kami (1966) found that sugarcane predominated, both in frequency and volume, in stomachs of Polynesian rats trapped in both fields and gulches, but he did not differentiate between young and old sugarcane. Many waste areas have wild sugarcane in all stages of growth, so resident rats in these areas would have access to mature cane at all times even if adjacent sugarcane were too young to be attractive.

Insects and other invertebrates are abundant in young sugarcane and may be the prime encouragement for rat movements into the fields at this time, even though Kami (1966) found only a 17.1 percent average frequency of occurrence in rats' stomachs throughout the crop cycle. Because the bare ground under the young sugarcane canopy is easy for the rats to traverse, insect and other invertebrate foods probably yield a high return of nutrients for the effort expended.

As the crop matures, the abundant and readily available stalks of cane, added to the

increasing invertebrate populations, provide a tremendous increase in the food supply, and gulch rats remain attracted to the field. Rats that have access to mature sugarcane will consume large quantities (Kami 1966), even though the digestibility of cane pith is low (Garrison and Breidenstein 1970), but they cannot survive on a diet of sugarcane and water alone (Caum 1922).

During the past decade, especially since the use of radiotelemetry has become common, biologists have attempted to find out why animals are in a particular place rather than to emphasize the shape of the home ranges (Sanderson 1966). However, home range shape may also provide pertinent information. Stumpf and Mohr (1962) pointed out that "linear" home ranges are common among small mammals and advanced several reasons to explain this elongated shape.

They suggested that "the less satisfactory that the home area is the longer and narrower the home range or territory may be." Seventy percent of the rats in this study had elliptical (i.e., linear) home ranges. The fact that nearly all of the elliptical home ranges of gulch rats had the long axis oriented toward the field suggests that rats do indeed find sugarcane fields attractive places to forage. Nass, Hood, and Lindsey (1971b) found evidence that many rats living in the field seldom visit the gulch edge. The circular home ranges of 50 percent of the canefield rats in this study suggest that they could find suitable food in any direction and within a smaller area.

Burrow or den location is rarely mentioned in animal movement studies, because it is an unknown when traps are used to determine movements, home range boundaries, or home range areas. I believe that the burrow is an important starting point for the researcher who is attempting to describe the movements or home range of an animal that returns to the same burrow each day or night.

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