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The Engebi Rats — Another Chapter

William B. Jackson

Bowling Green State University

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The story of rats at Eniwetok and their apparently uncanny ability to survive atomic detonations and inhabit areas with high levels of radiation has always focused on Engebi islet. The most available source of information has been the book, Proving Ground (Hines, 1962), which was in turn derived from reports of the Laboratory of Radiation Biology (LRB), University of Washington, as well as from other laboratory and government sources.

References to Eniwetok rats have appeared in various documents in the last few years (Hines, 1966; French, 1965; Woodbury, 1962); all are to some degree incomplete or in error. The purpose of this paper is to pull together the fragments of data that are available and, at this late date, attempt to piece together the Engebi rat story.

Historical Background

While specific records are lacking, I believe that the only rodent at Eniwetok Atoll prior to the initiation of the AEC program in 1946 was the Polynesian rat (Rattus exulans). This is the common rat of the Pacific islands, having moved with the Micronesians from island to island. Probably only the larger islets of the atoll (those with coconut plantings) were infested. No specimens or recorded observations from Eniwetok Atoll are known to exist from this early period.

Prior to the first test a biological survey occurred, and J.P.E. Morrison (pers. comm.) has indicated that in 1946 when he visited Eniwetok he

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saw only Polynesian rats — on one islet (Igurin) on which he camped overnight. His observations at Bikini Atoll the same year were much more extensive. Though he observed rats on a number of islets there, he indicated that all were Polynesian rats. I have examined five specimens, each collected on a ^{different} ~~separate~~ islet, in the National Museum and concur in the identification.

A similar, mono-specific rodent infestation can be cited for other relatively isolated areas in Micronesia prior to WWII or the post-war period. Thus it seems reasonable to conclude that only Polynesian rats were present at Eniwetok prior to 1946.

That an alternative hypothesis can be developed must be admitted. The Japanese had extensive fortifications at Eniwetok, largely on Engebi, Eniwetok, and Parry islets (Fig. 1). In 1944 more than 3500 troops and laborers were related to an air strip on Engebi; Micronesians were restricted to the Biijiri, Aomen, Rojoa complex (Hines, 1962, P. 84). Elsewhere in the Pacific, Japanese occupation on occasion brought with it the roof rat (Johnson, 1962); this possibility cannot be excluded here. However, the roof rat populations now present at Eniwetok and the Marshalls as a unit are morphologically similar to the roof rat of the western world rather than to subspecies of the Asian mainland or western Pacific (Johnson, pers. comm.). While post-war invasions of western roof rats could have swamped and replaced earlier introductions, this seems unlikely, based on interactions between the two subspecific groups in the Carolines (Johnson, 1962).

During the Japanese occupancy a major air field installation was constructed on Engebi. As a result, the islet was largely denuded, though a palm grove covering nearly one-sixth of the islet remained near its center; and some palms and/or second growth vegetation along the lagoon shore and the NW tip of the islet appear in war-period photographs. Though some palms remained standing after the invasion, much of the vegetation was badly shattered (Bryan, 1944). Thus rat habitat was relatively limited.

In the early test years, no specific observations of Eniwetok rats can be found, though reference is made to a collection of rats on Engebi in 1948 and 1949 (Hines, 1962, p. 106). ~~During this period considerable construction occurred on Engebi and included living quarters for 1400 men.~~

During the Sandstone series in 1948 one low yield device was exploded on Engebi on April 15 from a 200 ft tower. At H + 1 day the gamma radiation in the islet center was estimated roughly at 12 R/hr; the accumulated dose at H + 1 yr, 132 R (LRB). Following the test, no exposed vegetation remained standing. Of the 43 plant species recorded from Engebi prior to the test, only 20 were not exterminated by the blast (St. John, 1950).

The Greenhouse tests in 1951 on Engebi (2 detonations) produced an initial gamma radiation of 6,400-10,000 R in the islet center (Hines, 1962, p. 210). At H + 1 yr the accumulated dose was 44 R. But the Polynesian rats apparently continued to exist on Engebi, though rats close to the detonation site likely were killed.

Probably about this time the roof rat (R. rattus) was introduced. It may have arrived a few years earlier at the main supply areas of the atoll on ships from the United States or from other areas of the Marshalls where it was abundant. But we have no specific records or observations, so this ^{statement} must be considered conjecture.

In 1952 in preparation for the Mike shot (Ivy series)), rats on Engebi were collected; no radioactivity in their bones was found (Hines, 1962, p. 151), though slight activity occurred in other tissues (UWFL-33). Rats were also collected on Biiijiri and Rojōa. All individuals were referred to as Polynesian rats. However, the single Engebi rat recorded (UWFL-33) was obviously not a Polynesian rat. Its weight (175 gm) was too great; in all probability it was a roof rat. Rats from the other two islets were most likely Polynesian rats, based on their weights (82 gm or less).

A thermonuclear device exploded on November 1 formed Mike crater on the former site of Elugelab and Teiteiripucchi islets, 3 miles from Engebi. On November 8, no living animals were seen on Engebi; rats, ill and lethargic, were found on Biijiri. On November 10 six rats were found in traps on Rojoa that had been set on November 7 and had been empty on November 8. These two islets are approximately 9 miles from Mike crater. (No size data appear to have been recorded for these specimens; the presumption is that they were all Polynesian rats.)

The gamma dose rate on Engebi at H + 1 day was 1000 R/hr; the accumulated dose at H + 1 yr, 11,000 R. (At Biijiri the annual accumulated dose was 1440 R.) The shot caused a tidal wave over Engebi, and only stumps of vegetation remained. Islets 14 miles from Mike crater had visible effects.

Many ^{observers} supposed that rats on Engebi had been wiped out by the combined effects of the 1952 test. But in 1954 rats were found on Engebi. This has led to prolonged speculation (Hines, 1962, p. 207-210). That the Polynesian rat was indeed exterminated by the thermonuclear test is a possibility. Roof rats perhaps survived, and their numbers may have been later supplemented by individuals on the supply boats traveling to Engebi.

LRB records give weights for 75 rats (identified as Polynesian rats) collected on Engebi in 1954. Seventy-one of these were surely roof rats, as the animals were far too big (weight) to be Polynesian rats; four were small enough and no sexual maturity data were given, so that no certain designation is possible. A poorly preserved remnant of one of the larger rats has been examined, and it surely was a roof rat.

During the pre-Nectar period in 1954 considerable transportation of rats (all termed Polynesian rats) from Engebi to adjoining islets occurred. Some 53 rats were involved, and the investigator (Barnes, LRB) records in his field notes that some of the rats on Engebi were of a "new gray species." This

could be taken to indicate that two rat species were present at this time. I prefer to discount this hypothesis, since the measurements plus two photographs of rats (identified as Polynesian) show them quite clearly to be roof rats.

No weights or other data from the "gray species" have been found.

Following the Nectar detonation of Castle series on May 13 in Mike crater, five rats from Engebi (N + 3 days) and 12 rats from Arambiru (N + 4 days) were transported to Bogombogo. On N + 7 days eight rats were caught on Engebi and transplanted to Bogombogo. No further notes were made about their survival, and no rats have subsequently been trapped on this islet. On the same day (N + 7), five rats that had severe radiation burns were captured on Engebi and returned to the laboratory for processing (LRB, Barnes). No rat collections were made after N + 7 days until September and October, 1954, when six specimens (all of roof rat weight) were logged. Gamma radiation on Engebi on H + 1 day was 10.7 R/hr; H + 1 yr, 118 R (accumulated).

In 1955 rats (termed Polynesian) were reported present on Engebi in tremendous numbers (Hines, 1962, p. 210). Pictures taken of 8 rats in 1957 show all individuals to be roof rats. The first complete specimens of Engebi rats that we have been able to find were five animals (originally identified as Polynesian) collected in 1959 by LRB. These are now in our possession and are quite clearly roof rats. Our field studies on Engebi in 1964, 1965, and 1966 have shown through extensive trapping on the islet that only the roof rat is now present.

Analysis of Rat Species

For a non-mammalogist, the distinction between these two rat species is not easy. Some differences in size and body and tail proportions exist; behavioral aspects may provide a clue, but the pelages may look amazingly alike. It would be very easy for an individual who was not looking for species differences to be unaware of the problem. No mammalogists were involved in any of

the field surveys; and no one, based on field notes, correspondence, and conversations (with the exception of Morrison) was aware of the rodent species which might be expected at Eniwetok. They all quite clearly expected to find the Polynesian rat, and they did!

I propose that this misidentification has seriously clouded the picture. Without adequate records and specimens, we can only guess as to the history. In all probability the Polynesian rat was exterminated by the Mike test in 1952. Based on a single record, we can hypothesize that the roof rat had been introduced to Engebi prior to the 1952 Mike test. Had it been exterminated, the only source of this species on the atoll would have been Eniwetok and Parry and perhaps Biijiri and Runit Islets, so natural invasion by swimming was not a possibility. Currents surrounding Engebi are such that rats could not have crossed from adjoining islets, even if those islets had had rats. Exposed reefs, even at maximum low tide, do not provide the necessary pathway between islets.

As a result of earlier construction activity and tests and finally the thermonuclear blast in 1952, Engebi was stripped of vegetation ~~cover~~. The only remaining source of protection would have been various construction artifacts, test buildings, photographic and instrument bunkers, and cable tunnels. Many have assumed that rats which had burrowed under such structures would have been sufficiently shielded to permit survival.

The Polynesian rat is not a burrowing animal but makes a nest under surface vegetation or debris. The roof rat, while often nesting under similar circumstances, may burrow. Usually the tunnels we found were adjacent to a concrete wall or slab or under or adjacent to a coral block or tree root. This kind of physical support may be necessary if the burrow walls are not to collapse in the friable coral sand. Thus, if rats were to survive a near-by detonation, the roof rat is the likely species..

Rats are highly adaptable and successful animals. While they orient poorly when visual contact with land has been broken (e.g., swimming in the lagoon), they often do live in marsh areas and successfully survive seasonal flooding (Steininger, 1949). Perhaps the ability of hibernating ground squirrels to survive early spring floods (Quanstrom, 1966) has some parallel to the possible tidal wave survival of rats on Engebi. Air trapped in burrows might have prevented complete flooding and provided the necessary oxygen supply.

How many could have lived to form the nucleus of a new population can only be speculation, though sufficient protection probably existed for several hundred rats. The major limiting factor, after the period of heavy radiation, would have been food. Until vegetation reappeared the rats would have had to exist on beach debris (of which there was probably considerable), beach invertebrates, and cannibalism. Their omnivorous food habits make this not unlikely.

Not until a year after the Mike test did intensive preparations start for the Castle series of tests, and no observations of flora and fauna on Engebi for the intervening period are available. Rats could have been transported to Engebi in the movement of supplies in early 1954. Field notes of LRB personnel (especially Barnes) indicate that rats were relatively common immediately prior to the Nectar shot; by 1955 the population asymptote was probably being approached, for Lowman records his "rat colony" observations during this period. Thereafter, the populations probably declined to present day levels.

Lowman's estimate of the Engebi rat Population was meant only as an approximation. In an area 100 feet square he saw up to 60 rats at once/during the day. Extrapolating to the 15 acres of available grassland resulted in an estimate of 1000-4000 rats (Hines, 1962, p. 209). Since total land area on Engebi is 260 acres, and some scrub areas were present, further extrapolation

to an island population of 10,000 animals was not difficult (French, 1965). A current estimate, based on trapping data, suggests the population now does not exceed 4500 rats.

Additional construction and

Vegetational succession may have caused a lowered carrying capacity. The old "rat colony" area of Lowman is now overgrown with Scaevola and Messerschmidia trees 15-25^{ft} in height (Fig. 2). While the airfield remains a grassland complex, the rest of the islet is covered to various degrees by second growth. That the sand burr (Cenchrus) might have been virtually exterminated by the rats is possible, since Lowman observed rats' frequently feeding on the seeds. In 1964 none could be found (though in 1966 a few small patches were discovered). The loss of this single species by intensive feeding might of itself have reduced the carrying capacity significantly. In any event, rats are no longer as abundant as they were in 1955; rodent activity during the day (prior to late afternoon) and abundant rat burrows are not now observed.

Radiation Effects

For very practical reasons few studies have been able to evaluate radiation-induced population changes of rodents under field conditions (Dunaway, 1965). Several studies (briefly reviewed by Provost, et al., 1965) have subjected individual to acute radiation and returned them to their natural environment. Doses below 500-750 R generally were ineffective in reducing reproductive rates of population size.

Only one, low level chronic field study has been reported in detail. Dunaway and Kaye (1964) have evaluated a cotton rat population living in an area with a radiation level of 15 mR/hr; no unequivocal effect of radiation on body weight or breeding could be demonstrated. Analysis of roof rat data from Odum's El Verde study revealed no change that could be related to radiation exposure (Jackson, ms). Papers at this symposium (French, et al.; Pelton and Provost) hopefully will add to the knowledge in this area.

Laboratory studies (cited by Dunaway and Kaye, 1964) of the impact of radiation on mammalian reproduction suggest that cumulative doses above 300 R result in sterility. Except for the Mike shot, estimated annual accumulated gamma doses (exclusive of prompt radiation) for rats living on Engebi did not exceed 132 R (Sandstone). For Nectar the dose was 118 R. At daily doses of less than 1 R, some reproductive cycle disturbances do occur, and partial loss of fertility would be expected at sub-lethal levels (See Dunaway + Kaye, 1964).

Certainly any rat caught unprotected above ground by a detonation would have been killed immediately or in a matter of days or weeks by radiation effects. Initial gamma dose above ground ranged from 6,400-10,000 R (Greenhouse) to 2800-6700 R (Mike) to somewhat lesser levels on subsequent test. Animals protected in burrows were estimated to have received an integrated dose in the nine days following Mike shot of 250-2500 R; in the week following the Nectar shot, 55-80 R (Hines, 1962, p. 210-211). Rats in deeper burrows would have had more protection, but those moving above ground to feed would have proportionately increased their load. Certainly these estimates provide a basis for assuming survival of some individuals, for the LD₅₀ (5 days) for laboratory rats is 800 R (Bond, et al., 1965).

Population Dynamics of Rats

At the Hanford symposium, Radiation and Terrestrial Ecosystems, French (1965) considered the growth potential and recovery of the Engebi rat population. Since he assumed the wrong species, based on published sources, calculations of reproductive and survival rates are not strictly applicable. Could the roof rat have populated Engebi to the density observed in the time period available?

Let us assume maximal reproductive rates, even though the roof rat population on Engebi now has stabilized and shows a very low level of reproduction. Under condition of habitat exploitation, high reproductive and low death rates would be expected (Davis, 1951).

Reproductive data for Pacific roof rats are poorly known. Average litter size, for example, varies considerably. On Ponape (a different subspecies), the value was 3.8; in Malaya, 5-6; in temperate region (the same subspecies), 6-7; in the southern Marshalls (Majuro) in a limited sample, 5 (Jackson, 1962, 1965). In our current Eniwetok studies litter size has averaged 6.1 (31 pregnancies). As an estimate for the increasing Engebi population, use a litter size of six.

Mortality data are even less well known. Too few data were obtained in the PIRATE study to make estimates for the Ponape population of roof rats (Jackson and Barbehenn, 1962). Harrison (1965) cites some data for a similar species (R. diardii) in Malaya (Fig. 3), but this is a mainland population; and the mortality rates calculated probably are considerably higher than experienced in an island situation.

Assume the same natural mortality rate used by French (1965); actually this was composite of PIRATE estimates for Polynesian rats on Ponape and Harrison's (1956) estimates for the same species in Malaya. On this basis, using a litter size of six, the annual rate of population multiplication is 7.5 (more than twice that calculated by French).

Following through with calculations and assumptions made by French, estimates of surviving populations necessary to produce the 1955 estimated population have been made (Fig. 4). The interval between shots was 18 months; between the 1954 shot and the 1955 observation, 12 months. [French had taken a three-year period; consequently his estimated initial populations were actually too small (e.g., where $R_a=4$, initial population would have had to have been 300, not 150; where $R_a=3$ (1 y), $R_a=2.1$ (1.5 y), 1050 rather than 700 rats).] Assume also, as did French, following the Mike shot a 50% reduced fertility (multiplication rate); following Nectar shot, 25%.

With these restrictions and assuming that no mortality resulted from

and a nucleus survived the heavy initial radiation by being in deep burrows.
Calculations show that
A Repopulation by the 1954 and 1955 observations is theoretically possible.

The decline of the Engebi rat population from its high density in the mid-fifties is ~~certainly not~~ a result of ~~radiation but~~ probably of a change in the carrying capacity of the environment.

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REFERENCES

- Bond, Victor P., Theodor M. Fliedner, and John O. Archambeau. 1965.
Mammalian radiation lethality.
Academic Press. New York. 340 pp.
- Bryan, Edwin H. jr. 1944.
Revegetation of certain Marshall Islands.
Headquarters Central Pacific Base Command, mimeo, 28 pp.
- Davis, David E. 1951.
The relation between level of population and pregnancy of Norway rats.
Ecology 32(3):459-461.
- Dunaway, Paul. 1965.
Problems of evaluating consequences of irradiation on populations of native rodents.
Radiation effects on natural populations, Argonne National Laboratory:11-18.
- _____ and S. V. Kaye. 1964.
Weights of cotton rats in relation to season, breeding, and environmental radioactive contamination.
American Midland Naturalist 71(1):141-155.
- French, Norman R. 1965.
Radiation and animal populations: problems, progress, and projections.
Health Physics 11:1557-1568.
- French, N. R., B. G. Maza, and H. W. Kaaz. 1967.
Mortality rates in irradiated rodent populations.
Second national symposium on radioecology.
- Harrison, J. L. 1956.
Survival rates of Malayan rats.
Raffles Museum Bulletin 27:5-26.
- Hines, Neal O. 1962.
Proving ground.
University of Washington Press, Seattle. 366 pp.
- Jackson, William B.
Comments on growth and mortality rates.
Manuscript.
- Jackson, William B. 1962.
Reproduction, pp. 92-107. In Storer, T. I. ed. Pacific Island Rat Ecology.
Bishop Museum Bulletin 225.
- _____ 1965.
Litter size in relation to latitude in two Murid rodents.
American Midland Naturalist 73(1):245-247.
- _____ and Kyle R. Barbehenn. 1962.
Longevity and mortality, pp. 107-113. In Storer, T. I. ed. Pacific Island Rat Ecology.
Bishop Museum Bulletin 225.

Johnson, David H. 1962.

Rodents and other Micronesian mammals collected, pp. 21-38. In Storer, T. I. ed.
Pacific Island Rat Ecology.
Bishop Museum Bulletin 225.

Pelton, M. R. and E. E. Provost. 1967.

The effects of radiation on survival of wild cotton rats (Sigmodon hispidus)
in enclosed areas of natural habitat.
Second national symposium on radioecology.

Provost, E. E., Michael R. Pelton, and Forest B. Kellogg. 1965.

The effect of acute gamma irradiation on survival in feral rodents.
Radiation effects on natural populations, Argonne National Laboratory:11-18.

Quarstrom, Walter Roy. 1966.

Flood tolerance in Richardson's ground squirrel.
Journal of Mammalogy 47(2):323.

St. John, Harold. 1950.

Flora of Engebi, Aomori-Bijirip and Runit Islands, pp. 37-54.
In Radiobiological survey of Bikini, Eniwetok, and Likiep Atolls- July-August 1949.
Applied Fisheries Laboratory, University of Washington (UWFL-23).

Steiniger, F. 1949.

Biologische Beobachtungen an freilebenden Wanderratten auf der Hallig Norderoog.
Zoologischer Gesellschaft Verhandlungen 13:152-156.

Tomich, P. Quentin.

Movement patterns of field rodent in Hawaii.
Manuscript.

UWFL-33. 1953.

Radiobiological studies at Eniwetok Atoll before and following the Mike shot
of November 1952 testing program.
Applied Fisheries Laboratory.

Woodbury, Angus M. 1962.

A review of the ecology of Eniwetok Atoll, Pacific Ocean.
Institute of Environmental Biological Research, University of Utah:1-123.

LEGENDS

Figure 1. Map of Eniwetok Atoll.

Figure 2. Engebi rat colony area as it now appears. Messerschmidia and Scaevola trees are 15 feet in height.

Figure 3. Survival curves for roof rats (after French, 1965).

Figure 4. Population estimates for roof rats (after French, 1965).

Fig 3

Fraction of Cohort Remaining

KE SEMI-LOGARITHMIC 46 4970
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig 4

SEMI-LOGARITHMIC
3 CYCLES X 84 DIVISIONS
KEUFFEL & ESSER CO.

46 5730
MADE IN U.S.A.

Population Size