EFFECTS OF ACUTE RADIATION IN CAPTIVE AND FREE-RANGING

POCKET MICE, Perognathus parvus*

CONF-710501--11

Thomas P. O'Farrell
Ecosystems Department
Battelle Memorial Institute
Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

RECEIVED BY DTIC JUN 4 1964

Abstract. There was no significant difference between the responses of captive and free-ranging Great Basin pocket mice, Perognathus parvus, to acute ionizing radiation. The $LD_{50/30}$ values were 858 ± 27 rad and 834 ± 32 rad respectively, and slopes of both survival curves were parallel.

INTRODUCTION

Most studies of the effects of acute ionizing radiation in native mammals have been conducted either in laboratory colonies (Gambino and Lindberg 1964, F. B. Golley et al. 1965, Dunaway et al. 1969, O'Farrell 1969) or fenced enclosures (Pelton and Provost 1969, Golley and Gentry 1969). Because of the many differences in experimental protocol, especially the dose rate used, reported conclusions concerning the responses of indigenous mammals to acute radiation relative to laboratory strains are also different.

It is important to know how wild species respond to radiation under natural conditions if we wish to predict the effects of radiation in the environment. If laboratory results can be extrapolated to field conditions then the task of prediction will be easier. The conditions

*Research sponsored by the U. S. Atomic Energy Commission under Contract AT(45-1)-1830.

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experienced by wild mammals in laboratory colonies or fenced enclosures are considered to be unnatural and the results obtained might not be applicable to free-ranging mammals. Animals in their natural habitat might be more resistant to radiation because they are in a familiar environment, or they might exhibit a lowered resistance due to synergistic effects of radiation and environmental stresses. There was no readily available information on the effects of acute ionizing radiation in free-ranging mammals until results of studies with unconfined pikas, Ochotona princeps, were published by Markham and Whicker (1970).

The objective of this study was to determine the survival of free-ranging pocket mice, Perognathus parvus, exposed to acute radiation, and to compare the results with data obtained for the same species under laboratory conditions.

MATERIALS AND METHODS

Laboratory Exposure

All Perognathus were housed singly in disposable plastic cages on a contact-type bedding (Sterolit). Water and food (mouse biscuits, a mixture of small seeds, oatmeal, and sunflower seeds) were provided ad libitum. The colony was maintained at a temperature of $21 \pm 3^{\circ}\text{C}$, a relative humidity of 28%, and a photoperiod of 12 hours light and 12 hours dark. Pocket mice were acclimated to the laboratory conditions for at least two weeks before treatment.

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Radiation exposures were effected by confining animals in ventilated plastic vials and placing them in a vertical geometry next to a 10,000 Ci ^{60}Co source. Controls were kept in vials for a duration equal to that of the animals receiving the highest dose. Doses varying from 400 to 1600 rad were delivered at a rate of 9.6 ± 0.2 ($\bar{x} \pm \text{SD}$) rad/sec. Three types of dosimeters were employed: standard rate meters; encapsulated silver metaphosphate glass rods; Teflon capsules containing lithium fluoride. Reference material for the latter two types of dosimeters were irradiated by the Ecological Sciences Division, Oak Ridge National Laboratory.

Weights were taken to the nearest 0.5 g on a self-damping balance immediately after exposure and then at 7, 14, 21, and 30 days postirradiation, or at the time of death. Notes on visible abnormalities were made during the weighing sessions and also when the animals were checked twice daily for deaths.

Field Exposure

In 1967 a 2.8 hectare (7 acre) study area was established in a uniform stand of big sagebrush, Artemisia tridentata, near Rattlesnake Springs on the Hanford Reservation, Benton Co., Washington. The ground cover consisted of scattered perennial grasses, Poa secunda, and annual grasses Bromus tectorum, and forbs, Descurainia pinnata. These provided the major food item of Perognathus parvus: seeds. The particular site was selected because of the uniformity of the shrub and ground covers, the density of pocket mice, and the protection afforded by the ecology reserve near the springs.

A total of 400 Sherman live-traps were arranged in a grid of 20 x 20 sites with 10 m spacing. The live-traps contained a sufficient quantity of seeds to prevent torpor in trapped animals, as well as dacron batting for use as a nest during confinement. The traps were shielded by a large can which provided protection from environmental extremes, and efforts were made to locate traps and cans in the shadow of shrubs to prevent mortality due to heat.

Starting in April 1967 traps were opened 3-4 evenings per week and a small quantity of bait (oatmeal/peanut butter) was placed in the trap entrance. Early in the morning animals were removed from traps and examined. All animals were individually marked by a series of toe amputations, their sex and reproductive condition were noted, as well as general condition, pelage, and location of capture. A computer diary was checked at each capture to insure that animal numbers were not misidentified. Animals were immediately released at the site of capture.

On 31 July 1967 all traps were opened and animals were removed as soon as they were captured. A group of 193 pocket mice were live-trapped before sunrise and transported to the laboratory in ventilated metal cans containing mixed seeds. They were weighed, toe-clipped for identification if necessary, assigned to an exposure level by lottery, and irradiated.

Exposure procedures were identical to those described above for laboratory animals, and included a range of doses from 500 to 1100 rad. A total of 25 animals were assigned to each exposure except the 500 rad level which had only 18 animals. Immediately after treatment animals

were transported back to the field and released at the point of capture. Because of the logistic problems involved in the irradiation, animals were in the cans for at least 15-18 hours.

Live-trapping was conducted throughout the night at 14, 21, 28 days postirradiation. Trapping was not begun earlier because laboratory studies had indicated that 98% of the decedents would not survive longer than 14 days and we did not want to superimpose trap stress during this critical period. Captured animals were weighed, and abnormalities were noted before they were released at their capture point shortly after sunrise.

Periodic sampling of the population was conducted over the next 3 years to document the long term effects, such as changes in longevity of those animals surviving the acute exposure, and to quantify possible alterations in reproductive performance in subsequent breeding seasons. From 1 September 1967 until 31 December 1970 25,300 trap-nights of effort were expended collecting information on 1297 individual pocket mice captured 9671 times.

RESULTS

Mortality data for populations of confined and free-ranging pocket mice are presented in Table 1. The threshold dose in the laboratory, defined as the dose affecting 5% mortality, was 700 rad. No animals survived doses greater than 1000 rad, and the decedents survived less than 10 days after exposure.

Data concerning survival of pocket mice released to their natural habitat are presented in Table 1 under two columns. The first summary includes only that information gathered during the trapping session 28 days postirradiation. Animals that were not captured were assumed to be dead. This appeared to be a valid assumption because four months of trapping success preceeding the treatment indicated that most of the population could be live-trapped on any given night. Susceptibility to live-trapping is a characteristic of the rodent family Heteromyidae, one which prompted the use of Perognathus as a test species.

Mortality at all dose levels, including controls, appeared to be high as 40% or more of the animals were not retrapped. A similar proportion of control, 500 and 600-rad animals were trapped, but there was an apparent loss of 68% of the mice exposed to 700 rad. It appeared that the threshold dose was lower, but the increased survival at 800 rad precluded any immediate conclusions.

The second summary of survival information in Table 1 includes supplementary data gathered during trapping sessions in fall, winter, and spring, 1967-1968. When the pocket mice emerged from hibernation in 1968, an additional 19 animals appeared that were thought to be dead in 1967. The additional survival data supplemented information at all dose levels less than 900 rad, but the most significant data were the 8 additional 700-rad animals found to be alive. Their survival doubled the number of survivors at that level compared with the data in 1967. After the spring emergence in 1968 no new survivors were captured at later dates.

For both the field and laboratory data the best fitting straight lines were obtained from a weighted regression analysis using maximum likelihood. For the field data the weights were adjusted for natural mortality. The natural mortality of free-ranging animals, while contributing somewhat to the computational effort was not a serious problem in the analysis (Finney, pp. 88-100, 1964). The field data were adjusted for natural mortality, denoted by C, using the estimate $\hat{C} = 0.314$. The two resulting regression lines were tested for parallelism by the usual F test which in this case had 1 and 14 degrees of freedom. Since this test was nonsignificant at the .05 significance level, an estimate of the common slope of the two lines was obtained. The resulting best fitting lines for the field and laboratory data using this common slope are given in Figure 1.

Data from the weighted regression analysis were used to estimate the median lethality doses for both populations of rodents. The $LD_{50/30}$ of Perognathus parvus exposed to an acute dose of gamma-radiation and then maintained in a laboratory colony was 858 ± 27 rad. The estimated $LD_{50/30}$ value for free-ranging pocket mice was 834 ± 32 rad.

The survival of laboratory and field animals was compared by computing their relative potency (Finney 1964), a technique long used in bioassay to compare the effectiveness or potency of two or more drugs. The relative potency of radiation dose in the field to that in the laboratory is defined as

$$P_{FL} = 10^{\frac{M_{FL}}{M_{FL}}}$$

with

$$M_{FL} = m_L - m_F$$

where m_F and m_L are the $\log_{10}LD_{50}$ values for the field and laboratory data respectively, computed using the estimated common slope $\hat{b}$. Estimated values of $\hat{m}_F$ and $\hat{m}_L$ were 2.92096 and 2.93350, respectively. Thus $\hat{M}_{FL} = 0.01254$ and $\hat{\rho}_{FL} = 1.02929$. We note that if m_F equals m_L , i.e. if a given radiation dose is equally potent in the field and laboratory, then $\rho_{FL} = 1$. A test of $H_0: \rho_{FL} = 1$ is made by computing the 95% fiducial limits on ρ_{FL} using equation (5.4) in Finney (1964). The standard deviation of $\hat{\rho}_{FL}$ was 0.0495 resulting in 95% fiducial limits of 0.926 and 1.159 which are seen to bracket 1. On the basis of this analysis there was little evidence to suggest large differences between the $LD_{50/30}$ values for captive Perognathus parvus compared with free-ranging pocket mice.

DISCUSSION

Initial publications concerning radiation effects in wild mammals concluded that native rodents tested were less sensitive to radiation than laboratory counterparts. Pocket mice were reported to be the most radioresistant of any animals tested to date (Gambino and Lindberg 1964): the published $LD_{50/30}$ values for Perognathus longimembris and P. formosus were 1520 R and 1300 R. A later publication also concluded that wild mice exhibit unusual radiation

resistance, and that a real difference between families of rodents (Muridae vs. Cricetidae) was observed (Golley et al. 1965).

The results of studies conducted under comparable colony care and exposure regimens did not fully support the earlier findings since laboratory strains (RF₁ and C57B1 X BALB) had LD_{50/30} values similar to 13 species of wild animals tested (Dunaway et al. 1969, O'Farrell 1969).

When attempts were made to test radiation responses of small mammals in field enclosures it was not surprising that the results were contradictory. Adult female Sigmodon hispidus exhibited similar radiation responses when the LD_{50/30} derived in the laboratory was compared with the LD_{50/15} obtained with penned animals (Pelton and Provost 1969). Penned Mus musculus also had similar responses in the laboratory vs. field, but Peromyscus polionotus had a lower LD_{50/30} in the field (Golley, and Gentry 1969).

The results of these experiments failed to show any significant difference between the LD_{50/30} of captive and free-ranging Perognathus parvus exposed to acute ionizing radiation. I was unable to show that radiation insult is any more or less effective in an unconfined population living in its natural habitat; in fact, I could have predicted the median lethal dose for the free-ranging pocket mice based upon laboratory studies. Perhaps this conclusion could have been anticipated, but conflicting reports in the literature did not provide sufficient

evidence for assuming that results of radiation effects studies using captive wild rodents could be safely extrapolated to field conditions.

There were reasons to believe that the combined effects of radiation insult and environmental stresses during the recovery period would lower the apparent survival of animals exposed to doses from 500 to 800 rad. Animals exposed to sublethal doses were debilitated to some degree, particularly those receiving 600-700 rad which is near the threshold dose for Perognathus. During this period the pocket mice had to defend their burrows from a growing cohort of juveniles. Pocket mice are not communal and apparently defend their burrow even from the opposite sex. Since a nesting site is critical to survival in this harsh environment during the peak summer heat, defense of established territories is a key to survival of established residents. I felt that this social conflict, an integral part of the overall environmental stress of the species, would provide an excellent test of possible synergistic effects of radiation and natural stresses. There were, however, no apparent differences between survival of the controls and the 500, 600, and 700-rad pocket mice. They appeared to be able to defend their burrow and survive in spite of their temporary radiation sickness.

That animals receiving doses in excess of 900 rad did not survive in the field experiment substantiated the severity of radiation insult in this range. Even under ideal laboratory conditions only 10% of the animals exposed to 1000 rad survived: none survived in the field. Radiation doses of this magnitude cause such massive damage that there was little reason to suspect that some unknown mechanism would provide a protective influence under free-ranging conditions.

Continuation of trapping efforts beyond 28 days postirradiation was justified the following spring when 19 additional mice were recaptured that were assumed to be dead in 1967. After examining the dynamics of this population over four annual cycles I suggest that normal behavioral patterns were responsible for the disappearance of irradiated animals which reappeared the following year.

The Great Basin pocket mouse has a complex annual cycle of activity above ground. Adults reach their peak numbers during the breeding season and apparently enter their torpid period as early as July or August. Juveniles, born from June to August, often remain active above ground until November or early December. It appears that I irradiated the population at a time when both juveniles and adults were active, but the latter were just beginning to estivate. Some of the adults were irradiated and then promptly disappeared underground, only to reappear the following spring. A complete understanding of the ecological life history of an indigenous species is a necessity before field experiments of this type are commenced.

Markham and Whicker (1970) speculated that probable differences between radiation LD_{50/30} values for unconfined and captive pikas may have been due to synergisms between radiation and social stress as well as predation. I have examined their data using computational procedures for testing relative potency (Finney 1964) and have been unable to demonstrate any significant difference between median lethal responses of the two groups of pikas. Their discussion of the probable differences, although they state that it cannot be tacitly assumed as real, does not appear to be warranted by the data presented.

The experimental design testing responses of the unconfined population was quite different from designs testing penned populations (Pelton and Provost 1969, Golley and Gentry 1969), particularly as regards artificiality, dose rate, and duration of trapping after exposure. Comparisons between my results and those from penned populations are probably not justified.

CONCLUSIONS

The response of Great Basin pocket mice, Perognathus parvus, to acute ionizing radiation was tested in both laboratory and free-ranging populations. The laboratory derived LD_{50/30} was 858 ± 27 rad, and the value for unconfined mice was 834 ± 32 rad. There was no evidence to suggest large differences between the median lethal values for pocket mice irradiated in the laboratory as compared with free-ranging mice.

ACKNOWLEDGEMENTS

The difficult and demanding task of following the dynamics of the free-ranging population under our harsh field conditions would have been impossible without the help of my excellent field colleagues, J. D. Hedlund, W. P. Neal, and T. F. Winsor. R. J. Olson and R. O. Gilbert of the Statistical Design and Analysis Section greatly aided data reduction and analysis efforts. I wish to acknowledge their assistance and the aid of all members of the Pacific Northwest Laboratory who contributed to this study.

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Fig. 1. Survivorship curves of captive and free-ranging Perognathus parvus obtained by probit transformations of mortality data following exposures to acute radiation. Data for unconfined pocket mice has been corrected for mortality in controls and the median lethal doses are bracketed by the 95 % fiducial limits.

Table 1. Survival of Perognathus parvus under laboratory and field conditions after exposure to acute ionizing radiation.

Dose (rad)	Number N	Survived γ + 30 days		Number N	Survived γ + 28 days			
		N	(%)		N ^a	(%)	N ^b	(%)
0	10	10	100	25	14	56	18	72
400	10	10	100					
500	10	10	100	18	10	55	12	67
600	20	19	95	25	15	60	18	72
700	10	10	100	25	8	32	16	64
800	20	14	70	25	11	44	13	52
900	10	6	60	25	5	20	5	20
1000	20	2	10	25	0	0	0	0
1100	20	0	0	25	0	0	0	0
1200	20	0	0					
1400	10	0	0					
1600	10	0	0					

^aData from γ + 28 days trapping session only.

^bCorrected for animals caught at later trapping sessions.