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Intraspecific Competition and Response of Pikas
(Ochotona princeps) to Radiation

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ABSTRACT

This study was designed to demonstrate the effect of social interaction upon the response of pikas (Ochotona princeps) to 500 R Cobalt-60 irradiation delivered acutely. Two one-acre enclosures were stocked with 15 and 31 pikas and another group of experimental animals was held captive in individual cages. One experiment was begun in August, 1969 and another was conducted in October of the following year. Results indicated that animals confined individually had a significantly higher survival rate and longer survival time than animals free to interact in each of the two enclosures. These results substantiate findings of a previous experiment in which pikas studied in the natural environment at 4055 meters elevation on Mount Evans, Colorado had a lower LD₅₀(30) and shorter survival times than individually-caged animals in captivity. Animals in the 15 cage enclosure appeared to have a lower survival rate than animals in the 31 cage area. This difference may be explained by the greater number of dens and rock piles available per pika in the 31 cage area which resulted from a greater number of deaths caused by territorial battles prior to the irradiation treatment.

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INTRODUCTION

Recently we reported that pikas (Ochotona princeps) in the natural environment at elevations of 3960 to 4175 m on Mount Evans, Colorado appeared to be more radiosensitive than pikas held captive in individual pens near Fort Collins, Colorado (Markham and Whicker 1970). Pikas in the natural environment aggressively established and defended their territories but social interactions in captivity were limited. We suggested that this type of social aggressive behavior was partly responsible for the difference in radiosensitivity. Predators in the natural environment were also thought to have affected the results by preying on animals that were suffering from radiation sickness before they had a chance to recover. Further, the effects of the climatic differences between the natural environment and captivity were not known. Therefore, the object of this study was to attempt to evaluate the effect of aggressive interaction alone on the response of pikas to ionizing radiation.

The enclosures in which this study was carried out were located in a foothills shortgrass vegetative type (Hanson and Ball 1928) near Fort Collins, Colorado at approximately 1555 m elevation (Fig. 1).

METHODS

Two square one-acre areas were enclosed by rodent-proof fences similar in design to one reported by French (1964). The fence consisted of a 1.3 meter high 1.3 cm mesh hardware cloth which extended 30 cm into the ground. Sheet metal flashings mounted on the top of the fence prevented

animals from entering or leaving the enclosures. An electrically charged single-strand wire was mounted 13 cm above the fence to help prevent predators from entering the enclosures. In one area 15 cage-den assemblies, each consisting of an above-ground wire cage connected to an underground wire den by a wooden tunnel (Markham and Whicker 1970), were installed 10.4 meters apart in a circular pattern. The other one-acre enclosure had 31 cage-den assemblies 4.8 meters apart. All cages in both areas were 25.9 meters from the center of the area. A pile of rocks 45 to 60 cm high and 45 to 60 cm wide was placed approximately one meter in front of each cage entrance with another rock pile located between adjacent cages but approximately 6 meters nearer the center of each area. Seven similar rock piles were distributed within 5 meters of the center of each enclosure. The rock piles provided the pikas with places to hide, rest and store collected vegetation.

Fifteen cages in one acre permitted irradiating enough animals for reasonable statistical estimates and also provided for a minimum of control animals. Observations at Mount Evans, where habitat in terms of shelter and food seem excellent, suggest that this population density is probably obtained in some areas during certain years.

Pikas captured at Mount Evans, Colorado at an elevation of approximately 3900 m were placed in all the cage-den assemblies in the two enclosures. Some pikas were also placed in a complex of individual

cage-den assemblies (Markham and Whicker 1970) and were held captive in these cages throughout the experiment. Social competition was limited and no signs of aggressive behavior were observed in the individual cages. In the individual cage-dens, animals were only able to see each other in adjacent cages and then only when they were above ground at the same time. Water and commercial rabbit feed were provided ad libitum in all cages throughout the experiments. Dandelions (Taraxacum sp.) were fed daily to the animals in the individual cage-den complex and to the pikas in the enclosures until one week after release from their cages.

One experiment was conducted in late August and September 1969 and another in late September and October 1970. The animals in the two one-acre enclosures were held captive in the cages for a minimum of two weeks to permit adjustment to the cage-den assembly. Then the doors on the cages in the enclosures were opened, permitting the animals to interact. All pikas were ear tagged (Markham and Whicker 1970) approximately one week prior to being released in the enclosures. In the first experiment pikas in the one-acre enclosures were permitted to interact for a minimum of twelve days prior to irradiation. In the second experiment the enclosures were originally stocked to capacity and the animals released in early July, more than two months prior to irradiation.

In each experiment, after the animals had established territories, ten animals from each of the two enclosures and from the individual cage-den

complex were captured with No. 1 Havahart traps, immediately transferred into 10 x 20 x 10 cm ventilated 3/8" (0.95 cm) plywood boxes, and each received an exposure of 500 R at 50 R/min from a 4430 curie Cobalt-60 source. The animals were trapped, irradiated and released in early morning in order to avoid any heat stress. The sexes and ages of the irradiated and control pikas are shown in Table 1. The pikas were grouped according to age in the first experiment, but a division in the later experiment was not necessary as all the pikas were approximately the same size.

Two observers, who daily alternated enclosures, recorded the locations and activities of pikas from one to four hours daily starting at daylight. In the 1969 experiment and during warmer periods in the later experiment, the animals were usually active only during periods of cooler temperatures. During the first experiment an attempt was made to record the participants in many of the chases. Since identification of the color coded ears of a pika was necessary, this procedure took a longer period of time than did the recording of a chase in the second experiment where only the number of chases were recorded without regard to the identity of the participants. Therefore, there may have been a greater number of unobserved chases in the first experiment than in the later trial.

An effort was made to determine the status (alive or dead) of every animal each day following irradiation. If an animal was not seen, a

search was conducted for fatalities in the enclosure. All but three fatalities in the 15 cage area were located the same day that the animals were not seen in the observation period. Fatalities in the 31 cage area were much more difficult to locate because of the greater number of rock piles, and the larger number of haypiles, especially in the later experiment. The presence of day-old dandelions in the cage of an individual pika was usually the first clue that the animal was sick or dead.

In the September-October 1970 experiment, the animals were weighed monthly during the pre-irradiation period. The pikas were captured with No. 1 Havahart traps baited with dandelions. Immediately after capture the animals were transferred without direct handling to the 10 x 20 x 10 cm ventilated boxes, weighed, and then immediately released at the site of capture.

Many of the released animals did not survive the pre-irradiation period, probably as a result of battles over territories. Two attempts were made in the second experiment to restock the two enclosures back to their original densities. These attempts were not successful because newcomers in the colony were frequently killed by pikas with established territories.

RESULTS

The mortality data obtained from the irradiation experiments are listed in Table 2. Significantly ($\alpha = .005$ and $.05$) more irradiated

animals died in the 15 cage area than in the individual pens during both experiments. The mortality response in the 31 cage area was not significantly greater than the response in the individual pens for either experiment alone but when the chi square analysis was applied to both experiments together the values were significantly different ($\alpha = .05$). Although there were more irradiation mortalities in both experiments in the 15 cage area than in the 31 cage area, these differences were not statistically significant. During each of the 30 day post-irradiation periods, no mortalities were recorded among the control animals.

Mean survival times for irradiation-associated mortalities appeared to be inversely related to relative mortality in the three conditions of captivity (Fig. 2). Irradiated pikas in the 15 cage area that died within the 30 day period lived for an average of 9.85 ± 1.1 days in the two experiments while pikas that died in the individual pens and in the 31 cage area lived an average of 13.8 ± 5.0 days and 12.0 ± 1.9 days, respectively. An analysis of variance demonstrated that the mean survival times of the pikas that died within 30 days in the three areas were significantly ($\alpha = .01$) different.

In both years, the chases per pika hour did not differ significantly between enclosures (Table 3). However, in the 15 cage enclosure, there were significantly more ($\alpha = .05$) daily average number of chases per pika

hour in 1969 than in the 1970 experiment.

During the second experiment, adults sampled in the 31 cage area gained significantly ($\alpha = .025$) more weight (+24.9 g/pika) during the two months after being released and prior to irradiation than did the individually confined animals (- 4.3 g/pika). Not enough data were gathered on the 15 cage area to make a comparison for the above time period. The average adult weight prior to irradiation in early September 1970 was 174.6 grams in the 31 cage area, 164.6 gm in the 15 cage area and 149.1 grams in the individual cages.

DISCUSSION

Golley and Gentry (1969) found that old field mice (Peromyscus polionotus) appeared to be more sensitive when irradiated after spending four weeks under field conditions inside an enclosure than when irradiated in the laboratory. However, wild house mice (Mus musculus) in the enclosures survived at the same rate as those in the laboratory. Pelton and Provost (1969) did similar work with the cotton rat (Sigmodon hispidus) and suggested that the survival rates between field and laboratory were similar. In our experiments pikas which were free to interact with one another in enclosures appeared more sensitive to ionizing radiation than animals which were individually confined. This observation is consistent with findings from a previous study (Markham and Whicker 1970) which indicated that the LD50(30) of individually caged animals in captivity was greater than that for pikas studied in their natural environment on Mount Evans, Colorado. In the

August-September 1969 experiment reported here, the average mortality in the two enclosures from 500 R ^{60}Co irradiation was 68%. The response curve of the LD50(30) experiment in the natural environment which was conducted during the same month but one year earlier reveals an expected mortality of 69% for the 500 R dose level. The average mortality in the two enclosures for the September-October 1970 experiment was 56%.

The increase in radiation-induced mortalities in the enclosures as compared to those in the individually caged animals may be due to aggressive competition necessary for gaining and retaining territories. Most of the pikas had established territories prior to irradiation but chasing still occurred as intruders were driven from territories, especially in protection of their haypiles. In the natural environment, observations revealed that in at least one case after an animal was captured, other pikas took vegetation from the vacated haypile within an hour. Also in our previous work on Mount Evans, Colorado, experimental animals which were taken from their habitat for 12 to 20 hours and then returned, often had to regain their territories which had been claimed by other pikas during this brief period of absence. From considerable observation it appears that aggressive acts such as chasing, fighting and calling are necessary in order for an individual to retain its territory.

The effect of shock disease on the results of the experiment is unknown. Pikas are extremely sensitive to shock and it was necessary in

the study to employ special handling techniques and facilities in order to avoid death from this cause. Perhaps social aggression induced a sufficient degree of shock disease to weaken animals in the enclosures sufficiently so that they were not as able to survive the irradiation treatment as the animals which were individually confined.

Pikas in the two one-acre enclosures did not appear to be stressed by their diet. Severaid (1955) indicated that pikas are able to survive by eating only commercial rabbit feed. He also compiled a bibliography of workers who cited a long list of plant species in a variety of habitats which are eaten by pikas and collected for their haypiles. In general pikas seem to eat almost any herbaceous vegetation in their habitat. Since pikas in the enclosures were supplied with rabbit feed and appeared to gather and eat a variety of native plants, it seems that the diet of the animals in the enclosures should not have been a limiting factor in these experiments. The weights of animals in the two enclosures in September prior to irradiation in the 1970 experiment did not significantly differ from the weights of 60 pikas captured at Mount Evans, Colorado, in September 1967 (Markham and Whicker 1968). However, the pikas in the individual pens weighed significantly less than those at Mount Evans. Adults in the individual pens lost weight during the two month pre-irradiation period in the 1970 experiment, whereas, those in the enclosures gained weight. From these observations, it would seem that animals in the enclosure were similar in size to their counterparts in the

natural environment while those in the individual pens, if weight is an indicator of health, may have been stressed by captivity.

Although the differential in mortality between the 15 and 31 cage areas was not statistically significant at the 5 per cent level, the mortality was actually higher both years in the 15 cage area. Since there were no significant differences in the number of chases per unit time per pika between the two areas in either of the experiments, it does not appear that the relative irradiation mortality figures can be explained by any differential aggressiveness, at least as indicated by the frequency of chases. During the pre-irradiation periods when some pikas died or disappeared because of territorial battles in the enclosures, no attempt was made to close a corresponding number of cages. At the time of irradiation, there were more cage-den assemblies per pika in the 31 cage area than in the 15 cage area. These additional cage-den assemblies and rock piles may have offered additional places for the animals to hide or escape from their neighbors and therefore there may have been more territories available per pika. These extra cages may have provided a more secure territory as many of the pikas controlled several cage-den assemblies in their territory, and at least one pika in the 31 cage area stored vegetation in four cage-assemblies. Therefore, the extra cage-den assemblies and rock piles may have been related to the observation of fewer irradiation deaths in the 31 cage area.

There were significantly more chases per pika hour in the 15 cage

area in 1969 than in 1970 (.174 per pika-hour in 1969 compared to .005 per pika-hour in 1970). The irradiation mortality response of eight out of nine animals in 1969 compared to five out of eight in 1970 reflects a corresponding decline, which is consistent with the hypothesis that social aggression among irradiated pikas leads to increased mortality.

Although no controls died during the 30 day post-irradiation periods, deaths were recorded prior to irradiation when the animals were establishing their territories. The first two weeks after the animals were released seemed critical for their survival as it was during this period that the animals established their territories by physical combat, by repeated chasings and to some extent by calling. In the earlier experiment, two pikas died in the 15 cage area while 8 died in the 31 cage enclosure during the time the animals were establishing their territories. Deaths also occurred in the 1970 experiment and two attempts in early August and early September were made to restock the enclosures to their original densities. The same procedures were used in restocking as were used in the original release. As the new animals were released from their cages in the enclosures an incumbent animal usually attempted to drive the new animal from the area. Incumbent pikas were usually successful in chasing the newcomers from specific territories. One situation was observed where the series of fights and chases between two animals lasted 30 minutes. In the restocking attempt as well as in the original release, many of these combats resulted in wounds

on the pikas. In at least three cases, combat-related deaths occurred within two to three hours after the new animals were released from their cages. Of the 19 animals introduced in the restocking attempts in the 31 cage area and seven subadults which were born and raised there, only five were present at the time of irradiation. At least three of these five animals did not establish territories in or near the cage-den assemblies. Two dug burrows approximately half-way between the cages and the occupied rock piles in the center of the area and a third pika appeared to have a territory in one corner of the 31 cage area. A nearly complete restocking was necessary in the 15 cage area in the second experiment as most of the animals escaped through a hole in the fence. Ten additional animals were also added by two restockings in August and five survived to the time of irradiation. Combats were seldom observed after the animals had established their territories.

Animals in the enclosures normally could be observed in any one observation period. If an animal was missing this was often a clue that the animal might be dead, and a search was made for the remains. Another clue to an expected mortality was inactivity of an irradiated animal one day prior to death. In some cases other pikas were chasing or fighting to gain control of the territory of an animal which had expired during the previous twelve hours. Similar observations were also recorded during our previous work in the natural environment at Mount Evans, Colorado (Markham and Whicker 1970).

Data indicated that the higher the mortality of pikas, the shorter the mean survival time for radiation-associated mortalities. A similar relationship also occurred in our previous study in which pikas in the natural environment were more sensitive and had shorter survival times than animals held captive in individual pens.

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Table 1. Numbers and description of pikas present in each area at time of irradiation

	15 Cages/Acre		31 Cages/Acre		Individual Cages	
	Control	Irradiated	Control	Irradiated	Control	Irradiated
<u>Aug. - Sept. 1969:</u>						
Male Adults	1	4	5	5	3	5
Male Subadults		2	2	1	5	1
Female Adults	1	3	3	3	2	3
Female Subadults	1	1	1	1	5	1
* Unsexed Adult			1			
* Unsexed Subadult	—	—	1	—	—	—
Totals	3	10	13	10	15	10
<u>Sept. - Oct. 1970:</u>						
Male		5	5	6	3	3
Female	2	5	4	4	5	7
* Unsexed Adult	1	—	1	—	2	—
Totals	3	10	10	10	10	10

* Lost identification tags

Table 2. Comparison of the number of deaths of pikas 30 days after an acute exposure to 500 r ^{60}Co irradiation in three areas by the chi-square test

	Individually Caged (Expected)		15 Cages/Acre*		31 Cages/Acre	
	Aug.-Sept. 1969	Sept.-Oct. 1970	1969	1970	1969	1970
Number Alive	7	7	1	3	5	5
Number Dead	3	3	8	5	5	5
Significance of Chi-square value			***	**		
Significance of Chi-square value on both years			***		**	

* One animal in 1969 and two in 1970 not included died from causes other than irradiation.

** $\alpha = .05$

*** $\alpha = .005$

Table 3. Daily average number of chases per pika-hour in two one-acre enclosures for a three-week period ending one week after acute exposure to 500 r ^{60}Co radiation.

	15 Cages/Acre	31 Cages/Acre
August-September 1969	$.174 \pm .037^*$	$.152 \pm .023$
September-October 1970	$.005 \pm .027$	$.137 \pm .041$

* Standard Error

FIGURE CAPTIONS

Fig. 1. General view of a one-acre pika enclosure, showing cage-den assemblies, rock piles, and rodent-proof fence.

Fig. 2 Mortality and mean survival times of pikas irradiated (500 R) under varied conditions of captivity. Points represent results averaged for 1969 and 1970 experiments.