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22,322
PROGRESS REPORT

UNITED STATES ATOMIC ENERGY COMMISSION
CONTRACT AT(11-1)-1332

EFFECTS OF IONIZING RADIATION AND OTHER
ENVIRONMENTAL FACTORS ON BREEDING BEHAVIOR,
ACTIVITY PATTERNS AND MOVEMENT OF SELECTED VERTEBRATES

JULY 1973

MASTER

Reporting Period
July 1, 1972-June 30, 1973

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Principal Investigator: Dr. John R. Tester

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Institution and Address:

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Principal Investigator:

Dr. John R. Tester, Professor

Project Titles:

Overall Project Title:

EFFECTS OF IONIZING RADIATION AND OTHER ENVIRONMENTAL FACTORS
ON BREEDING BEHAVIOR, ACTIVITY PATTERNS AND MOVEMENTS OF
SELECTED VERTEBRATES.

Subproject Titles:

- (1) Biological, Behavioral and Physical Factors Affecting
Home Ranges and Behavior of Selected Vertebrates Under
Natural Conditions.
- (2) Effects of Ionizing Radiation on Home Range and Movements
of Vertebrates, Including Snowshoe Hares, Raccoons, and
Striped Skunks.

Contract Number:

AT (11-1)-1332

Period Covered in PROGRESS REPORT:

July 1972 through June 1973.

TECHNICAL PROGRESS REPORT: JULY 1972 - JUNE 1973Project Summary

In view of the recommendation of Dr. Leslie Fraley, Jr., of the Ecological Sciences Branch to redirect our research efforts, this Progress Report will consist primarily of completed theses and manuscripts in various stages of preparation. These represent our major accomplishments in ecology and behavior during the past year. Progress in development of telemetry and other types of electronic equipment and in our computer software system for studying behavior and ecology will be presented as part of the Renewal Proposal.

One Master of Science thesis and five Ph.D. theses were completed during the contract period. Copies of the theses are submitted with this report and abstracts of each are presented below. While all of the theses present new information on vertebrate biology, two stand out as being especially significant.

Dr. G. G. Montgomery's simulation model of communication in red fox (Vulpes vulpes) represents an attempt to evaluate all possible modes of communication in a wild species living under natural conditions. The model is based on actual information on red fox movements and behavior obtained at Cedar Creek during the past few years and is indicative of the kinds of analyses that can be performed when adequate baseline data on normal behavior are available.

Dr. H. L. Archibald's dissertation on spacing and communication in Ruffed Grouse (Bonasa umbellus) is also unique in that it demonstrates quantitatively the characteristics of the zone of overlap where two territorial individuals of the same species come into contact. In addition, Dr. Archibald discusses the various factors that appear to influence the behavior of individuals in this overlap zone.

Both of these studies, while dealing with intraspecific behavior, provide much insight into how individual animals may interact with other animals occupying the same area. Our plans for future studies, as described in the Renewal Proposal, are based to a large extent on obtaining information of this type.

The paper titled "Behavior and mortality of free-ranging raccoons, snowshoe hares and striped skunks after exposure to 300 r gamma radiation" represents the culmination of our studies on effects of ionizing radiation on wild mammals. In general these studies have shown that ionizing radiation appears to have little or no effect on such parameters as activity patterns or home range size and shape. Mortality at an exposure of 300 r occurred in young raccoons (Procyon lotor) but was not observed in adult raccoons or in juvenile or adult striped skunks (Mephitis mephitis) or snowshoe hares (Lepus americanus).

SUBPROJECT ONE

BIOLOGICAL, BEHAVIORAL AND PHYSICAL FACTORS AFFECTING HOME RANGES AND BEHAVIOR OF SELECTED VERTEBRATES UNDER NATURAL CONDITIONS

During the past year we have continued with our studies of gray squirrels (Sciurus carolinensis), Ruffed Grouse and various species of hawks and owls. The numbers of new animals radio-marked from July 1972 to June 1973 was as follows: 27 gray squirrels, 2 red squirrels (Tamiasciurus hudsonicus), 29 Ruffed Grouse, 2 Great-horned Owls (Bubo virginianus), 10 Barred Owls (Strix varia), 1 Marsh Hawk (Circus cyaneus), 2 Red-shouldered Hawks (Buteo lineatus), 3 Goshawks (Accipiter gentilis), 6 Broad-winged Hawks (Buteo platypterus), 15 Red-tailed Hawks (Buteo jamaicensis), and 11 Cooper's Hawks (Accipiter cooperii).

Data on movements, behavior, mortality, population dynamics, etc. of all radio-tagged animals are continuously being tabulated and analyzed. Over 46 papers have been published, 20 theses have been written, and numerous manuscripts are in preparation. Published and mimeographed papers are listed and reprints or pre-publication copies of 10 papers and 6 theses completed or published since July 1972 are submitted with this Progress Report. The text of this subproject consists of summaries of papers published or in preparation and abstracts of completed theses. Copies of all papers and theses are also submitted. Results of our studies on gray squirrels are included as part of Subproject Three of the Renewal Proposal.

In July, 1967, a training program in "Vertebrate Behavior and Ecology" was funded by the National Institutes of Health. Dr. Tester is the Program Director and Drs. McKinney and Siniff are participants. This program was established to train predoctoral and post-doctoral students in the use of telemetry, radionuclide tagging and biomathematical aspects of ecology and behavior. Because the training emphasizes techniques, it overlaps in many ways with our established research program. Computer programs and other techniques of data analysis developed for the A.E.C. research program have been used by students supported on the N.I.H. Training Program. Credit is given to this A.E.C. contract in all publications resulting from this cooperation.

COMMUNICATION IN RED FOX DYADS:
A COMPUTER SIMULATION STUDY

Gerald Gene Montgomery

ABSTRACT

For any two animals, three major factors limit communication. These are (1) whether appropriate signal mechanisms are available to them, (2) whether the animals are motivated to communicate, and (3) whether their movements and locations are such that signal can pass between them. In this study, signal mechanisms and motivation were not considered as variables, but the role of animal movement in limiting communication was. A computer simulation study of amounts of communication which occur in red fox (Vulpes vulpes) dyads when various means of signalling are used, and when the animals move about and signal with various emission intensities and at various time intervals is reported.

Two parameters determined by the movements of any two animals affect the potential for communication by indicating optimal means of signalling and by restricting information transfer via those means. The parameters are (1) distance between the animals at points in time, and (2) times between the animals when they use corresponding areas of space. Because signals for various modes of communication differ in the way in which they are emitted and in the time over which they remain effective, the same pair of movement patterns can give more or less dyadic communication depending on the sensory mode used for signalling and, within each mode, on how the animals signal. Likewise, because of the dependence for communication on the temporal and spatial locations of the animals, different patterns of movement will result in different levels of communication with a given means of signalling and level at which signals are emitted. Limiting conditions for dyadic communication which depended on the movements of both individuals were developed for tactile, visual, vocal, and olfactory signalling. These conditions were then employed to develop simplified models of the ways in which red fox can communicate.

Computer programs were written to control the movements of both members of red fox dyads and, on the basis of the communication models, to control the means of signalling used for communication within the dyads. Only uni-directional communication, in which one animal always acted as a signaller and the other always acted as a receiver of the signal, was simulated.

Five simulated dyads were used in the study. For each dyad, communication under a total of 154 different controls on means of signalling was simulated. Movement patterns of the animals in each dyad were different.

While the animals moved about, one of them emitted signals of a programmed kind, of a programmed emission intensity, and on a programmed

schedule. Whenever the other animal moved within spatial or temporal range of these signals, communication was assumed to occur. The percent of time during which communication occurred was measured for each of the 154 different controls on means of signalling, for each of the dyads.

No tactile communication occurred between members of any of the five dyads, and close-range visual or vocal communication (from 16 m or less) occurred very rarely.

Simulation indicated that visual communication could occur frequently with reasonably short visual ranges (20 percent of the time from 306 m). However, visual communication in wild red fox is probably usually limited by darkness and terrain.

Scent path communication, where one animal crossed and reacted to the trail of scent left as the other moved about, could provide moderate levels of communication. An average of 7.6 hours of scent effect resulted in communication 20 percent of the time. Increasing scent effect times beyond about 9 hours did not result in further increases in level of communication. The primary function of scent path signalling may be to reveal the location of a signaller during the same daily activity period that scent trails are left in the wild. Ambiguity from scent persisting from one daily activity period to the next may be avoided by a signaller emitting scent which provides an optimal scent effect time of 9 hours, approximately the length of the red fox daily activity period.

For vocal signalling, changes in communication variables which increased the area covered by vocal signal, the time covered by such signal, or both, resulted in higher levels of communication. Linear increases in communication occurred with linear increases in frequency of vocalization, but the effect of increasing the vocal range on communication became less and less as the vocal range increased with a given frequency of vocalization. Vocal signalling could be an effective means for maintaining social contact in red fox dyads. Vocal signals which could be heard from 644 meters gave communication 20 percent of the time when the signaller vocalized 4.7 times per hour. However, wild red fox seldom emit loud vocalizations, and vocal communication is probably not of prime importance in maintaining dyadic social bonds.

With scent point signalling (scent marking) combinations of the three communication variables which resulted in relatively sparse, small circles of scent on the home range space gave low levels of communication. Communication was increased by changes in any combination of the three variables such that the total area of effective scent increased. When scent remained effective for 8 hours, could be smelled 96 m from the scent mark, and when the signaller marked twice per hour, communication occurred 20 percent of the time. Wild red fox scent mark more frequently, and the scent may remain effective for periods of days. Thus, high levels of dyadic communication may be achieved through scent marking, and this form of signalling may be of great importance in maintaining dyadic spacing and social bonding.

The particular movement patterns of the animals which formed each dyad had a differential effect on the level of communication, regardless of the means of signalling. The maximum levels of tactile and scent path communication which could be reached were limited by movements of the animals. Limitations placed by animal movement on visual and vocal communication could be overcome by increasing the spatial area of effect of the signal, and for scent point communication by increasing the spatial and temporal area of effect. Those means of signalling which involved the fewest communication variables were most severely limited by movements of the animals. Where more variables associated with emission of signal were available to the animal, emission could be optimized to minimize effects of movement on communication.

Likewise, because various ways of moving about differentially affected the level of communication with a particular means of signalling, levels of communication could be changed by changing the movement pattern of one or both animals. With tactile and close-range signalling, communication could be increased only by coordinating movements of dyad members such that they were seldom far apart. Some other means of communication would be necessary to establish this coordination, and to allow the animals to find each other when they became separated. Scent path communication could likewise be enhanced by coordination of movements, but not necessarily such that the animals traveled together. Rather, the coordination would require a leader-follower set of movement patterns. As shown by simulation, the initial contact or contact following separation would be enhanced by the signaller moving in a pattern in which it seldom turned and traveled at relatively high speed. For visual signalling, and for the spatial range variables of both vocal and scent point signalling, communication could be enhanced by proper choice of emission intensity and by travel by the signaller at relatively high speed. For the temporal variables of scent point signalling, communication could be made more efficient by the signaller moving at high speed and in relatively straight paths, and by choices of frequency of scent marking and scent effect time which reduce the probability that effective circles of scent overlap.

This study suggests that the animals can adjust the distance between them, the time between them, or both if prior communication has given mutual awareness of the locations and movement patterns. In these adjustments, they can increase or decrease the efficiency of signalling in one or more ways, and thus control the level of dyadic communication. These adjustments require changes in the movement patterns of one or both dyad members, and will be reflected by changes in one or both home range spaces. The degree of mutual adjustment in movement patterns which the two animals can make to change the level of dyadic communication will be limited by factors extraneous to dyadic communication, such as communication and social relations with other individuals, and dispersion of life requirements in the respective home range spaces of the dyad members.

University of Minnesota, Ph.D. Thesis, 1973.

SPRING DRUMMING ACTIVITY AND
SPACE USE OF RUFFED GROUSE

Herbert Lyle Archibald

ABSTRACT

During the spring of 1970, locations and activity of 10 male and 3 female Ruffed Grouse (*Bonasa umbellus*) were determined using an automatic radio-tracking system on the Cedar Creek Natural History Area in east-central Minnesota. The drumming activity of 7 males was monitored with modified radio-tracking equipment.

An inverse relationship was found between weekly mean range size of males (determined by a grid-square method) and the level of territorial behavior as manifested by drumming activity. Mean range size of females increased in an approximately linear manner during the 6 weeks prior to incubation but became much smaller (ca. 5 acres) during incubation. Overall ranges of males were more fixed in space than and approximately half as large as those of females. Male ranges became more highly fixed in space after the onset of the drumming season. Overall ranges of males contained centrally located core areas of intensive use and consistent occupancy over time, which averaged about 6 acres in size.

Adjacent males tended to use overlapping 0.064 acre grid-squares unequally. The possibility that actual boundaries between overlapping ranges existed in most cases was demonstrated by construction and evaluation of artificial boundary lines. Neighboring males were recorded in spatial and temporal proximity thought sufficient to permit interaction which may have involved active defense. The available data suggest a relationship between drumming and degree of boundary observance, with increasing exclusiveness of area use as the drumming season advanced. Results for range overlap support the contention of previous workers that males are territorial in the spring.

Males generally drummed at the same times of day. Certain individuals drummed at shorter and less variable intervals than others consistently throughout the day. The highest drumming frequencies within a day tended to occur at the beginning of a drumming period and immediately preceding sunrise. Nocturnal drumming by all males monitored was recorded on 11 nights during the first 2-1/2 weeks of the drumming season. Then, within about 5 days, there was a transition to a nearly exclusively diurnal drumming pattern which prevailed thereafter.

Two possible forms of communication between adjacent males were identified: 1) drumming almost immediately after the start of a neighbor's drum, 2) duplication of the interval between successive drums of a neighbor. Stimulus-response functions for two neighboring males showed a tendency for the drums of one bird to occur either within 10 seconds or between 50 and 130 seconds after the drums of the other bird.

Peak drumming periods coincided with the full moons in April and May. Estimated dates of copulation of 3 females coincided with the drumming peak in April. The second peak may have been associated with remating of hens which had lost their initial clutch. Approximately 67% of the variation in the seasonal distribution of the average daily total number of drums was accounted for by 5 environmental factors; an index of moon phase and miles of wind/day were the most important.

The basic temporal pattern of spring drumming activity is hypothesized to be regulated by moonlight. Weather factors such as wind and precipitation modify the basic pattern leading to day-to-day variations in drumming activity. Moonlight may also affect male behavior in the fall.

ECOLOGY OF WATERFOWL BROODS IN A FORESTED
REGION OF NORTH-CENTRAL MINNESOTA

Irvin Joseph Ball, Jr.

SUMMARY

Mallard and wood duck broods on my study area showed a number of general similarities in movements, habitat use, survival and behavior, as might be expected of two species which are basically similar in gross morphology and are subject to the influence of many of the same biotic and physical factors. There were also some definite differences, which would likewise be expected due to the differing immediate needs and evolutionary histories of the two species from separate tribes within the sub-family Anatinae.

Mobility in the long-term sense was highest in the first few weeks after hatching, and decreased thereafter as broods apparently reached suitable rearing areas. There was a trend for mallard broods to shift more often and for greater distances, although wood ducks more readily moved overland. Both species seemed to prefer moving by water to overland travel, and moved farther than would have been necessary just to reach the water areas nearest the nest. Daily movement patterns were similar between the two species: both usually moved away from shorelines and expanded their shoreline ranges laterally at night. Wood ducks were more likely to restrict their daily movements to the confines of small wetlands, however. Daily movements around a limited segment of habitat were extensive, and major shifts comprised only a small portion of the total amount of movement prior to fledging. Ducklings of both species fed heavily on invertebrates at night, and daily peaks in invertebrate availability probably influenced diurnal changes in brood movement and habitat use patterns.

Duck broods presumably select habitat on the basis of partly inherent responses to environmental cues, as well as on how well the habitat meets immediate needs for food and for cover. Both wood duck and mallard ducklings are known to eat aquatic insects and other invertebrates, but major food habit differences that could influence habitat preference may exist between the two. With regard to cover, mallards seemed more adaptable than wood ducks in utilizing areas with sparse cover. Rearing success was about 40 percent if hens losing all their ducklings between nest departure and fledging were taken into account. The bond duration between wood duck hens and their young was short, although the advantage of this system over the longer bonds in mallards may be realized only in the southern portions of the range, where two broods may be reared in one season.

Problems related to drainage and filling of wetlands are not so obvious on the study area as in agricultural regions, but some habitat types favored by broods are quite susceptible to destruction. Management efforts should focus first on saving existing habitat and secondly on developing new habitat if needed.

University of Minnesota, Ph.D. Thesis. 1973.

ECOLOGY OF BARRED OWLS AS DETERMINED
BY AN AUTOMATIC RADIO-TRACKING SYSTEM

Thomas Harlan Nicholls

ABSTRACT

During 1965 and 1966 a radio telemetry study was done on 10 barred owls (Strix varia) using the University of Minnesota's automatic radio-tracking system on the Cedar Creek Natural History Area in east-central Minnesota (93° 12' W. Longitude, 45° 24' N. Latitude). This study was the first attempt to test and refine automatic radio-tracking techniques for use on owls and to develop methods for analyzing the new and different kinds of data obtained.

Successful techniques were developed for trapping and attaching radio transmitters to barred owls. The owls' behavior did not appear to be affected by the transmitter and harness. More than 28,000 owl locations were sampled from some two million locations automatically recorded by the tracking system.

Barred owls were found to be territorial as exhibited by their high degree of exclusive use of areas within their home range. Vocal advertisement was the most important method of maintaining territorial boundaries and spatial distribution. Territorial boundaries were fairly constant from one year to the next despite changes in occupants.

A few members of the barred owl population did not exhibit strong territorial tendencies, if any. These owls were thought to be young birds or less aggressive birds that could not compete successfully for occupied territories.

The average home range size was 565 acres with size varying from 213 to 912 acres. There was little variation in home range size after an owl had been radio-tracked for a period of more than 40 days.

Barred owls showed consistent and highly significant preference or avoidance for different habitats despite changing seasons, phenology, weather conditions, and years. Oak (Quercus spp.) woods and mixed hardwood-conifer habitats were the most preferred. The physical arrangement of these two habitats was probably ideal for nesting, hunting, and locating and securing prey by sight and sound. White cedar (Thuja occidentalis) swamp, oak-savanna, alder (Alnus spp.) swamp, marsh, and open field habitats were used at sharply reduced rates.

Owls intensively used certain woodlots within their home range for short periods, then shifted their hunting activities to other woodlots. They often returned to woodlots formerly used. It is thought that this shifting intensity of use of areas allows an owl to develop an intimate knowledge of the physical arrangements and prey availability within its home range.

Barred owls were mostly nocturnal in their movements being about twice as active at night than during the day. Computer maps of owl movements and trapping of owls with mist nets provided evidence that owls often used favorite aerial "trails" to move about the intensively used woodlots by a series of short-distance flights.

ON THE ACCURACY AND OPTIMIZATION
OF TRACKING SYSTEMS

Roy Leon Sanford

ABSTRACT

A decision theoretic model designed to aid in the creation, development and critical evaluation of automatic animal tracking systems using two directional antennas is presented in this thesis. This model quantifies the performance of such tracking systems from a stochastic viewpoint by probabilistically treating both the propagation of radio waves from a radio tagged animal to the two directional antennas and the propagation of errors in the subsequent position determination. Estimation results basic to extending this approach to three tower tracking systems are given. The usefulness and flexibility of the two tower tracking system model is demonstrated with respect to considering improvements in the Cedar Creek Tracking System owned and operated by the University of Minnesota. To do this the consequences of proposed system improvements are evaluated by computer simulation. Indications of how this decision theoretic approach can be extended to other design questions in the field of biotelemetry are given.

BREEDING BEHAVIOR OF CAPTIVE MALLARDS

Julie Barrett

SUMMARY

The breeding behavior of eight pairs of wild-caught, full-winged Mallards was observed closely in large flight pens for two consecutive seasons (mid-April to mid-June). Special attention was given to interactions between pairs and promiscuous mating attempts of males, and the relationships of these activities to breeding chronology. The results provide baseline information on the characteristics of the social system for comparison with parallel studies on other species of Anas. They are intended to complement field studies on this species and to contribute to comparative study of the adaptive radiation of social behavior in the Anatini.

The captive Mallards maintained firm pair-bonds which were reinforced by a variety of activities. Males became sociable with each other, while still paired, soon after the females began to lay eggs and incubate them. Laying females joined their mates on leaving the nest, and at such times, males once again became aggressive toward each other. Late in the season pair-bonds appeared to dissolve.

Pairs copulated regularly especially during the week preceding egg-laying; some copulated several times during one whole day watch at this stage of the cycle. In addition to these matings, which were preceded by pre-copulatory displays ("Normal copulations"), males also attempted rape-like matings with their own mates. I have called these "Forced pair-copulations". They have been noted only incidentally in the literature and have not been clearly distinguished previously. Both of these types of pair-copulations occurred from the start of the study each year and continued until the pair finished egg-laying. The relative frequency of the two types changed, however, during this period, forced pair-copulations becoming more common.

All paired males, in addition to copulating with their mates, made attempts to rape females paired to other males. These attempts were most frequent at females in the laying stage of their nesting cycles. On days when certain females were subjected to both rape attempts and forced pair-copulations, the latter tended to follow the former within the hour.

The onset of nesting was signalled, in many cases, by the occurrence of Persistent Quacking by the hens. All but one of the hens had discontinued this calling by the time they had laid the first egg. Thirteen clutches of eggs were laid in the two years. There was a high nesting success in the first year, but in the second there was a great deal of duckling mortality. I attribute this largely to a high level of aggressive behavior among the overcrowded hens with broods. Only one female was harassed at the nest so much that she abandoned it.

Male Mallards chased both males and females. The chases at males occurred on the ground, while chases at females were primarily aerial. The chasing resulted in spacing out of the birds in each pen. In addition, high rates of chasing by some males tended to suppress the activities of the others, allowing a dominant male and his mate to use the available area relatively undisturbed by the others.

Fighting occurred between males also, in two contexts: (1) when two males were evenly matched and neither would retreat in a hostile interaction, (2) during rape attempts, when the female's mate attacked a male attempting to mount her.

WINTER ACTIVITY OF STRIPED SKUNKS
(Mephitis mephitis) IN EAST-CENTRAL MINNESOTA

M. E. Sunquist

ABSTRACT

The winter activity of 25 radio-tagged striped skunks was studied on the Cedar Creek Natural History Area during the winters of 1967-1968 and 1968-1969. A shift from aboveground and hollow log rest sites to underground dens by skunks began in early October. Den preparation and communal denning were other behavioral changes accompanying this shift. A reduction in home range size and level of activity was observed in October and November. Juvenile skunks showed higher levels of activity than adults in November. Skunks began winter denning in November and early December; juveniles were usually later than adults to begin winter denning. Eighty percent of all activity periods inside winter dens lasted 10 minutes or less. Skunks averaged one to three activity periods per day while inside their winter dens. The percentage of days on which activity inside dens occurred increased as the winter progressed, with juveniles showing a higher percentage of days with activity. Movements outside of dens were generally confined to an area near the den entrance. Snow depth appeared influential in limiting movements from dens. The mean length of the winter denning period was 90 days in 1967-1968 and 115 days in 1968-1969. Air temperature in an occupied skunks den averaged 4.5°C warmer than in unoccupied dens. Weight losses during the winter of 1967-1968 averaged 44.9 percent for males and 53.2 percent for females. The following year, weight losses for males averaged 53.9 percent and for females, 61.4 percent. Mortality related to winter denning was not significantly different between the two winters.

Submitted to Amer. Midl. Naturalist.

DESIGN AND TESTING OF A HEAT TRANSFER MODEL OF A RACCOON
(Procyon lotor) IN A CLOSED TREE DEN

Jeffrey Thorkelson and Robert K. Maxwell

ABSTRACT

A heat transfer model of a raccoon (Procyon lotor) in a hollow tree was designed and tested by simulating an overwintering raccoon with a fur-covered, electrically-heated cylinder in a closed den. A comparison was made between predicted and observed fur surface temperatures, and heat losses from the top, side, and bottom. Under these conditions, transfer coefficients derived from engineering relationships can be dependably used in the field; the average difference between predicted and observed fur surface temperatures was 1.6°C , and the sum of the predicted fluxes through the surfaces of the model was within 5% of the measured total.

Total heat loss increased approximately linearly as inside wall temperature decreased, but the contribution by convection and radiation to the total changed substantially. As inside wall temperature decreased, convective flux was an increasing percentage of the total; while radiation loss decreased to a minimum value of 56% of the total flux at the minimum wall temperature. Twenty-five percent of the total flux was lost from the top, 62% from the side, and 13% from the bottom.

More than 65% of the total resistance to heat loss through the model side was in the fur. The air space presented 17% with the balance in the den wall. With respect to heat loss through the base of the den, only 6% of the total resistance was in the compressed fur. But due to the high resistance of the den base, the loss was half that of the top.

Small variations in den wall thickness are not a major factor in reducing heat loss since the wall accounts for only about 18% of total heat flow resistance.

A correlation is presented between energy loss and average monthly weather screen air temperature.

Ecology (in press).

RAPTOR CONSERVATION AND MANAGEMENT APPLICATIONS OF BIO-TELEMETRY
STUDIES FROM CEDAR CREEK NATURAL HISTORY AREA

M. R. Fuller, T. H. Nicholls and J. R. Tester

ABSTRACT

The automatic radio-tracking system at Cedar Creek Natural History Area makes possible the gathering of information about raptor habits that would otherwise be virtually impossible to obtain in the multiple habitat conditions found on the area. A permanent record of up to fifty-two animals' locations is recorded every forty-five seconds. Analysis of these basic data reveal such important information as habitat use, intensity of use and habitat preference. Specific examples of Barred Owl habitat preference and movements are discussed. Barred Owls, Great Horned Owls, Saw-whet Owls, Red-tailed Hawks, Broad-winged Hawks, Cooper's Hawks, Kestrels, Red-shouldered Hawks and Goshawks have been radio-tagged and followed on the system. When more than one raptor is being maintained at once, valuable data regarding inter- and/or intraspecific spatial and temporal relationships can be obtained. Data on simultaneous use of an area by Broad-winged Hawk, Barred Owl, Red-tailed Hawk and Cooper's Hawk are presented. An example of Barred Owl - Great Horned Owl "avoidance" is discussed. These data reveal information about species diversity and species intensity that, in combination with habitat use and range size data, is vital to proper conservation and management of raptors.

Proceedings of Conference on Raptor Conservation Techniques, March 22-25, 1973, Ft. Collins, Colorado. (In press).

AN AUTOMATIC RADIO TRACKING SYSTEM FOR BIOTELEMETRY

M. R. Fuller and J. R. Tester

ABSTRACT

The automatic tracking system is located at the Cedar Creek Natural History Area in east central Minnesota. Signals from animals carrying transmitters are received by rotating antennas spaced 0.5 miles apart. The signals are fed to a 52-channel receiving and recording system located in a laboratory between the two antenna towers. Time and bearings for the animals are recorded once every 45 seconds on 16 mm film. The mechanical accuracy of the system is $\pm 0.5\%$. Tail mounted transmitters developed exclusively for use on raptors, or modified harness transmitters, weighing from 4 to 55 grams, are placed on the birds. Location and activity data from these animals can be analyzed with the aid of computer programs developed specifically for this system. These data lead to a better understanding of such behavioral and ecological aspects as spacing of individuals on the area, home range size, habitat utilization, daily activity rhythms, and predator-prey interaction. The advantages of this system over conventional radio-tracking techniques involving hand-held or vehicle-mounted receivers include: increased qualitative and quantitative data returns; simultaneous monitoring of several animals; animals are left undisturbed; while the time required to obtain the data is much reduced.

Proceedings of Conference on Raptor Conservation Techniques, March 22-25, 1973, Ft. Collins, Colorado. (In press).

RAPTOR REHABILITATION AND CONSERVATION IN MINNESOTA

M. R. Fuller, P. T. Redig and G. E. Duke

ABSTRACT

A substantial nesting population and an extensive migration of raptors occur in Minnesota each year. Suburban sprawl into breeding habitat and exhaustive year-round use of the state's natural resources result in many human-raptor encounters. Unfortunately, many birds are still shot, illegally trapped and taken from nests. Additionally, diseased and injured raptors are frequently found by the public. With the help of state and federal agencies, and many individuals, we have undertaken projects to diagnose, treat and release those that need medical care, live trap and relocate "nuisance" individuals and place permanently incapacitated raptors in education and research projects. We have initiated the practice of humane live-trapping at some state and private game farms and hunt clubs. News releases requesting that people finding injured raptors contact us have resulted in treatment for many common and some rare species from the entire state. During the last year we released over 20 hawks, falcons, eagles and owls. Additionally, research has been conducted regarding the occurrence and treatment of aspergillosis in Goshawks. The results of cultures from a wild population, and clinical studies are reported. If the trend continues as it has, our efforts to make the public aware of the raptors' important place in the ecology of Minnesota will result in fewer cases and a higher percentage of successful rehabilitations.

Proceedings of Conference on Raptor Conservation Techniques, March 22-25, 1973, Ft. Collins, Colorado (In press).

ANALYSIS OF RADIO-TRACKING DATA USING DIGITIZED HABITAT MAPS

David S. Gilmer, Steven E. Miller and Lewis M. Cowardin

ABSTRACT

A method is described that provides a rapid and accurate analysis of habitat used by radio-equipped animals. The digitizer (basically an X-Y plotter in reverse) converts maps into digital form by describing each habitat unit as a polygon that closely approximates the actual shape of the unit. The coordinates of each polygon are then stored on magnetic tape. Habitat classification data and other information are coded and combined with the proper polygon coordinates. This results in one file containing all habitat data. A computer program with inputs of tracking data and habitat data provides a listing of the habitat used by the animals studied. Analysis of habitat used by radio-equipped ducks is demonstrated using this method.

EFFECT OF RADIO PACKAGES ON DUCKS

David S. Gilmer, I. Joseph Ball, Jr., Lewis M. Cowardin, and John H. Riechmann

ABSTRACT

A total of 266 wild, free-flying mallards (Anas platyrhynchos), wood ducks (Aix sponsa), and blue-winged teal (Anas discors) were equipped with breast- or back-mounted radio packages during the breeding seasons of 1968 through 1972. Behavioral observations were made on unmarked as well as radio-equipped birds. Overall known predation loss of instrumented ducks was 9.6 percent. Sixty percent of the predation occurred within 3 weeks after equipping birds with radio-packages. The recovery rate for radio-equipped ducks was 18.7 percent. A higher direct recovery rate for instrumented birds than non-instrumented birds was probably due to the novelty of the transmitters to hunters. Departure patterns and locations of direct recoveries were similar between radio-equipped and normal-banded birds. Among female wood ducks with radios, recovery rates and recaptures in subsequent years were lower than expected. Questionnaires completed by hunters recovering instrumented ducks indicated that few ducks were having difficulty carrying radio-packages. Recaptures of ducks as long as 1 year after being equipped with radio-packages indicated that although some feather wear and skin abrasion were present, they were not serious. Behavioral observations indicated that instrumented birds were more likely to be observed "on land" than on water. This situation resulted because the transmitter enabled the observer to precisely locate these ducks. Feeding rates were similar between instrumented and non-instrumented ducks, but instrumented birds preened significantly more, particularly around the transmitter. As the bird became adjusted to the package, the frequency of comfort movements decreased and feeding on water increased.

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ECOETHOLOGICAL ASPECTS OF REPRODUCTION

Frank McKinney

ABSTRACT

By combining intensive studies of ecology and behavior of single species with comparative studies of closely related species, new ideas can emerge on the adaptive radiation of ecoethological strategies in the study group. Long-term field studies on each species are essential, and they should be deliberately directed toward questions of adaptive significance. Beyond the early exploratory stages, the breadth of this approach will usually require team effort, combining the talents of specialists in such fields as feeding ecology, nutrition, and reproductive physiology. Comparative ethologists can play a key role in such teams by revealing specific differences that require explanation. The adaptive characteristics of each species are interrelated in complex and often unexpected ways, and over-emphasis on one source of selection, or on one research strategy, is likely to lead to an unbalanced picture. Ecoethological research is time-consuming, and long-term programs are essential; but there seems to be no alternative if we wish to understand why each species behaves as it does.

In: Breeding Biology of Birds, Natl. Academy of Sciences, Wash. D.C.

DISPERSAL AND SOCIAL CONTACT AMONG RED FOXES:
RESULTS FROM TELEMETRY AND COMPUTER SIMULATION

G. L. Storm and G. G. Montgomery

ABSTRACT

The occurrence of dispersal in the red fox (Vulpes vulpes) is well documented (Errington and Berry, 1937; Sheldon, 1950; Arnold and Schofield, 1956). However, published reports provide few details of dispersal such as seasonal timing, rates and routes of travel, proportions of the sex and age segments of the population which disperse and amounts of social contact between transient and resident fox. These details are essential for understanding gene flow among fox populations, range extensions, epidemiology of fox-borne diseases and social control of dispersal. This paper reports on details of dispersal of red fox determined through use of radio-telemetry and other field techniques, and of social contact through computer simulation of red fox movements.

In Fox, M. W. (Ed.). Ecology and Social Behavior of Canids. Van Nostrand Reinhold Co., New York (in press).

SURVIVAL AND MOVEMENTS OF TRANSPLANTED
AND ADOPTED RED FOX PUPS

R. D. Andrews, G. L. Storm, R. L. Phillips and R. A. Bishop

ABSTRACT

The recovery rates and dispersal distances of transplanted juvenile red foxes (Vulpes fulva) were compared with those of controls released on their natal range. Transplanted juvenile foxes included one group held in captivity for 2 to 4 weeks before release (Group 1), one group added to other resident litters (Group 2), and nine family groups each consisting of an adult female and her offspring (Group 3). The overall recovery rate was not significantly different among Groups 1, 2, and 3, but rates of each of these groups tended to be higher than those of the controls. Mortality, other than hunting and trapping, was higher in the group held captive than in all other groups. Dispersal in all groups did not begin until late September and early October. Only one of the nine transplanted adult females showed a tendency to home back to the original den.

SUBPROJECT TWO

EFFECTS OF IONIZING RADIATION ON HOME RANGE AND
MOVEMENTS OF VERTEBRATES, INCLUDING SNOWSHOE
HARES, RACCOONS, AND STRIPED SKUNKS

Results of our investigations of effects of acute doses of ionizing radiation on mammals are presented below in detail. This report will be submitted to Radiation Research within the next two months.

During the past year we have irradiated one male and two female Ruffed Grouse and sham irradiated their controls. The three irradiated grouse died seven, 10 and 14 days following irradiation while the controls all survived more than 30 days following irradiation. Data on movements and activity patterns of these grouse are currently being analyzed.

No further field studies are planned for this subproject.

BEHAVIOR AND MORTALITY OF FREE-RANGING RACCOONS,
SNOWSHOE HARES AND STRIPED SKUNKS AFTER
EXPOSURE TO 300r GAMMA RADIATION.

Attempts to determine effects of ionizing radiation on the behavior and survival of wild animals living under natural conditions have been hindered by lack of suitable monitoring techniques. This paper reports on studies of free-ranging raccoons, snowshoe hares and striped skunks given an acute exposure to 300 r gamma radiation. All irradiated animals and their controls were monitored prior to and following irradiation by an automatic radio tracking station (Cochran et al. 1965) located in east-central Minnesota on the Cedar Creek Natural History Area.

Radiation effects on survival of similar-sized mammals held in captivity have been reported by Golley et al. (1965) and Markham and Whicker (1970) reported on comparative survival of free-ranging and captive pikas (Ochotona princeps). However, few data other than anecdotal observations are available on effects of radiation on behavior of unrestrained wild animals. Such information is necessary if we wish to predict possible effects of nuclear catastrophies on the natural environment.

Our hypothesis was that radiation sickness would occur following exposure and that irradiated animals would be active for a shorter time and would move over a smaller home range. This hypothesis was tested by comparing activity and movements of irradiated and control animals prior to and following irradiation. Support for this hypothesis was obtained from laboratory and field studies on birds by Wahlstroem (1969) and Schlumberger and Henschke (1956) and on mammals by Nash et al. (1970), Orr (1967) and others.

METHODS

All of the study animals were captured on the Cedar Creek Natural History Area using various methods such as live-traps and drive-nets. The first animals were captured in the spring of 1966 and the final irradiation experiments were carried out in 1970. At any given time, the maximum number of irradiated animals of a given species being monitored was six. Captured animals were brought to the laboratory where they were anesthetized with ether and equipped with a radio transmitter attached in the form of a collar. Transmitters were constructed by the Bio-electronics Laboratory at Cedar Creek to fit individual animals. Immediately following recovery from the anesthesia, animals were released at the point of capture. In all cases, animals to be irradiated and their controls were monitored for at least one month prior to irradiation to provide baseline data on behavior and activity patterns.

Radio-marked animals were monitored by the Cedar Creek Automatic Tracking System, which is capable of recording position and activity data

simultaneously for 52 animals, giving data once every 45 seconds for each animal. The system, which is based on two continuously rotating antennas located on towers 0.5 miles apart is accurate to $\pm 0.5^\circ$. Portable directional receivers were used to determine the exact location of a den or sleeping site and of dead animals.

On the day that an animal was to be irradiated, it and, if possible, the control animal were recaptured and brought to the Gamma Irradiation Facility, Department of Chemical Engineering, where the experimental animal was exposed to a 10,000 curie cesium-137 source and the control animal was sham irradiated. Animal placement within the irradiation chamber was determined by ferric-ferrous dosimetry and the actual exposure was monitored with a Victoreen rate meter. Control animals were captured for sham irradiation in approximately half of the experiments, but were monitored by telemetry in every experiment. The animals were then returned to their points of capture and released. This procedure was normally completed within four to six hours. The dose of 300 r, given at a rate of 25 r/minute, was considered to be sub-lethal for all three species (Golley *et al.* 1965 and Bond and Robertson 1957).

Data generated by the automatic tracking system are recorded on 16 mm microfilm. Bearings from the two towers to determine location by triangulation plus the state of activity are determined for each animal from the film record and are recorded on punch cards for input to a computer. Activity can be categorized as motionless, which indicates sleeping or resting, movement at the same location which may result from feeding, grooming or courtship display, and moving from one location to another. Movement of an animal causes a modulation of the radio signal which is recorded on the film record. Determination of home range size and patterns of activity were made using software programs developed for a CDC 6600 computer (Siniff and Tester, 1965).

RESULTS

Mortality

Mortality of irradiated and control raccoons within 30 days post-irradiation is shown in Table 1. No controls and no irradiated adults died; however, two of three juvenile males and three of four juvenile females died within 30 days of exposure. All deaths were presumed due to irradiation, as hemorrhaging was the only abnormality observed in postmortem examinations. The two juvenile males died on the 13th and 15th day after exposure; one juvenile female died on the 11th day and two died on the 13th day. Those animals surviving longer than 30 days were presumed to have recovered from radiation effects because they survived for many months and eventually died from causes we have observed in unirradiated raccoons. Golley *et al.* (1965) did not find any mortality in captive raccoons given 300 r. They report the LD₅₀₋₃₀ to be 580 r.

Table 1. Mortality of control and irradiated raccoons, snowshoe hares and striped skunks living under natural conditions. Each irradiated animal had a control of the same sex and age except for the juvenile female hare which had a juvenile male as its control.

Species	Number Irradiated	Deaths within 30 days post-irradiation	
		Control	Irradiated
Raccoon			
Adult males	2	0	0
Adult females	1	0	0
Juvenile males	3	0	2
Juvenile females	4	0	3
Snowshoe Hare			
Adult males	1	0	0
Adult females	7	1	0*
Juvenile males	1	0	1
Juvenile females	1	0	0
Striped Skunk			
Adult males	2	0	0
Adult females	3	0	0
Juvenile males	0	-	-
Juvenile females	1	0	0

*Radio contact with 1 irradiated adult female hare was lost on the 13th day after irradiation.

The mortality pattern of snowshoe hares revealed that only one irradiated animal, a juvenile male, died within 30 days after exposure. This hare was killed, probably by a mink (Mustela vison), on the fifth night following irradiation. No autopsy could be made. One control was killed by a red fox (Vulpes fulva) 23 days after the date of irradiation. It is possible that a second irradiated animal, an adult female, also died within 30 days. This animal dispersed from its normal home range on February 25, 12 days following irradiation, and was tracked for 3.5 miles. We were unable to relocate it on or after February 26 and therefore do not know if its radio quit functioning or if she moved beyond range of search.

Predation has been the primary cause of observed mortality in snowshoe hares. The irradiated juvenile female was killed by a mammalian predator, probably a fox, in March approximately five months after irradiation. Two other radio-marked juvenile hares were also killed by fox during this month. Since snowshoe hares have a high rate of mortality due to predation, we have no reason to believe that the deaths of the two irradiated juvenile hares were related to irradiation.

As further indication of the slight effect of irradiation on snowshoe hares, data from 1966 and 1967 reveal that both irradiated hare 225 and control 232 lived through the winter following irradiation on October 11, 1966. Both females had litters in late April 1967 and both conceived again during their post-partum estrous. In addition, neither animal lost weight between October 1966 and January 1967.

No mortality was observed in either the irradiated or control striped skunks within 30 days following irradiation. All of the experimental animals were irradiated in September or October 1970 and all survived and emerged from dens in March or April 1971. Since the normal winter denning period for striped skunks does not begin until some time in late November, the reduced effects of irradiation during "hibernation" which have been reported by Musacchia and Barr (1968) for 13-lined ground squirrels and by Smith (1960) for various mammals probably did not influence survival. Although we do not know the LD₅₀ of striped skunks, we assume that it is higher than the 300 r dose given. This assumption appears justified on the basis of lethal doses determined for other species of medium-sized wild mammals (Golley et al. 1965).

Home Range

Our hypothesis was that irradiated animals would move shorter distances and for shorter periods of time than would non-irradiated animals, and that this would result in reduced home ranges. This seemed logical in that irradiated animals might be expected to develop radiation sickness and its associated debilitations following exposure. Therefore, we measured the home range of all individuals for periods prior to and following radiation by the minimum area method of Mohr (1947) and by a method developed by D. B. Siniff based on dividing the

habitat into squares and summing the area of those squares in which the animal was located (Rongstad and Tester 1969). Both methods utilize radio tracking fixes sampled at 10 minute intervals from the microfilm record. The number of fixes on which each calculation is based varies due to the time when the radio signals were not received because of electrical interference or other limitations of the system.

A typical set of plots of home range as determined by the square summing method is shown in Fig. 1. The size and approximate shape of the home range for hare 228, a juvenile female, are similar for the 41 day period prior to irradiation compared to the 46 day period following irradiation. The home range of the control animal, a juvenile male, showed little change from pre- to post-irradiation. Such similarities were revealed frequently when plots of home ranges were examined visually. However, in some cases post-irradiation home ranges were smaller than pre-, as predicted by our hypothesis and in other cases, post-irradiation home ranges were larger, contradicting the hypothesis.

An effort was made to determine possible effects of time on home range size by calculating the home range for certain individuals for varying periods pre- and post-irradiation (Tables 2 and 3). Daily home ranges are presented in Table 2 for up to 10 days pre- and post-irradiation. These data do not reveal any obvious differences in home range size during the first days post-exposure compared to later periods. In addition, daily home ranges are frequently as large or larger following irradiation as prior to irradiation.

Home range sizes for a number of individuals for 30, 10 and two days pre- and two and 30 days post-irradiation are presented in Table 3. In general, these data indicate a considerable amount of variation both among and within species before and after irradiation. It is obvious when comparing the 2-day and 10-day or 30-day home range sizes that this value is correlated with the number of days monitored. We have considered this problem in detail (Tester and Siniff 1965) and feel that comparisons based on identical time periods are valid.

For some irradiated animals such as hare 248 and skunk 1287, the hypothesis of reduced home range size following irradiation appears supported for the 2-day periods, but data from other individuals such as hare 265 and skunk 1212 show a larger home range for the two days post-irradiation. In other cases, the home ranges of the controls change in the same way as those of the irradiated animals, thus making evaluation of the radiation effects difficult.

Normal seasonal changes in movement patterns were observed for many of the study animals. As an example, data for irradiated raccoon 620 and its control 604, both adult females, are presented by weekly intervals for 4 months (Table 4). Raccoon 620 was irradiated on October 2, 1968. No obvious change in weekly home range size occurred following irradiation. The home range size of 604 was rather consistent until winter weather in late November curtailed movement. Animal 620, however,

HARE

Fig. 1. Home ranges for hares 228 (irradiated) and 229 (control) pre- and post-irradiation.

Table 2. Daily home ranges as computed by the minimum area method for 10 days pre- and 10 days post-irradiation.

Days Pre- and Post- Irradiation	Hare 265		Skunk 1212		Raccoon 625	
	Number of Fixes	Home Range (Acres)	Number of Fixes	Home Range (Acres)	Number of Fixes	Home Range (Acres)
10					59	766.7
9			13	342.2	40	1298.8
8					130	1546.8
7			23	67.9	69	466.1
6			31	406.8	39	833.6
5			64	353.3	50	171.9
4			15	43.9	33	599.7
3	29	1.5	35	327.6	94	197.9
2	60	3.5	20	27.9	37	1822.2
1	35	4.6	26	204.4	85	554.9
1	26	.9	2	-	84	347.2
2	36	5.3	26	325.1	116	1234.2
3	17	4.5	39	70.4	32	2907.2
4	49	3.8	23	34.5	72	626.2
5	64	6.2	25	-	22	922.6
6	53	5.2	-	-	25	124.8
7	12	.6	20	4.0	86	366.4
8	40	1.7	54	348.4	62	454.1
9	91	5.7	50	862.3	8	377.8
10	76	24.0	66	458.1	15	58.3

Table 3. Home range sizes as computed by the "minimum area method" for irradiated and control snowshoe hares, raccoons and striped skunks for the indicated periods pre- and post-irradiation.

Time Period	Irradiated			Control		
	Animal	Number of Fixes	Home Range Size (acres)	Animal	Number of Fixes	Home Range Size (acres)
30 days pre		2428	65		1750	32
10 days pre	Hare	870	40		920	22
2 days pre	228	146	7	229	165	10
2 days post		181	8		196	23
30 days post		2296	67		2282	52
10 days pre	Hare	411	42		216	53
2 days pre	248	85	28	250	71	24
2 days post		56	2		37	10
30 days pre		721	25		575	99
10 days pre	Hare	499	8		286	36
2 days pre	254	94	7	260	102	13
2 days post		89	1		111	4
30 days post		-	-		528	99
10 days pre	Hare	435	30		598	9
2 days pre	264	*	*	267	*	*
2 days post		63	3		*	*
30 days pre		555	52		547	14
10 days pre	Hare	335	22		388	9
2 days pre	265	54	9	268	121	4
2 days post		81	21		200	2
30 days post		1647	64		1525	40
10 days pre	Hare	289	55		712	61
2 days pre	266	153	52	269	195	8
2 days post		44	11		111	17
10 days pre	Hare	1458	112		657	191
2 days pre	275	155	48	271	146	22
2 days post		184	8		184	65
10 days pre	Hare	733	111		789	21
2 days pre	268	155	101	285	155	8
2 days post		132	7		163	14

Table 3 continued

Time Period	Irradiated			Control		
	Animal	Number of Fixes	Home Range Size (acres)	Animal	Number of Fixes	Home Range Size (acres)
30 days pre	Skunk 1212	275	596	1284	299	61
10 days pre		197	528		206	61
2 days pre		65	241		62	54
2 days post		150	332		58	1
30 days post		318	918		570	22
10 days pre	Skunk	592	556	1280	9	18
2 days pre	1275	61	82		*	*
2 days post		142	375		*	*
10 days pre	Skunk	441	229	1280	*	*
2 days pre	1281	-	-		*	*
2 days post		-	-		*	*
10 days pre	Skunk	817	570	1279	*	*
2 days pre	1283	91	69		*	*
2 days post		123	121		*	*
10 days pre	Skunk	109	585	1288	271	247
2 days pre	1286	55	167		*	*
2 days post		19	71		26	6
10 days pre	Skunk	648	825	1288	271	247
2 days pre	1287	68	301		*	*
2 days post		62	97		26	6

Table 3 continued

Time Period	Irradiated			Control		
	Animal	Number of Fixes	Home Range Size (acres)	Animal	Number of Fixes	Home Range Size (acres)
30 days pre	Raccoon 625	1046	6198	654	1017	7685
10 days pre		337	1703		528	1748
2 days pre		18	25		125	1189
2 days post		200	1234		125	881
30 days post		1765	7552		843	9800
10 days pre	Raccoon	428	584	664	271	621
2 days pre	660	*	*		*	*
2 days post		42	107		21	40
64 days pre	Raccoon 620	2765	1587	604	2651	1325
10 days pre		563	730		645	744
2 days pre		57	229		392	615
2 days post		*	-		202	184
72 days post		3110	1568		2790	1178
10 days pre	Raccoon	338	1239	676	*	*
2 days pre	683	25	161		*	*
2 days post		91	529		*	*
10 days pre	Raccoon	578	883	699	714	889
2 days pre	698	1	*		129	181
2 days post		97	196		263	425
10 days pre	Raccoon	621	805	6015	552	676
2 days pre	6014	2	*		*	*
2 days post		186	170		129	145

*Data not completely tabulated from film record.

Table 4. Home range in acres for irradiated (620) and control (604) raccoons for 7-day intervals pre- and post-irradiation, which occurred 2 October 1968.

Begin			End			604-Control		620-Irradiated	
Month	Day	Time	Month	Day	Time	Number of positions	Home range area (acres)	Number of positions	Home range area (acres)
08	15	0140	08	21	2100	380	300.2	267	404.8
08	21	2100	08	28	1820	318	340.8	152	96.0
08	28	1820	09	04	1800	418	443.2	340	621.4
09	04	1800	09	11	1830	376	280.0	303	656.0
09	11	1830	09	18	2220	350	240.0	275	335.6
09	18	2220	09	25	1810	412	369.6	401	598.4
09	25	1810	10	02	1830	411	334.4	427	320.0
10	02	1830	10	09	1800	378	182.4	328	592.0
10	09	1800	10	16	1800	415	270.4	363	310.4
10	16	1800	10	23	1800	374	275.2	335	771.2
10	23	1800	10	30	1800	383	180.8	327	406.4
10	30	1800	11	06	1810	363	336.0	334	275.2
11	06	1810	11	13	2012	408	225.6	476	393.6
11	13	2012	11	20	1912	223	180.8	351	291.2
11	20	1912	11	27	1800	218	126.4	510	555.2
11	27	1800	12	04	1810	185	14.4	521	257.6
12	04	1810	12	12	1740	174	27.2	572	190.4
12	12	1740	12	20	0915*	220	70.4	181	185.0

*Ending time for animal 604; the last time for animal 620 was 12/14/0840.

demonstrated more variation in home range size from week to week, both before and after irradiation. In spite of this, the overall sizes of home ranges for the entire pre- and post-irradiation periods showed little change prior to winter denning (Table 5). Differences were observed, however, in the curtailment of movement with the advent of winter weather. Control 604 reduced its home range and appeared to begin winter dormancy about November 27 whereas 620 continued moving over an area of several hundred acres during this same period (Table 5). This behavior is in marked contrast to that shown by another set of raccoons radiated December 1, 1966. Both the irradiated and control animals entered the same winter den on December 2 and remained dormant throughout the winter.

One example of possible radiation effects associated with movements and predation occurred in September 1968. Juvenile male hare 248 was irradiated on September 18, 1968 and was killed, probably by a mink, the night of September 22, 1968. Its home range for two consecutive three-day periods prior to irradiation was 21 and 18 acres compared to eight acres for the three-day period following irradiation. The reduced post-irradiation home range was within the area used previously. It seems probable that this animal may have responded to the radiation stress by moving less and that it may have been less wary and therefore more vulnerable to predation. No reduction in home range was observed for its control.

It would be desirable to draw some conclusions about effects of irradiation on home range. However, even for those animals where data are complete, one can readily see that no clear relationship exists for any of the three species. It appears that if changes in movement pattern occur due to the stress of radiation, they are more subtle than our measurements of home range size can demonstrate.

Activity Rhythms

Patterns of activity and rest for irradiated and control animals were plotted for selected 24-hour periods before and after irradiation. Visual examination of these plots did not reveal any consistent changes that could be attributed to radiation. Only one animal, hare 268, exhibited an obvious change in rest pattern after radiation (Fig. 2). Although this hare showed numerous short rest periods during nights prior to irradiation, indicated by the horizontal lines in each day's record, the frequency and length of these rest periods increased markedly after irradiation. The record for its control, hare 285, does not show similar changes.

Ratios of total minutes of activity to total minutes of rest per 24-hours for periods when the radio signals enabled us to determine activity are presented in Table 6. This ratio, expressed as percent of time active, is similar to the alpha:rho ratio frequently used in analyzing circadian rhythms (Aschoff 1965). As in the case of home range, data for some irradiated animals fit our hypothesis of reduced

Table 5. Home range in acres for irradiated (620) and control (604) raccoons for selected time intervals, 1969.

Time Period	Days	<u>Home range in acres</u>	
		604	620
08-15-0140 to 12-20-0915 (All data)	128	233.2	403.3
08-15-0140 to 10-09-1800 (Pre-irradiation)	56	311.2	453.0
10-09-1800 to 11-27-1800 (Post-irradiation prior to winter denning period)	48	227.9	429.0
11-27-1800 to 12-20-0915 (Post-irradiation during winter denning period)	24	37.3	211.0

HARE 268

HARE 285

Fig. 2. Record of activity of snowshoe hares 268 (top) and 285 (bottom) living in the wild for a 12 day period, December 6-18, 1970. For each day the vertical lines indicate activity; horizontal lines no activity (interpreted as rest); and blank spaces show that the data record is incomplete. Hare 268 was captured at 0900 hours on December 16, exposed to 300 r gamma irradiation and released at its point of capture at 1630 hours (shown by asterisk). Hare 285, the control animal, was also captured and sham irradiated on December 16.

Table 6. Ratios of the total minutes of activity to total minutes of rest per 24 hours for periods when the radio signals enabled us to determine activity, expressed as percent of time active, for selected irradiated and control snowshoe hares, raccoons and striped skunks.

Animal	Percent of time active per 24-hours			
	Pre-irradiation		Post-irradiation	
	1 Day	10 Days	1 Day	10 Days
Hare 228-Irradiated	20.7	31.0	30.3	33.7
Hare 229-Control	5.6	22.1	34.4	39.3
Hare 265-Irradiated	57.6	40.6	29.2	42.3
Hare 268-Control	46.1	52.7	46.4	50.8
Raccoon 625-Irradiated	26.6	58.7	71.1	60.8
Raccoon 654-Control	28.5	59.9	75.1	62.5
Skunk 1212-Irradiated	26.9	26.0	68.3	43.9
Skunk 1284-Control	18.5	25.6	19.1	12.7

activity immediately following irradiation whereas data for other irradiated animals contradict it. For the 10-day periods, all irradiated animals showed a reduction in percent of time active following irradiation. However, some controls showed similar reductions.

Activity histograms covering periods of from 30 to 60 days before and after irradiation were prepared for selected snowshoe hares and raccoons in an effort to detect delayed effects which might become apparent during this time period (Fig. 3, 4 and 5). For each 30-minute interval on the abscissa, the ordinate shows the percent of sampling periods, i.e. days, in which the animal was moving. In general, the histograms clearly demonstrate the nocturnal activity pattern of all three species. Phase relationships or timing of onset and cessation of activity are obvious and are apparently not affected by irradiation in any predictable manner. For example, hare 228 shows a reduction in total activity following irradiation, as hypothesized; however, its control, hare 229, shows a similar reduction (Fig. 3). In contrast, hare 266 (Fig. 4) had a marked increase in total activity following irradiation as revealed by the height of the bars in the histogram.

Data for two irradiated and two control raccoons (Fig. 5) do not reveal consistent differences in percent activity following irradiation. Raccoon 620 was active more during mid-day following irradiation whereas 660 was active less during mid-day. It is interesting to note that 660 and 664 maintained their circadian rhythms even though they entered their winter den a few hours after irradiation. Timing of onset and cessation of activity remained in phase with sunset and sunrise, respectively although the amplitude was obviously decreased.

CONCLUSIONS

The presence of ionizing radiation in the environment poses a number of questions of ecological importance. However, even at doses much higher than the minimum established by regulatory agencies, it is difficult to detect effects of this radiation (Natl. Acad. Sci. 1972). Our studies support this conclusion, but do suggest that juvenile raccoons living in the wild are more sensitive to exposure to 300 r than are adult raccoons or juvenile or adult snowshoe hares and striped skunks. This sensitivity resulted in death within 30 days for five out of seven juvenile raccoons. No deaths could be attributed to the irradiation of hares or skunks.

No consistent pattern of effects of the irradiation could be detected in terms of size of home range or in activity rhythms. Some irradiated animals showed reduced home ranges and less total activity per day following irradiation, but some controls also exhibited these same changes. Furthermore, some irradiated and control animals had larger home ranges and were more active following irradiation.

Similar conclusions that ionizing radiation has little or no

Fig. 3. Activity histograms for snowshoe hares 225 and 229 (irradiated), and 232 and 229 (controls) pre- and post-irradiation.

Fig. 4. Activity histograms for hares pre- and post-irradiation. These animals were all exposed to 300 r whole body irradiation from the Cesium-137 source.

Fig. 5. Activity histogram for raccoons pre- and post-irradiation.

observable effect on behavior have been reached in other studies on toads (Tester et al. 1970) and on several species of ducks (D. F. McKinney, unpublished data). It is possible, however, that in all of these investigations the irradiation may have caused behavioral effects which were not detected.

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- Thorkelson, J. 1972. Design and testing of a heat transfer model of a raccoon (Procyon lotor) in a closed tree den. Univ. Minn., Ph.D. Thesis. (COO-1332-75).

PAPERS PRESENTED DURING REPORT PERIOD

- December 1972. Minnesota Ornithological Union Annual Meeting, Minneapolis, Minnesota. M. R. Fuller. "Status of falconry in Minnesota".
- December 1972. North Central Section, Wildlife Society, Des Moines, Iowa. I. J. Ball, Jr. "Ecology of waterfowl broods in a forested region of north-central Minnesota".
- January 1973. Beta-Beta-Beta Biological Honorary Society, University of Wisconsin at Eau Claire. S. Pierson. "Recent advances in biological telemetry at Cedar Creek Natural History Area".
- March 1973. Conference on Raptor Conservation Techniques, Ft. Collins, Colorado. M. R. Fuller, T. H. Nicholls, and J. R. Tester. "Raptor conservation and management applications of bio-telemetry studies from Cedar Creek Natural History Area".
- March 1973. Conference on Raptor Conservation Techniques, Ft. Collins, Colorado. M. R. Fuller, P. T. Redig and G. E. Duke. "Raptor rehabilitation and conservation in Minnesota".
- March 1973. Conference on Raptor Conservation Techniques, Ft. Collins, Colorado. M. R. Fuller, and J. R. Tester. "An automatic radio tracking system for biotelemetry".
- April 1973. Department of Zoology, Ohio State University, Columbus. J. R. Tester. "Telemetry techniques for studying ecology and behavior of free-ranging vertebrates" and "Effects of ionizing radiation on the ecology and behavior of selected vertebrates".
- May 1973. COSPAR Symposium; Approaches to Earth Survey Problems Through The Use of Space Techniques. Konstanz, West Germany. D. B. Siniff and V. B. Kuechle. "Remote sensing of Antarctic biological resources; Vertebrates".
- June 1973. Fifty-third Annual Meeting American Society of Mammalogists, Asilomar Conference Grounds, Pacific Grove, California. D. B. Siniff and V. B. Kuechle. "Some characteristics of the under-the-ice territory of male Weddell Seals".

LIST OF REPORTS AND PUBLICATIONS SUBMITTED WITH THIS PROPOSAL

- Andrews, R. D., G. L. Storm, R. L. Phillips and R. A. Bishop. 1973. Survival and movements of transplanted and adopted red fox pups. J. Wildl. Manage. 37(1):69-72. (COO-1332-82).
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- *Ball, I. J., Jr. 1973. Ecology of waterfowl broods in a forested region of north-central Minnesota. Univ. Minn., Ph.D. Thesis. (COO-1332-86).
- *Barrett, Julie. 1973. Breeding behavior of captive mallards. Univ. Minn., M.S. Thesis. (COO-1332-92).
- Fuller, M. R., T. H. Nicholls and J. R. Tester. 1973. Raptor conservation and management applications of bio-telemetry studies from Cedar Creek Natural History Area. Proc. Conf. on Raptor Conservation Techniques, March 22-25, 1973, Ft. Collins, Colo. (In press). (COO-1332-87).
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Thorkelson, J. and R. K. Maxwell. 1973. Design and testing of a heat transfer model of a raccoon (Procyon lotor) in a closed tree den. Ecology (In press). (COO-1332-81).

*In final stage of preparation. These reports will be submitted to AEC by August 15, 1973.

EFFORT REPORT

Percent Effort
Devoted to Project

Dr. J. R. Tester, Principal Investigator	
October 15, 1972 through July 15, 1973	25%
July 16, 1973 through October 14, 1973	25%
Dr. D. B. Siniff	
October 15, 1972 through July 15, 1973	20%
July 16, 1973 through October 14, 1973	20%
Dr. D. F. McKinney	
October 15, 1972 through July 15, 1973	20%
July 16, 1973 through October 14, 1973	0%
Mr. V. B. Kuechle	
October 15, 1972 through July 15, 1973	17%
July 16, 1973 through October 14, 1973	17%