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Radioecology of the Colorado Front Range

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Radioecology of the Colorado Front Range

The one-year Contract No. AT(11-1)-1445 was granted for the express purpose of reducing, analyzing, and preparing for publication data collected under Contract No. AT(11-1)-1191. Thus the terminal report submitted to the Atomic Energy Commission in February, 1966 under the latter contract should have carried both of the two above contract numbers. As it failed to carry Contract No. AT(11-1)-1445 and as a number of papers have been published (and as time permits, others will follow) since submission of the terminal report, the following may be considered as a terminal report for Contract No. AT(11-1)-1445 between the U. S. Atomic Energy Commission and Colorado State University.

This report will be numbered COO-1445-5 and will be divided into three sections. Section I, Publications under contract No. AT(11-1)-1191; Section II, Publications under contract No. AT(11-1)-1445; and Section III, Initial drafts of papers presently under preparation.

I. Publications under Contract No. AT(11-1)-1191

- COO-1191-1 Osburn, W.S. 1964. Technical Progress Report on Contract No. AT(11-1)-1191.
- COO-1191-2 Mericle, L.W., R.P. Mericle, and W.S. Osburn. 1963. Is Mutation Rate Significantly Altered by Five-fold Differences in Natural Background Radiation? Radiation Research, Vol. 19, No. 1.
- COO-1191-3 Mericle, L.W., R.P. Mericle, and W.S. Osburn. 1964. Somatic Mutation Rate as a Biological Discriminator of Natural Background Radiation. Radiation Research, Vol. 22.
- COO-1191-4 Mericle, L.W., R.P. Mericle, and W.S. Osburn.
& 1964. Factors Associated with Differences in
COO-1400-2 Radiation Level Discrimination. Genetics, Vol. 50:268.
- COO-1191-5 Osburn, W.S. 1963. Factors Involved in Origin and Modification of Several Types of Alpine Mass-Wasting. Presented September, 1963 as an invited contribution to the American Geographical Society.
- COO-1191-6 Osburn, W.S. 1964. Comparisons of Standing Crops Among Four Types of Alpine Plant Communities. AIBS Bulletin.
- COO-1191-7 Osburn, W.S. Accountability of Fallout Deposited in a Colorado High Mountain Bog. Abstract.
- COO-1191-8 Quick, H.F. Small Mammal Populations and Ecological Variations in an Alpine Watershed (In press).
- COO-1191-9 Mericle, L.W., R.P. Mericle. 1965. Reassessing the Biological Role of Background Terrestrial Radiation
& as a Constituent of the Natural Environment. Health
COO-1400-5 Physics II.

- COO-1191-10 Osburn, W. S. Terminal report to the U. S. Atomic
Energy Commission on Contract No. AT(11-1)-1191.
- COO-1191-11 Mericle, L. W., and R. P. Mericle. 1965. Biological
& Discrimination of Differences in Natural Background
COO-1400-4 Radiation Level. Radiation Botany.

II. Publications under Contract No. AT(11-1)-1445

- COO-1445-1 Osburn, W. S. 1965. Primordial Radionuclides: Their Distribution, Movement, and Biological Effect within Terrestrial Ecosystems. Health Physics 11 (1275 - 1296).
- COO-1445-2 Osburn, W. S., R. Foreman, and D. Jessup. 1966. Mechanisms of Radioactive Fallout Reduction in an Alpine Drainage System. Abstract. Colorado - Wyoming Academy of Science.
- COO-1445-3 Osburn, W. S. 1966. Morphological Variability: A Sensitive Indicator of Response to Ionizing Radiation. Abstract.
- COO-1445-4 Osburn, W. S. 1966. Ecological Concentration of Nuclear Fallout in a Colorado Mountain Watershed. In: Aberg, Radioecological Concentration Processes (in press) 675-709.
- COO-1445-5 Osburn, W. S. 1967. Terminal report to U.S. Atomic Energy Commission on Contract No. AT(11-1)-1445.

III: Initial drafts of papers now under preparation.

- A. Patterns of Radioactive Fallout Distributed Within the Avifauna of a High Mountain Watershed, pp. 6-27 of COO-1445-5.
- B. Primula parryi: Correlation of Morphological Variability with Background Radioactivity, pp. 28-35 of COO-1445-5.
- C. Penstemon - Environmental Responses in an Area of Relatively High Natural Background Radioactivity, pp. 36-38 of COO-1445-5.
- D. Radioactive Fallout Interception and Retention Efficiency of Several Alpine Vegetation Types, pp. 39-49 of COO-1445-5.
- E. Radiation Doseage of Several Species of Small Mammals in an Alpine Watershed, pp. 50-60 of COO-1445-5.

A. Patterns of Radioactive Fallout Distributed Within the Avifauna of a High Mountain Watershed. (rough draft of paper to be published)

W. S. Osburn

Schultz (1963) lists 328 references in his bibliography of Radionuclides and Ionizing Radiation in Ornithology. Of these references only 69 are concerned with wild bird populations. Excluding research in areas of nuclear testing or reactor environs, references are almost nonexistent. The scarcity of references alone indicates that little is known about the mechanisms of natural or fission produced radionuclides becoming concentrated in birds. Even less is known about radiosensitivity of wild birds (Willard 1960, 1963). Lack of radiation research on birds seems incongruous as interest in these animals is almost surely greater than for nearly any other group of animals, man excepted.

Birds occupy numerous ecological niches; and wherever a food source exists, there seems to be a representative from the bird world to exploit this source. They enter streams and compete with fish for food; on land birds are found in grass, shrub or tree ecosystems competing with mammals and reptiles of all sizes, they compete ably with bees and insects for nectar, and are nearly sole rulers in the air high above the ground. Some birds fly almost continuously while others cannot fly at all; some search for food in the day, others at night; some weigh only a fraction of an ounce while others many pounds; some live out their lives within a single marsh while others

annually migrate from one end of the earth to the other; some show extreme specialization and may subsist on a single food source while others are omnivorous. An attempt to untangle the complex pathways of possible radionuclide contamination in birds -- brought about by overlapping combinations of food sources, behavior patterns, and environs-- almost staggers one's imagination. However, attempts to do this may well demonstrate the value of thorough ecological studies. In this report, where ecology is reasonably well-known, many pathways of nuclear fallout concentration seem to unravel readily.

This manuscript reports the gross beta radioactivity of fission products concentrated on the skin and pelage, within the flesh, of the crop and of the preceses of nearly all the bird species commonly frequenting the alpine and sub-alpine region of a Colorado high mountain watershed. (See addendum for species list). Collections were made during autumn of the years 1962, 1963, and 1964. The radiation dosage is grossly estimated for particular birds and group of birds. Pathways by which radionuclides are concentrated within these birds or portions of these birds are discussed. The gross beta radioactivity, and in some cases radioactivity from specific radionuclides in portions of birds, are discussed.

Research Area Characteristics

The Boulder city watershed is located at 40° 04' north latitude and 105° 40' west longitude about 15 miles west of Boulder, Colorado.

Specifically, the watershed occupies approximately 11 square miles.

Between the rocky and barren continental divide, its western boundary at 13,000 feet; and its eastern boundary at about 10,000, it drops approximately 750 feet per mile. Two nearly parallel tundra vegetated ridges form boundaries on the north and south. A long lateral moraine clad ridge, supporting a dense forest largely of lodgepole pine (Pinus contorta) forms the eastern enclosure to the watershed (Figure 1).

Physiographically the region appears to be representative of the east slope of Colorado Front Range mountains at the general altitude of 10,000 to 13,000 feet.

Aerially the watershed presents a mosaic of plant communities, lakes, snowfields, bare rock outcrops, and patterned ground features. The influence of glaciers and the associated frost climate have left a strong imprint on the relatively young landscape. Approximately 1/3 of the area is covered with forests of lodgepole pine, limber pine (Pinus flexilis), spruce (Picea engelmannii) and sub-alpine fir (Abies lasiocarpa).

Another 1/3 of the area is covered with tundra types of vegetation. Lakes and streams cover approximately 4 percent of the area while the minimum yearly snowfields (perennial snowfields) cover about eight percent of this area. Bare rock or substrate having less than ten percent of its surface covered with vascular plants comprise the remainder. However, a very small percent of the watershed is covered by Sphagnum, Betula, and Salix bogs in the lower regions. Aspen groves also occur but cover less than one percent of the total area. All in all, a wide range of habitats are available for bird occupation.

See Betts (19) and Alexander (19) for pertinent information concerning birds found in the higher reaches of the Colorado Front Range.

Examination of nearly ten years of weather records obtained in this watershed by the University of Colorado's Institute of Arctic and Alpine Research reveals that precipitation is unevenly distributed throughout the year and that most of the precipitation is accounted for by relatively few storms (quote Garnsey). Though many months may receive little more than one (1) inch of precipitation (and 1/2 of this may be from one storm), excepting September and October, a full week without a measurable amount of precipitation is a relatively rare occurrence. Hence the regularity of small storms is demonstrated.

The general sequence of climatic events and the usual associated bird activities will be outlined for an entire year.

Springtime in the high country is characterized by storms of heavy wet snows with reduced wind velocities. In April 1921 (Leudlum, 1953) nearly seventy-six inches of snow fell in a 24 hour period, an official U.S. Weather Bureau record. The conditions (up-slope Mexico Gulf air) which accounted for this type of storm may be expected each spring. These storms leave a deep snow mantle over the entire region. At this time strong up-drafts of air, originating over the Plains region several thousands of feet below where summer-like conditions have produced a large number of insects, serves as an aerial pathway into the high country for winged insects. Representative species of nearly all of the winged orders of insects which normally occur in the Plains area have been found abundantly deposited on these alpine snowfields. Data to confirm that this is a general occurrence may be found in records of military explorations and from early biologists. (Caudell, 1909).

These insects become immobilized on the snow and are easy prey for early arriving alpine birds such as the horned lark (Otocoris alpestris) brown capped rosey finch (Leucosticte australis) and water pipit (Anthus spinoletta).

Summer returns abruptly to the alpine region. There is a greater increase in free air temperature during June than at any other time of the year, thus spring snow melts rapidly and the tundra soil is irrigated thoroughly. Plant dormancy is disrupted and a rapid growth sequence is initiated. June starts the nesting season of the ptarmigan (Lagopus lettcurus), pipits, horned larks, and brown capped rosey finches.

The first three species nest on the ground receiving but little protection from overhanging stones, while rosey finches nest along the cliffs. As the summer progresses young birds become evident. Plants ripen seeds, grasshoppers (Aeropedalus clavatus and Melanapplus dodgii dodgii) and mormon crickets (Anabrus simplex) mature and young birds are assured of abundant fuel from seeds and insects for later migration. However, frost, snow, and sharp drops of air temperatures to ten or more degrees below freezing may occur. Or hailstones may chill the young birds for 24 hours at a time. As this condition may take place with dramatic suddenness and is frequently accompanied by strong (35 to 45 mile per hour) winds, fledglings occasionally succumb to the harsh weather or are captured by predators such as fox, weasels, or coyotes.

As summer draws to a close and fall days materialize, birds begin to band together, and particular groups of birds may be seen sheltered or feeding in specific habitats throughout the day. Mountain bluebirds (Sialia currucoides) may be seen snatching insects (largely moths) from the air, bands of rosey finches and horned larks are usually feeding in topographic depressions where an abundance of seed producing plants are found, bands of ptarmigan are plentiful but are infrequently seen as they sit silently and unobtrusively among rocks depending upon their marvelous camouflage to go undetected, and in the evening, particularly the lower reaches of the alpine, western night hawks (Chordeiles minor hemyri) gather insects from the air and dusky grouse (Dendragapus obscurus obscurus) feed largely upon blueberries in snowbed communities. The grouse have followed the sequency of ripening fruit up from lower elevations. Ducks are in moraninal ponds, dippers (Cinclus mexicanus unicolor) along stream borders, robins and white crowned sparrows are in the krumholz region. Perhaps the most obvious and distinctive group of birds which may be seen are the hawks. In fact, each major group of hawks is represented in the avion fauna of the high country. The accipiters, are best represented by the western Goshawk (Astur atricapillus strictulus) the sharp skin (Accipiter velox) and the coopers (Accipiter cooperi). With their short, rounded wings and long

tails these hawks combine speed with great maneuverability; consequently, prey upon birds of the open tundra and among the trees of the sub-alpine forest. The marsh hawk (Circus cyaneus) a harrier, commonly is seen flying a systematic pattern of search over Carex meadows where voles (Microtis pennsylvanicus) frequently abound. These birds are especially common in late summer and early fall when field mouse populations are high. In fact, the numbers of hawks can be used as a relative measure of mouse densities.

The falcon is best represented in the high country by the sparrow hawk (Falco sparverius). Numbers of these hawks may be seen daily hovering or perched on observation points above timberline when grasshopper and mormon crickets begin to reach late stages of development. Crop examination of these birds has revealed that nearly 100 percent of their diet is composed of grasshoppers and crickets.

Buteos may frequently be seen executing lazy flatwinged spirals across wide mountain valleys as they search extensive areas from high up. Of the buteos the western red-tail (Buteo borealis calurus) or Ferruginus rough-leg (Buteo regalis) and Swansons hawk (Buteo swainsoni) are the most frequently seen.

Short intervals of cold snowy days usually in September and October foretell of approaching winter, but winter conditions seldom are continuous until the latter days of October. However, the migratory birds usually

disappear after one or two intervals of cold weather.

During the winter months (November through April) very little bird activity may be observed in the alpine region; however, on mild days a Raven (Corvus corax sinuatus) may be seen winging over the ridges or ptarmigan may be seen feeding on willow buds well above tree line, while rosey finches, may on rare occasions feed in the lower tundra region. In general, one will not see birds above tree limit during December, January or February.

A number of birds, such as dusky grouse, clarks nutcrackers (Nucifraga columbiana), pine grosbeaks (Pinicola enucleator montana), crossbills (Loxia leucoptera), Mt. Chickadees (Penthestes gambeli gambeli), and the arctic three-toes woodpecker (Picoides arcticus), may stay in the sub-alpine forests all winter.

Again different bird groups have distinctive areas of feeding. For instance, clarks nutcrackers and crossbills take advantage of the super abundance of cones of lodgepole pine and spruce. The woodpeckers feed along insect infested boles of the "over mature" trees and the chickadees are constantly searching the tips of branches.

Methods and Materials

The birds for this study were collected as a part of a larger project to establish the patterns of radioactive fallout and the processes responsible for this distribution in an alpine watershed. In general birds were collected in late August or early September. No effort was made to collect birds at all stages of their life history. Each bird was skinned, eviscerated, crop and prefeces separated and each of the four types of samples analyzed separately. Samples were ashed for a minimum of 72 hours just below 425° C and a portion of the ash counted on a Nuclear Chicago automatic proportional counting system.

The counting efficiency of the scaler was determined as follows: Three samples consisting of ashed skins, bodies, and crop contents were composited from six ptarmigan and sent to Hazleton Nuclear Science Corporation for gross beta counting and analyses for six fission produced nuclides: Sr-90, Cs-137, Ru-106, Sb-125, Mn-54, and Ce-144. From comparisons of gross beta counts a counter efficiency of 24 percent was established for the Nuclear-Chicago instrument. Regardless of the time of counting all samples were extrapolated to 1 September of the year in which they were collected.

Numerous observations were made concerning the habits of various species of birds during the three study years and over the ten years preceding this specific study.

Results (reduced data were submitted as part of the terminal report on Contract No. AT(11-1)-1191.

Discussion

A number of things are immediately apparent from an examination of the tables. The gross beta radioactivity per gram per species is quite different and these differences vary proportionally each year for various species. Further, the relationships of body parts - skin, body, crop, prefeces - varies from species to species. Some of these differences are readily explained. Specifically, birds that spend a considerable portion of their life in the air will accumulate fallout particles on and within their body surface. This phenomenon has been previously reported for ducks and jet aircraft. Birds such as clark's nutcrackers that utilize pine seeds which contain small amounts of radioactivity have reduced flesh radioactivity. Birds which have immediate environs of high radioactivity such as ptarmigan (walking among plants containing fallout on the leaves) contrast sharply with those such as water ouzels which either are moving through water or are perched on rocks away from contaminated vegetation.

Predaceous birds such as sparrow hawks, goshawks, horned owls, usually show a stepwise reduction of radioactive nuclide concentration as one moves up the food chain ladder.

Sharp differences may be observed between juveniles and adult birds (see blow) and should be expected. However, it is noteworthy that several species of birds seem to accumulate fallout at a rate more

rapid than others. This may be seen in figure where juveniles of _____ though only about 1/2 grown contain an amount of radioactivity closer to that of their adults than do juveniles of species _____ which are of a like stage.

Little or no evidence exists to suggest that the uptake of radioactivity is proportional to the rate of growth of a particular species.

Little has been published concerning the radiosensitivity of wild birds - see biological data and check Willard - but a dose of _____ rads does not seem to be an unreasonable one to use before effects become apparent. None of the birds are approaching this figure but as Sr-90 and Cs-137 is still increasing in their environment and in the tundra where calcium may be minimal it might behoove an investigator to pursue the pathways of Sr-90 or Cs-137 at all stages in the life history of several of the high mountain species. Though data are too few to present concrete arguments, it is tempting to make postulations, such as what alpine bird could be expected to accumulate the greatest load of radioactivity.

Perhaps, the black swift or night hawks should be investigated. The black swifts spend hours on the wing, are fast flyers; therefore, moving through lots of air, feed on insects at the base of cumulus clouds which may well be enriched with debris, dust, pollen, etc. in the uprising columns (responsible for the formation of the clouds). Radioactivity is probably increased because insects with fuzzy wings may wash out nuclides and be rather radioactive and birds collecting nuclides directly from the air and from their food could well result in black swifts being among the hottest of

of birds. The bat, though a mammal, has a somewhat similar type of feeding habit (although at night rather than day) and was found to contain relatively high concentrations of radionuclides.

The number of environmental pathways by which radioactivity becomes accumulated in various birds (or organs) is fascinating to conjure, and evidence from this study serves largely to tease the imagination. However, a number of considerations are discussed below. (1) The kind of nest built by the birds may modify this external radiation environment; for instance, most birds construct nests of weathered plant materials (grasses) that are soft, flayed and, consequently, relatively old and have intercepted and retained fallout nuclides from having been exposed to rain and snow. In general, the thicker the nest the greater amount of radioactivity; sometimes the linings are of particularly radioactive materials, such as willow catkins, reused nests (if protected from rain and snow tend to become less radioactive), nests on the ground may be in a more radioactive environment than those in trees; ouzels may construct nests of moss which, having filtered radionuclides from huge volumes of water, produce relatively high radioactivity counts, and exposure of young birds to radiation is further increased as these nests entirely enclose the young. (2) Longevity needs to be considered. (3) Check migratory birds and categorize as residents or migrators. This complexes the picture in that during this period of collection (August and September) some birds, such as robins, juncos, and Mt. Bluebirds, may have been taken from migratory bands which have nested elsewhere during the summer. However, looking at birds collected before and after

1 September (a reasonably good line of demarcation between residents and a mixture of residents and migrants) shows no striking difference in amounts of accumulated radioactivity. (4) Mention behavior, especially of the nervous little chickadees which are constantly in motion among conifer needles (relatively fallout contaminated) vs. flickers and woodpeckers which hunt along the bole of the tree (relatively low contamination).

Birds that spend a proportionally large amount of time flying have increased levels of radioactivity, much of which is concentrated on wing surfaces. However, critical organs of these birds may be subjected to less radiation dosage than expected as their extended wings alter the exposure geometry of their vital organs to the irradiation than birds which have their wing folded adjacent to their bodies when they are sitting alone or huddled in a covey where they may receive an additional amount of radiation from their neighbors.

Birds which take frequent dust baths may well take up an increased amount of radioactivity as the ground surface contains relatively large levels of radioactivity. Also, as the dust bath sites are recessed below the ground surface level, they accumulate surface water runoff and become increasingly radioactive as water evaporates and leaves more radionuclides behind. By use of a beta probe, it has been noted that these sites may have several times more radioactivity than adjacent soil surfaces.

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Note #1

Radioactivity of birds' feathers - can check to see if juveniles are
not - must compare adults to _____ ?

If there is a step down (per year) decrease in skin radioactivity
proportioned to decay of Ce-137 or proportional to concentration on plants
or in snow or some other means to compare years - maybe runoff of water -
one might say this species has feathers or habits which make it a
concentrator of fallout; some can be used as an index, others not.

Note #2

Animals mainly

Until proven differently, one must assume (though no real basis
for it) each group of animals (general species, etc.) will have relatively
the same discrimination efficiency to accumulate nuclides from "identical"
dietary materials. However, Longhurst, Comar, have shown that between
groups (?), wide discrimination exists to accumulate Cs-137 and Sr-90.
Pika have higher levels of Sr-90 than do ptarmigan and marmots. How
much is due to differences in food selection and how much is due physiologically
(metabolically) is important but not possible to detect.

However, take pine squirrel, clarks nutcrackers, crossbills, all eating radioactive foods of about same level (of course, some animals probably eat a lot more bulk than others) have body radioactivity quite different.

Pika data indicate they rapidly reflect the change of dietary fallout contamination.

Concentration in DPM per gram ash tissue (of several radionuclides in portions of Ptarmigan (composite of six (1963) sub-adults).

<u>Nuclide</u>	<u>Feathers & Skin</u>		<u>Stomach Contents</u>	<u>Viscera</u>
	<u>Flesh-Bone</u>	<u>MMc/g dry wt.</u>		
Strontium-90	(97.2)	88		43.5 1/28655
Cesium-137	(14 3)	54.1		65.1 11/1/64
Cerium-144	(9.07)	80.6		89.0 "
Anatomy-125	No	20.0		21.0 "
Ruthinium-106	(38.8)	69.3		124.0 "
Manganese-54	(N.D.)	17.0		48.4 "
gross beta	(879.5)	1,718		2,257 3/26/64
		382		
gross gamma	(85.8)	419		591 "

Reduction wet wt. to ash wt. of dry wt. ppcg/			Wet	Skin Ash
	39	66	63.91	4.35
	51	67	53.40	3.77
	39	68	62.40	1.93
	45	69	46.78	1.86
	43	70	67.20	2.22
93 ppcc/g	14		<u>36.49</u>	<u>2.67</u>
			330.18	16.80

Note #3 - Bird paper

Animals and birds

Int. pick up by chance a super-hot particle - quote reference -

Martel - Science article.

Animals are what they eat, i.e., the radioactivity of their flesh, in general, matches that of their food, stomach contents, etc.

Compare stomach with intestine for discrimination.

Int. when and how or what determines when animals pull nutrients or nuclides from food stuff - if eat small amount are they likely to pull more nuclides (proportionally - etc.) (during hunger periods - more complete and thorough digestion - int. a goat hotter)? ?

Mention - intestine - prefeces - counts were (on birds) quite small and some of counts probably not long enough to be valid - or occasional error in weighing - could help account for occasional erratic result.

Perhaps during periods of decreasing fallout the hide of organisms will show a negative correlation, between size (age) and amount of radioactivity.

Note #4 - Bird paper

The birds sort into several categories very readily; however, a number of circumstances cause a good deal of overlap in other categories. It is at this time of year that grasshoppers and Mormon crickets become plentiful and many groups of birds capitalize on this abundant food supply; consequently, the body burden of radioactivity converges toward that imposed on them by these food sources. The crops of Canada jays and sparrow hawks, especially, were found to be bulging with the grasshoppers. These sparrow hawks collected in August (at the beginning of feeding on the grasshoppers and still using mice) at a level of radioactivity rather low, but a sparrow hawk collected in late September, presumably after extensive and nearly exclusive grasshopper feeding had doubled its body burden and radiation.

Also, moths, in certain years are very abundant; mayflies, too, or strong updrafts may bring a new supply of food material.

Ptarmigan and grouse, too, may be influenced by these hoppers. Also, the two species of game birds may be eating lots of fruit such as blueberries (low in radioactivity) or buds of willow, or Vaccinium (high in radioactivity).

Also, a number of migrates appear - Juncos, robins especially may be reflected in the wide body variability among individuals of the same species.

Note #5 - Bird paper

Shape the same - ratio of skin wt. to body wt. .5.

1. Correlation between skin radioactivity and ratio of skin to body weight - within a group and all birds considered as a whole.
2. Correlation between skin radioactivity graph $\mu\text{pc/g}$ and are wing length - birds as a whole (use means). Basic premise is that long-winged birds have more proportionally skin surface than short-winged birds; however, might have average correlation as wing beat, more wing beats to stay aloft: wash out more nuclides.
3. Correlate skin activity with habitat - wing feeding, among tree branches, in water, among grass.
4. Flyers vs nonflyers - ptarmigan, grouse.
5. Body activity - correlate with stomach content.
6. Scavengers? - insectivorous - seeds - animal

scale insects grasshoppers fruits??
aquatic

Note #6 - Bird paper

High metabolic rate in proportion to their size; they consume enormous amounts of food - really prodigious. Smaller birds flap wings more often than large ones - wash out more nuclides. Sr-90 in bones of birds - air directly into bones as continuation? of air sacs - unique - number of feathers per unit of skin surface:

1. Relate radioactivity of feathers with percent of bird weight - that is, feathers - $\mu\mu\text{c/g}$ feathers with total weight. As premise, bigger birds - more feathers - but probably less per unit area. Correlation should exist.

2. Wing bent correlated with size.

3. Time of molt.

4. Efficient respiratory system.

5. Discuss structure of feathers as fallout sieves - preening may remove or lock particles into the mesh of oil (smearing oily secretion on feathers to hold particles, parallel barbs with a mesh-work of hooked filaments - lock into a mesh works?).

<u>Bird Feeding Categories</u>		<u>Hide (Feathers)</u>	<u>Flesh</u>
1. <u>Aquatic insect feeders</u>			
dipper (ouzel)	14	18	
spotted sandpiper	31	18	
2. <u>Predators (scavengers)</u>			
goshawk	66	7.0	
magpie	118	7.0	
sparrow hawk	31	9.25	
g. horned owl	21	4.0	
raven	--	6	
sharpshin hawk	--	7	
3. <u>Conifer seed eaters</u>			
pine siskin	38.67	11.33	
Clarks nutcracker	92.33	14.67	
crossbills	250.00	16.00	
4. <u>Insectivorous</u>			
flying - bat	846.0	54.0	
attached (aphids, scales) - chickadee	109.83	28.33	
5. <u>Seed eaters (weeds)</u>			
cassins finch	118.0	14.0	
white crowned sparrow	49.37	14.62	
horned lark	24.5	8.5	
6. <u>Omnivorous</u>			
mostly ground dwelling insects - Robin	25.5	8.5	
largely, but larger number of flying			
ones - Townsends solitaire--	47.0	12.0	
largely, but more flying ones - bluebird	50.25	11.00	
(small flying insects) - wren	27.0	11.0	
mostly flying type insects - pipet	37.0	15.33	
7. <u>Omnivorous (Misc.)</u>			
Mostly plant leaves & fruit - grouse	20.67	20.8	
Mostly fruits - Pine grosbeaks--	49.67	14.0	
Seeds shifting to grasshoppers - ptarmigan	38.17	16.0	
Insects and seeds - junco	66.62	20.25	
Grasshoppers - Canada jay	90.00	14.28	
Insects (ground, dwelling & flying) - pipet	37.00	15.33	
8. <u>Wood boring larva</u>			
woodpecker	23.00	7.5	

Bird Paper References

Willard, W. K., 1960. Avian Uptake of Fission Products from an Area Contaminated by Low-Level Atomic Wastes. Science 132 (3420): 148-150.

Davis, J. J., W. C. Hanson, D. G. Watson, and W. H. Rickard, Jr., 1962. Radionuclides in Arctic Plants and Animals. Hanford Atomic Products Operation, U. S. AEC Report HW-72500.

Schultz, V. (Bird bibliography)

B. Primula parryi: Correlation of Morphological Variability With Background Radioactivity. (rough draft of paper to be published)

Volumes of information have been accumulated concerning the distribution of nuclear fallout debris. Although the reasons for gathering these data largely are because of biological concern, excluding areas close in to nuclear test sites, few studies have attempted to directly determine if biological effects have been produced within the biota.

This paper reports the results of a study in which morphological features of Primula parryi were correlated with the levels of gross beta and gamma irradiation (mostly fission produced) to which they were subjected. The basic premise being, if there was a plant response to radiation, plants growing in sites of highest gross radioactivity would have greater departures from normal morphology. As a minimum this study provides a quantitative characterization of a group of plants which occupy sites subject to potential increase in radioactivity and may be used as a base level reference for future comparisons if background radiation increases.

Methods and Materials

Snowfields in the alpine tundra of the Front Range in Colorado have been reported to concentrate nuclear fallout to relatively high amounts (Osburn, 1963 and 1966). Upon melting, nuclear debris released from the snowfield becomes concentrated within several of the associated plant communities. One plant community which has concentrated radioactive debris to a relatively high degree is dominated by Primula parryi (parry's

primrose) plants. A project to determine whether the morphology of this plant species varied in response to various levels of ionizing radiation was conducted in the fall of 1963.

Five patches of parry's primrose were subjectively selected in four different sites characterized by late lying snowfields. Within each of these patches or stands every third plant was examined. The total height, number of flowers per spike, number of sepals and petals per each flower and the number of gross morphological anomalies of approximately 200 plants were measured or counted. Each of these parameters were correlated with the gross beta and gamma radioactivity to which the plant was exposed.

The gross radioactivity of the site was established as follows: a portable scintillation counter-scaler, E.M.I. Electronics, Ltd., with a 0.5 square decimeter probe (described by Brown, J. R., 1958) was used in the field. The probe was placed adjacent to the primrose plant and a five-minute reading was secured. The counting efficiency of the unit was established by collecting samples of the substrate, taking them into the laboratory for repeated counting, the sample then ashed and forwarded to Hazleton Nuclear Science Corporation for gross beta, gross gamma, and specific nuclide determinations.

1963 PRIMULA PARRY I STUDY

SAMPLING SITE COMPARISONS (Mean $\pm$ Standard Error)

<u>Sampling Site</u>	<u># Flowers on Spike</u>	<u>#Flowers with Abnormal Petals</u>	<u># Flowers with Abnormal Sepals</u>	<u>% Flowers with Ab- normal Petals per # Flowers on Spike</u>	<u>% Flowers with Ab- normal Sepals per # Flowers on Spike</u>	<u>Spike Height in cm.</u>	<u>Corrected KILO pC/dec² at Spike Site</u>
Niggerhead Area	7.0 $\pm$ 0.6	0.9 $\pm$ 0.3	2.6 $\pm$ 0.4	13 $\pm$ 3	37 $\pm$ 6	17.0 $\pm$ 1.2	24 $\pm$ 2
Lower Martinelli's	8.3 $\pm$ 0.7	1.0 $\pm$ 0.2	1.4 $\pm$ 0.2	13 $\pm$ 3	18 $\pm$ 4	17.7 $\pm$ 0.8	25 $\pm$ 3
Red Snow Drift North	9.6 $\pm$ 0.6	0.6 $\pm$ 0.2	1.9 $\pm$ 0.5	6 $\pm$ 2	18 $\pm$ 4	15.7 $\pm$ 0.9	20 $\pm$ 2
Red Snow Drift South	9.1 $\pm$ 1.1	0.7 $\pm$ 0.2	1.6 $\pm$ 0.3	7 $\pm$ 3	18 $\pm$ 6	13.9 $\pm$ 1.3	16 $\pm$ 2

Plants were collected in mid-August. At this time each clone had reached at least flowering maturity. Measurements of site radioactivity were made several weeks later.

Results

Reduced data were submitted as a part of the terminal report under contract No. AT(11-1)-1191. However, correlations and regressions between radioactivity and the various plant parameters, listed above, will be presented.

Discussion

Primula parryi is a perennial plant which grows along streams, and within bogs, and seeps. It may be found from approximately 9,500 to at least 12,000 feet in altitude. At higher elevations it may be a major snow bed plant. Here its growth characters are dictated by the late-lying snowfields. Occasionally the snow remains so long the plant is not able to produce a flowering stalk. However, it can produce a flowering stalk and mature its fruit within 3-4 weeks after the snowbank melts. The plant grows from a large corum, produces large spatulate basal leaves, the scapose flowering stalk typically is 1.5 to 4 decimeters tall.

The plant species is probably not very radiosensitive. Although nuclear volume has not been determined, other species of Primula are known to have small nuclear volumes (Sparrow 19). However, the floral buds are set at least eleven months before flowering and possibly 2 or more years in some cases. This would allow for a rather extended time period to accumulate a radiation dose.

The radiation environment of the primula plants varies widely between sites and may vary materially within or between years for a particular plant site. The amount of radioactive materials in the vicinity of a plant may vary according to a number of conditions. The primary pathway which determines the amount of naturally occurring ionizing radiation in the vicinity of a particular plant depends on the type of bedrock, its weathering sequence, and type of substrate.

Fission products were brought in mainly by snowfall. As the snow-fields represent areas of snow accumulation, they also represent areas of fallout concentrations, roughly proportional to the snow depth.

The amount of radioactivity to which the terminal and floral meristems are exposed depends upon the type of radionuclide, its proximity, and the types of barriers between the radionuclides and sensitive tissue. The method by which the radiation was measured makes it impossible to estimate the actual radiation dose the plants may have accumulated; thus, the radioactivity correlated with a particular plant is only a relative measure.

As the large spatulate leaves tend to intercept and channel fallout debris into the center of the plant, it is worthy of considering this pathway of meristem irradiation. In autumn of 1959 composited samples of approximately 100 washed and unwashed flowers and flower buds, washed and unwashed leaves, substrate (earth shaken from the plant roots) and of the washed corums of the parry's primrose contained per gram dry weight 201, 334, 378, 387, 813, and 108 μCi of gross beta radioactivity respectively. All of which indicates that there is some exposure due to the deposition of internal emitters.

The base of the plants is frequently immersed in water during most of the growing season. It is at this time that the plant is developing rapidly and is at its most sensitive stage (Sparrow 19). However, the water is an effective barrier to beta ray exposure and may decrease the gamma contribution slightly.

The amount of radiation exposure received by the plants can be only grossly estimated.

Assuming 1.2×10^{-9} R/hr per $\mu\text{Ci}/\text{dec}^2$ gamma radiation, 25,000 $\mu\text{Ci}/\text{dec}^2$ of gamma irradiation over a one-year period would equal an exposure of 2-3 R. However, contributions due to beta radioactivity and microsites of higher gamma concentration and five-year period of floral development might conceivably increase the "lifetime" exposure of a flower bud by a factor of 10. Regardless, we are dealing with relatively low levels of irradiation.

Very few of the parameters measured showed any degree of association with the amount of radioactivity. Specifically, the number of flowers per flowering stalk and height of the flowering stalk showed no correlation with radioactivity. The background radioactivity increased by 2,000 $\mu\text{Ci}/\text{dec}^2$ for plants having (1) normal numbers of sepals and petals; (2) to those having fewer or more sepals or petals; (3) to those having a greater or lesser number of sepals or petals. However, the standard deviation was so large the difference did not have statistical validity. Perhaps a larger number of plants should have been examined?

A 0.29 cm. change in height per each one thousand μCi of radioactivity existed. In this stand a relationship also existed between plant height and its distance from a perennial snowfield. This was also an indirect relationship to the length of the growing season; i.e., the plants farthest from the snowfield had been free of snow for progressively longer periods than plants growing closer to the snowfield.

Furthermore, as Fig. 1 demonstrates, an inverse relationship between radioactivity and distance from the center of the snowfield (all samples of the same substrate) existed. The deeper the snow, the more radioactivity it contains and the longer it lasts. Thus, either or both conditions, amount of radioactivity, and length of snow cover, could have influenced the height of the plants. In another snowfield where the plants were all released from snow cover at essentially the same time, no correlation between radioactivity and plant height was detected. This was used as evidence that the correlation between radioactivity and decrease in plant height was incidental and not a causal relationship. Further support comes from comparing plant heights and radioactivity collected from mossy sites or from gravel sites. Gravel tends to be the substrate of later lying snowfields, to have greater concentration of radionuclides but subjects plants to less radiation because of the amount of water in the substrate acting as a barrier.

Conclusions

One must know the complete ecology of a situation or erroneous conclusions may be reached. i.e., the correlation between radioactivity and plant response appeared to be cause and effect when it was really a correlation between plant response and snow depth (or growing season).

Additional Items to Discuss

1. When grouped according to substrate type, i.e. moss vs. gravel:
 - a. No significant difference in the number of flowers (per flowering stalk) per site of similar radioactivity. Significance of difference of regression lines for moss vs. gravel of number of flowers per spike vs. radioactivity-- F value of .002. With gravel substrate mean radioactivity--21,434 pCi/dec^2 , mean number of flowers per spike=8.1 and slope of line 0.0000440. For moss substrate mean radioactivity= 23,083 pCi/dec^2 , mean number of flowers per spike = 8.6 and slope of line= 0.0000413. However, there was a slight increase in number of flowers with increase in radioactivity/(with each 20,000 pCi/dec^2 increase in radioactivity an increase in one flower per spike resulted.)
 - b. Number of flowers per spike vs. height in centimeters. For each 5 cm. increase in spike height, one can expect an increase of another flower per spike. No difference existed between moss or gravel substrate.
2. Factor distribution:
 - a. Level of site radioactivity - log normal distribution.
 - b. Height of Primula parryi spikes - normal distribution.
 - c. Number of flowers per spike - log normal distribution.
 - d.

C. Penstemon - Environmental responses in an area of relatively high natural background radioactivity. (rough draft of paper to be published)

All living organisms are bombarded continuously by naturally occurring radioactivity. Since the discovery that ionizing radiation could produce biological effects, many have speculated on the effects background radiation may have on the biota. Although reports conflict greatly: Bugher's (1962) statement likely still holds: "despite much speculation we simply do not know even approximately the biological impact of natural radioactivity about us". New evidence culminating in the definitive study of Mericle & Mericle (1965) indicates that the question of the biological effectiveness of background radiation be examined carefully.

At the present time prediction of plant radiosensitivity is based largely on nuclear characteristics (Sparrow 196_, etc.). In laboratory or optimum environmental circumstances dose effect predictions correlate to a seemingly high degree for most plant species. However, as Platt pointed out in 1965, wide variations occur in field situations and combinations of variations often override responses predicted from nuclear characteristics. Platt, Caldecott, McCormick, Mericle and Mericle, Osburn and others have shown that the intensity of simultaneously operative or post-irradiation environmental factors may alter plant response to ionizing radiation. As yet no method to predict "radiation effects" upon plants or groups of plants living under other environmental stresses has yet been developed. Few experiments have been carried out investigating the interaction of ionizing

radiation and other stresses on plants and animals (McCormick). Consequently, excluding chronic radiation, no one has ventured an hypothesis whereby the total effect of these interactions would be anticipated. Under conditions of chronic radiation exposure any environmental factor which slows plant development, and thus increases both irradiation time and accumulation, usually increases the radiation response (Sparrow & Woodwell).

In order to hasten the improvement of our radiation effect sensitivity predictions, more data must be gathered, particularly concerning environmental interactions.

This paper reports the results of an ecological investigation of a population of Penstemon virens growing at a site of relatively high background radiation. The investigation period fell during a drought year and an optimum moisture year. The research suggests (1) that under particular sets of circumstances the radiation levels of a natural area are high enough to produce discernible effects in plants, (2) that stress factors can increase the radiosensitivity of plants materially, and (3) that variability can be used as a sensitive measure of radiation effects.

Methods and Materials

The geographical research area was west of Central City, Colorado, at a radioactive bostonite dike regarded by Phair (1952) as perhaps the most radioactive igneous rock on the North American continent. Physical, chemical, and radiation characteristics of the dike have previously been described by Phair (1952) and Mericle and Mericle (1965). The level of radioactivity to which plants are exposed varies between 0.05 and 0.40 R, depending on the specific microsite.

During August 1961 four ripened flowering stalks were collected from each of 100 Penstemon virens clones living in five different habitats:

- (1) radioactive dike (highest level of radiation), (2) radioactive dike (intermediate radiation level), (3) adjacent to the radioactive dike (low level of radiation), (4) cliff face (an area of extreme environmental conditions), (5) altitudinal limit (highest elevation that Penstemon virens could be found).

Two of the four stalks were selected at random, one chosen as the tallest, and a fourth picked as the shortest stalk in the clone. Each flowering stalk was measured for (1) total height, (2) number of fruits, (3) number of peduncles, (4) numbers of aborted and normally-developed fruits, (5) regularity of inter-modal lengths, (6) number of flowering stalks per clone and (7) number of gross anomalies. Means and standard errors of each parameter were calculated and comparisons made within and among the various groups.

During August, 1963, after a very dry spring, the same experiment was repeated for Penstemon growing in the first three habitats. However, since the number of flowering spikes seldom exceeded four, all were collected.

Gross gamma radioactivity was measured with a modified Nuclear Chicago survey meter and portable scaler next to each Penstemon clone. The parameters measured were then correlated with the amount of radioactivity. Also, in 1960 ten clones of Penstemon growing in sites of highest, and ten growing in sites of lowest radioactivity, were split, and one-half of the plant was transplanted back into the site and the other half placed in the opposing site. In 1964 a number of these sites were relocated and comparisons made.

D. Radioactive Fallout Interception and Retention Efficiency of
Several Alpine Vegetation Types. (rough draft of paper to be published)

Extensive research has been conducted concerning alteration of fallout nuclide composition beginning with nuclear detonation and projected until final decay. Several general and detailed models have been constructed (Miller, 1963) to depict and predict these sequences. Research has substantiated the accuracy of many compartments of these models but unproven sections exist. One of the sections which is poorly known concerns the amount of fallout intercepted and retained by various types of natural vegetation.

In particular, mechanisms responsible for differential interception and/or retention efficiency have been studied in only a few geographical regions, under a limited number of weather sequences, and for a minimum of vegetation types. Consequently, few principles to predict quantitatively fallout concentration have been formulated. Romney, et al (1964) and Martin (1965) working in a cold desert region, Richard (1966) carrying out studies in a palouse prairie region, Russel (19) reporting results from a region of relatively large precipitation and of permanent pasture, Menzel, et al (1963) experimenting with horticultural plants in a dry and a wet region, all agree that the major amount of fallout was associated with foliar deposition and in general related to total precipitation.

This paper reports the amounts of fallout* found concentrated within

*gross beta radioactivity

various types of alpine tundra vegetation at the end of the growing season of the years 1962, 1963, and 1964. Attempts were made to relate differential concentration with specific factors, such as the gross morphology and phenology of the plants, and the length of growing season. In particular, the amount, type, and distribution of rainfall and the density of the plants was considered.

Methods and Materials

Plant collections were made as follows: One-fourth square meter plots, located well within the boundaries of each major plant community type named Kobresia myosuroides, Carex scopulorum, Deschampsia caespitosa and Geum-Sibbaldia, were subjectively delimited and the plants clipped near ground level during early September. Samples were air dried to a constant weight, ashed, and counted for gross beta radioactivity.

The amount of rainfall to occur within each vegetation type during the growing season, amount of fallout to be brought to ground level during the growing season, exposure of each clipped quadrat, length of growing season, and numerous miscellaneous observations were noted.

The amount of fallout to come down per unit area was calculated as follows: Plastic lined number 10 cans (15 cm in diameter) were placed in the general vicinity of the clipped quadrats, twice during the summer the contents of the gauges were collected, the water evaporated and the residue counted in a Baird-Atomic proportional counter. The efficiency

of the counter was established by sending residue and plant samples to Hazleton Nuclear Science Corporation for gross beta counting and specific nuclide determination.

Discussion:

An examination of the picocuries per gram dry weight of plant material makes it appear as if the Kobresia community was more efficient than either of the other two types to intercept and retain fallout. However, based on the total amount of fallout intercepted per unit area and in regard to the amount of fallout which came to earth during the growing season a quite different retention actually occurred. In addition one can see that the interception and retention efficiencies of the three plant communities varies a good deal within a particular type of plant community and also the efficiency per plant community varies per year.

Each community type will be described briefly and its ability to intercept and retain fallout discussed.

Kobresia myosuriodes community

Mature Kobresia plants vary from 5 to 35 centimeters in height and spreads centrifrically by the development of short rhizomes. The center culms of the older tussocks are commonly dead, black, broken off at a common level, and may be partially covered by growths of liverworts or lichens. Each culm is stiff and slender and appears to have no special morphology to intercept or hold fallout particles.

Kobresia plants initiate growth in early spring, when the ground is

nearly saturated, and has the ability to grow, flower and fruit with the addition of little or no rainfall. However, its total productivity is quite influenced by the amount of summer rainfall.

This community type can not tolerate a winter cover of snow and is usually exposed to the full force of winds the year around. Hence wind may be an important factor by which the plants may either gain or loose fallout particles.

Because it renews growth early in the summer Kobresia plants collect a good deal of fallout. The efficiency for fallout collection in 1962 was 29% and only 8% the following year, although the total amount intercepted in 1962 was one-half of that in 1963. It is quite possible that the decrease in efficiency to collect fallout was related to the decrease in plant yield or density, which dropped about one-half from 1962 to 1963. However when samples of the same weights, from 1962 and 1963, are compared it is clearly evident the efficiency of the Kobresia to intercept and retain fallout was much reduced in 1963. One explanation of this would be that there was a change in the kind and type of fallout to come down and that Kobresia was less able to intercept the kind coming down in 1963 as opposed to 1962. However, the most plausible explanation concerns weather conditions in 1962 as contrasted to 1963. In 1962, summer rains were very light, only rarely did more than 1/4" of rain fall in one day's time. In general, the vegetation would become thoroughly wet and the rain stopped before

there was much penetration of water through the foliage. The total summer precipitation was much less than four inches of rain. In 1963, nearly 13 inches of rain fell with approximately six inches of rain falling in the four weeks prior to clipping the plants for radioanalysis. Average wind velocities were higher in 1962 than 1963 but was not excessively so and is not postulated as having a major influence on the differential fallout accumulation.

Hairgrass (Deschampsia caespitosa) stands may be located exposed to wind much of the winter but in general snow cover is moderate to deep during the winter and spring months. Typically, many of the stands are snow free by mid June but some may be covered until mid August and upon occasion they may not be snow free for an entire summer. Stands released from a winter snow cover late in the season tend to grow less than other stands.

Snow melt water undoubtedly plays an important role in the distribution of this vegetation type and the soil is moist during most of the growing season even though sites are reasonably well drained. In response to plentiful annual moisture this vegetation type consistently produces an abundance of vegetation each year regardless of the amount of summer rainfall.

The dominant plant D. caespitosa forms dense tufts and in mature stands appears to form a closed canopy. Leaves and flowering spikes are rather coarse but do not appear to have especially favorable

characteristics such as stickiness, pubescent leaves, etc., to entrap fallout. The plants grow rapidly and cover the ground quickly after the snow cover is removed. The leaves are quite flexible. Total height is variable but above timberline seldom exceeds 15-18 inches.

In 1962, the hairgrass community intercepted an average of 77% of the fallout which was measured to have been brought to the ground. The correlation between the total radioactivity and total dry weight per each $1/4 \text{ m}^2$ plot was . A regression analysis showed that for each 10 gram increase in dry weight of plant material resulted in a gain $4 \times 10^3 \text{ } \mu\text{mc}$ of gross beta activity. With few exceptions quadrats which had more than 60 grams of vegetation (dry wt.) failed to retain this total amount of fallout as measured to have come down. In fact, several of the clipped quadrats contained significantly more radioactivity than was measured to have come down. This was interpreted as evidence that the plants almost surely gained some radioactivity from wind deposition.

In one instance in 1962 and in 1963 a sample of the ashes of the hairgrass counted approximately 100 times higher than any of the others. By covering portions of the planchet it was determined that nearly all of the radioactivity was due to one small point within the sample. The occurrence of such hot particles has been previously reported but usually from areas closer to the Nevada test site.

In 1963 the fallout interception-retention efficiency was reduced from 77 to 21%. This reduction agrees quite closely with that of the Kobresia community. However, the yield of dry matter in the hairgrass meadow was almost as high in 1963 as in 1962 which tends to discredit yield change as a total explanation. Again it would appear that the difference in weather between the two seasons is the major factor explaining differential efficiencies.

Carex scopulorum

This type of community is dominated by the sedge Carex scopulorum which can grow in a wide range of circumstances but forms dense stands in areas supplied with an abundance of water. Usually the best stands are located at the base of late lasting snowfields. Typically the stand is not snow covered much of the winter though it can tolerate a snow cover. Plants can tolerate standing water sites but they do not grow nearly so well as they do when the ground is reasonably well drained.

The productivity of this community type may be quite high and as it is irrigated by a prolonged supply of snow-melt water, its annual productivity is consistently high.

The culms of this plant are coracious with some surface hairs but otherwise it has no conspicuous characteristics to collect fallout.

The effeciency of this plant community to collect fallout was intermediate to that of Kobresia and Deschampsia when total amounts are compared. However, when one examines the amounts of fallout

intercepted by the same amounts of vegetative matter per quadrat, it was much less efficient than either of the other community types. In 1962 for every ten grams increase in plot productivity the picocuries gross beta activity increased 1.86. Another bit of evidence that bears out relative efficiency to intercept is from radioanalysis of hay from pika (Ochatona principis) piles of hay. Instances where the Carex composed a major portion of the hay were always much less radioactive.

It would appear that Carex scopulorum while inefficient to collect fallout in 1962 was relatively efficient in 1963. It is possible that the average fallout particle size in 1963 was smaller than in 1962 and that the coracious leaves retained the particles better than in the previous years. It may simply be that the more densely plant covered stands tend to be more efficient to intercept fallout during periods of time of high rain. That is if the fallout is washed or blown off the upper leaves lower ones catch and retain it- where there is less impact from rain or wind.

One other factor assumes importance. The amount of Cs-137 in the samples of the three plant types increased from 1962 to 1963 but in the Carex increased by a factor of nearly 4 while it no more than doubles in Kobresia and Hairgrass.

It was found that Carex can and does translocate Cs-137 from the leaves to overwintering buds. In the case of the 1962 samples it is almost a surety that a portion of the Cs-137 had been translocated from the leaves, hence a lower count of radioactivity. Carex plants in 1963 had not progressed as far towards winter dormancy at the date of collection as they had in 1962.

Note

Nuclide Analyses Interpretations of Clipped Quads

One must interpret the per cent of specific nuclide composition intercepted during 1962 and 1963 with a number of things in mind.

1. Certain plants have their morphological optimum period of vegetative interception at different times. That is Carex scop. might be "green and growing" and have lots of little hairs on leaf blades functioning during August, and lose them at maturity. Carex scop. can be "green" from early season- June - to late October. Yet another year earlier or later. Heavy August 1963 rains would certainly affect nuclide results if actively growing plants probably would absorb nuclides from leaves and metabolize them -- if not actively growing the particles might be held on leaves for short time, then washed off.

2. Of course, time of year that clip quadrats were secured has a big effect on nuclide content of plant if translocation is a factor. It certainly seems to be a very important factor at least in case of Cs-137 and Carex scop. and possibly Kob. It is possible, too, that Ce-144 is translocated or samples were mixed during processing.

3. As the average particle size of fallout decreases, the efficiency of particular plants to trap and retain it may also change. i.e. dense very small hairs might retain particles less than 0.1 micron very effectively but not particles of greater size. That is, average size of delayed fallout particles decreases through time the efficiency of various species to intercept and retain fallout may well change also.

Check for evidence - may be why Carex and Kob both went (?) up in total catch - but not as much as Hairgrass.

4. Some plants might have a high interception ability and/or a low retention ability--high interception related to density--yet the morphology of the leaves may be such that material is easily washed off--that is plants--thus the ability to function as to fallout interception and retention may be related to environmental conditions. Under dry conditions one plant may be very efficient, during low rainfall; yet, another year this same plant (even if average fallout particle size remains relatively constant) might be quite inefficient under periods of intense rainfall.

In comparing 1962 and 1963 data it seems that density is of top importance in intercepting fallout, but the amount retained is less a function of plant density.

Fallout Interception-Retention Efficiency

Collecting efficiency of the foliage surfaces for particles of different sizes, environmental factors, such as wind, rainfall amount, and intensity, morphology of the plant, rose , channels to axils, etc., efficiency in terms of retained per gram of dry foliage, mature plants (appear to be correlated with particle size of the deposited fallout).

Amount taken up by roots is not considered (but it could contribute). Also disregarded was amount that might have been deposited by wind on wet surfaces, dust from erosion and settling, etc. assuming that all of activity is from fallout.

Foliage contamination factor should depend on type of plant, the height or age of, humidity (dew or rain on leaves), fallout particles may be lodged between the sheathing base of the leaf and stem.

Fallout retained by the plant foliage is directly proportional to the surface density of the foliage.

E. Radiation Doseage of Several Species of Small Mammals in an Alpine Watershed. (rough draft of paper to be published)

Since the advent of nuclear fallout volumes of information have been published concerning the distribution of fallout debris, especially in regard to man's immediate environment. Pathways of fallout contamination leading to man have been examined extensively and are reasonably well understood. In contrast to this, the radiation doseage wild animals are receiving from natural and fission produced radionuclides is scarcely known.

This manuscript reports the radiation dosage accumulated by species of small mammals during one summer in a Colorado high mountain region. The doseage is shown to be related to particular species, to the age of the animals, and to specific habitats.

See Osburn 1963 for a discussion of climate.

During the summer of 1964 as a portion of a project attempting to determine and explain the pattern of fallout concentration in an alpine watershed the small mammal population was censused on three occasions (Quick, 1965). On the final census in September 150 animals trapped from five different plant communities were analyzed for gross beta radioactivity as follows. Sixty of the animals were ashed whole, 35 separated into skin, stomach contents, and body fractions. Each sample was counted on a 5% level of confidence in a Nuclear Chicago automatic proportion counter. Efficiency of the counter was determined from counting ashed samples of small mammal flesh and skin and sending the

samples to Hazleton Nuclear Science Corporation for gross beta counting and examination for the following nuclides. Ce-144, Ru-106, Cs-137, Sr-90, Mn-54 and Sb-125. Doseages were calculated largely after Comar (19), however a number of assumptions had to be made. (1) That the entire beta radioactivity was absorbed, (2) that the gross radioactivity of each animal would continue to rise until they were adults, (3) that this level would remain constant throughout the fall and winter and that these animals would all live until the following April, the beginning of a new breeding season (4) that the beta activity was due to _____ % Ce-pr, _____ % _____ % Cs-137 _____ % etc.

The external radiation environment was measured by a portable beta monitor. The amount of radioactivity that penetrated a layer of _____ grams per centimeter aluminum foil was multiplied by _____ an efficiency factor calculated as follows. Surface soil samples of a measured area and depth were collected, air dried, weighed, ashed, weighed again, and sent to Hazleton Nuclear Science Corporation for gross beta and gross gamma counting and nuclide determinations. From the gross gamma counting an efficiency factor of _____, on dry soils, was calculated. However, it is known that radioactivity is greatly attenuated by soil water. However, as this gamma radiation was originating in the upper 1-2 centimeters of the soil for the purposes of dosage estimation, the wetness of the soil was

ignored. However, this dosage is regarded as a conservative estimation as the small mammals could receive gamma irradiation from well below this 1-2 centimeter depth and from the concentration of Cs-137 and other gamma emitters on surrounding vegetation.

In all, the sample was broken into a number of sub-samples. See table on figure X.

Results

Results were submitted under terminal report AT(11-1)1191.

Discussion

A number of things are immediately apparent upon examination of the tables. It is evident that the radiation dosage from internal emitters, is higher in some species than in others, see T test, that the radiation load from external radiation sources are higher for animals occupying certain habitats, that the "radiation load" varies with species and with the habitat in which they are living. Further, the accumulation of gross radioactivity is log normally or linearly related to weight (indirectly age) of the mice.

The LD₅₀ has been determined for a number of laboratory strains of mice but has yet to be determined for wild mouse populations living under natural circumstances. By using the LD₅₀ (reference Biological information) one can see that even the projected accumulation for the small mammals is still far below that necessary to produce lethal effects. However, two considerations must be taken into account: (1) Effects have been detected in laboratory mouse strains at far lower levels; (2) Environment stresses such as intense cold, strong wind, and reduced food supplies may place the

animals in situations very nearly at the limit of their ecological tolerance. It is known that shrews and mice must replenish their bodies with food roughly equal to their own body weight every twenty-four hours (dormancy of 1 species) or succumb. Also, the author has observed *Peromyscus* and *Micratus* to die within minutes upon removal from snowbank protection and exposed to wind cold during the winter.

Also, population density may influence. It could be that mice evicted from more favorable habitats (in the lesser populated sites) could become more radiosensitive.

Discuss each species separately to explain their relative load of radiation. Start with so much is fetus and gain from rubbing off from environment--wet or dry--and from eating either seeds, grasses, etc. Also, dormancy may reduce radiation effects.

Summary

State number of mice examined from _____ number of habitats. Levels of radiation, etc. Biased sample--all were young of the year. High percentage of juveniles to sub-adults reflect rate of animal turnover.

Birds too.

Animals that lick their fur and groom their coats a lot may well have high level of internal radioactivity.

Results

Most results were submitted under terminal report No. AT(11-1)1191.

1962 ppt-fallout-intercept

Precipitation

June 1-9 = 1.00

9-15 = .00

15-22 = .20

22-30 = .00

July 1-6 = .50

6-12 = .10

12-19 = .40

19-26 = .40

26-31 = .20

Aug. 1-7 = .20

7-15 = .05

15-22 = .45

22-31 = .10

Growing Season

Kobresia = 1 June to 1 September

Carex Scop. = 9 June to 1 September

Hairgrass = 21 June to 1 September

Geum-Sibbaldia = 21 June to 1 September

Amount of Fallout Possible to Intercept During Season

(a) Kobresia	2.20"	- 3,000 $\mu\mu\text{c}/\text{can}$	) 2,037 $\mu\mu\text{c}/\text{dec}^2$
	1.30"	- 748 $\mu\mu\text{c}/\text{can}$	) 203,700 $\mu\mu\text{c}/\text{m}^2$
(b) Carex scop.	1.20"	- 1,650 $\mu\mu\text{c}/\text{can}$	) 1,303 $\mu\mu\text{c}/\text{dec}^2$
	1.30"	- 748 $\mu\mu\text{c}/\text{can}$	) 130,300 $\mu\mu\text{c}/\text{m}^2$
(c) Hairgrass	1.00"	- 1,375 $\mu\mu\text{c}/\text{can}$	) 1,154 $\mu\mu\text{c}/\text{dec}^2$
	1.30"	- 748 $\mu\mu\text{c}/\text{can}$	) 115,400 $\mu\mu\text{c}/\text{m}^2$
(d) Sphagnum moss	May	- 3.00)	
		)	
	June	- 1.82)	4,938 $\mu\mu\text{c}/\text{dec}^2$
		)	
	July	- 1.68)	493,800 $\mu\mu\text{c}/\text{m}^2$
		)	
	Aug.	- .77)	
		)	
		7.27")	

1963 ppt fallout intercept data

<u>Growing season</u>	<u>inches of rain</u>
Kobresia - 25 May to 1 September	12.81
Carex scopulorum - 2 June to 1 September	12.40
Deschampsia - 10 June to 1 September	11.26
Juncus - 20 June to 1 September	8.11

Plants are not very efficient interceptors till they are about a week or two along.

Probably are less efficient after losing green color.

	<u>inches</u>
May 21-31	0.60
June 1-7	1.05
7-14	1.10
14-21	2.25
21-30	0.10
July 1-7	0.35
7-14	0.36
14-21	0.09
21-31	1.20
August 1-7	2.25
7-14	1.95
14-21	.65
21-31	1.15

(1963 Continued)

<u>Intercept</u>	$\mu\text{pc}/\text{dec}^2$
Kobresia - $12.81 \times 950 =$	12,169
Carex - $12.40 \times 950 =$	11,780
Deschampsia - $11.26 \times 950 =$	10,697
Juncus - $8.11 \times 950 =$	7,704

<u>Vegetation Type N</u>	<u>Dry Wght gm/m²</u>	<u>Radioactivity Intercepted gross beta /m²</u>	<u>Gross beta Activity Dep. /m² growing season μpc</u>	<u>Fallout Interception & Retention Efficiency</u>
Kobresia (8)	63.6 ± 5.6	$99,508 \pm 10,864$	1,216,900	8.1%
Carex Scopulorum (12)	244.8 ± 40.0	$212,024 \pm 51,456$	1,178,000	17.9%
Deschampsia (5)	176.0 ± 18.4	$222,956 \pm 25,504$	1,069,700	20.8%
Juncus (12)	194.4 ± 13.2	$222,488 \pm 30,000$	770,400	29.1%

Comparison of fallout interception and retention efficiency between years:

	<u>1962</u>	<u>1963</u>	<u>Percent Reduction</u>	<u>Percent Change in Standing Crop</u>
Kobresia	29.0	8.1	72	48% reduction
Deschampsia	76.8	20.8	73	8% reduction
Carex scopulorum	37.1	17.9	52	4% increase
Juncus drummondii	97.8	29.1	70	12% reduction

In 1963 almost all of the Juncus growing season was during the period of heavy rains.

Juncus grows in areas of alluvial accumulation; therefore, it is likely one has contamination from overland flow of water. Juncus stands have high productivity. Also, this stand is difficult to clip without getting a lot of the previous season's growth and therefore contamination.

Clipped Quadrats 1962

<u>Community Type</u>	<u>μpc/sample</u>	<u>μpc/gram</u>	<u>weight/l/4m²</u>	<u>N</u>
Kobresia myosuroides	14,978 ± 1,611	501 ± 23	30.5 ± 3.3	20
Deschampsia caespitosa	22,177 ± 3,867	437 ± 37	47.6 ± 4.2	25
Carex scopulorum	12,105 ± 1,436	215 ± 20	58.7 ± 6.7	15
Carex pyrenaica	45,278 ± 15,392	769 ± 243	57.0 ± 5.3	3
Juncus drummondii	27,385 ± 2,804	528 ± 71	55.1 ± 8.7	5
Geum rossii	12,133 ±	326	37.2	4*
Gopher garden	24,618 ± 6,233	531 ± 166	52.1 ± 20.3	3
Geum Sibbaldia	6,325 ± 480	579 ± 88	11.1 ± 0.85	3
Mature Lodgepole Pine	6,825 ± 1,980	270 ± 10	25.5 ± 7.3	4*
Caltha leptosepla	9,264 ±	204	45.4	4*
Ligusticum	30,562 ±	371	82.3	4*
Geum carex sage	11,429 ± 3,403	300 ± 78	44.0 ± 22.8	3
Spruce fir	2,544	330	7.7	4*
Parry's clover	9,112	241	37.8	4*
Calamagrostis	6,648	83	80.0	4*

Clipped Quadrats 1963

Kobresia myosuroides	24,877 ± 2,716	1594 ± 71	15.9 ± 1.4	8
Deschampsia caespitosa	55,739 ± 6,376	1297 ± 206	44.0 ± 4.6	5
Carex scopulorum	53,006 ± 12,864	802 ± 99	61.2 ± 10.0	12
Juncus drummondii	55,622 ± 7,500	1125 ± 128	48.6 ± 3.3	12

*composited

For Vegetation-Interception-Retention Paper

Comparison of Gross Beta Radioactivity within and
Between Tussocks and Between Various St and Types

Stand Type	ON			BETWEEN			LITTER		
	n	piC/dec ²	error of the mean	n	piC/dec ²	error of the mean	n	piC/dec ²	error of the mean
Hairgrass	16	57,254 ±	4,679	36	34,588 ±	1,213	7	73,768 ±	9,567
Juncus	13	68,631 ±	4,738	25	67,873 ±	3,262	13	103,417 ±	10,562
Geum-Sibbaldia	17	27,235 ±	1,551	27	15,895 ±	490	4	39,335 ±	4,813
Carex pyrenaica	11	40,502 ±	1,970	10	31,748 ±	2,014	9	78,020 ±	4,166
Kobresia	12	19,307 ±	755.2	16	31,384 ±	1,273	--	-----	
Carex scopulorum	17	84,852 ±	4,477	22	33,949 ±	1,172	4	66,420 ±	2,817