DOE/ID-12111
June 1987

Summaries of the Idaho National Engineering Laboratory Radioecology and Ecology Program Research Projects

O. Doyle Markham

Idaho National Engineering Laboratory

U.S. Department of Energy • Idaho Operations Office

DISCLAIMER

DOE/ID-12111

SUMMARIES OF THE IDAHO NATIONAL ENGINEERING LABORATORY RADIOECOLOGY AND ECOLOGY PROGRAM RESEARCH PROJECTS

Compiled by O. Doyle Markham
June 1987

Radiological and Environmental Sciences Laboratory
U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 83402

CONTENTS

RESEARCH SUMMARIES

ACKNOWLEDGMENTS

This report provides summaries of individual research projects conducted by the Idaho National Engineering Laboratory Radioecology and Ecology Program. Summaries include projects in various stages, from those that are just beginning, to projects that are in the final publication stage.

The research discussed in this report was funded primarily by the Office of Health and Environmental Research, U.S. Department of Energy and the Division of Waste Products, U.S. Department of Energy through the Fuel Reprocessing and Waste Operations Division, Idaho Operations Office. Funding and equipment were also provided by various universities associated with this program and the U.S. Fish and Wildlife Service through the Cooperative Wildlife Research Units in Montana, Iowa and Wyoming. Associated Western Universities, Inc. also provided support to this program. The technical assistance of many dozens of people is gratefully acknowledged.

Results from studies on this program have been published in a variety of technical journals. A list of these publications is provided in the publication entitled "Publications of the Idaho National Engineering Laboratory Radioecology and Ecology Program: 1974-1986," DOE/ID-12109.

RESEARCH PERSONNEL
INEL RADIOECOLOGY AND ECOLOGY PROGRAM

PROJECT MANAGER

O. Doyle Markham, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy, 785 DOE Place, Idaho Falls, IDaho 83402

PRINCIPAL INVESTIGATORS

Timothy D. Reynolds, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy, Idaho Falls, Idaho 83402

Susan K. Rope, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy, Idaho Falls, Idaho 83402

Jay E. Anderson, Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

Stanley H. Anderson, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming 82071

I. Joseph Ball, Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana 59812

Louis B. Best, Department of Animal Ecology, Iowa State University, Ames, Iowa 50011

Jerry J. Bromenshenk, Department of Zoology, University of Montana, Missoula, Montana 59812

Robert L. Eng, Department of Biology, Montana State University, Bozeman, Montana 59717

Lester D. Flake, Department of Wildlife and Fisheries Science, South Dakota State University, Brookings, South Dakota 57007

Les Fraley, Jr., Department of Radiology and Radiation Biology, Colorado State University, Ft. Collins, Colorado 80523

George E. Hart, Department of Forest Resources, Utah State University, Logan, Utah 84322

Shawki A. Ibrahim, Department of Radiology and Radiation Biology, Colorado State University, Ft. Collins, Colorado 80523

James B. Johnson, Department of Plant, Soil and Entomology, University of Idaho, Moscow, Idaho 83843

Barry L. Keller, Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

John W. Laundre', Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

Robert S. Nowak, Department of Range, Wildlife and Forestry, University of Nevada at Reno, Reno, Nevada 89512

Lorentz C. Pearson, Department of Biology, Ricks College, Rexburg, Idaho 83440

Kenneth L. Petersen, Biology Department, Monmouth College, Monmouth, Illinois 61462

Leon R. Powers, Biology Department, Northwest Nazarene College, Nampa, Idaho 83651

RESEARCH STAFF

Michael Abbott, Department of Radiology and Radiation Biology, Colorado State University, Ft. Collins, Colorado 80523

Paul E. Blom, Department of Plant, Soil and Entomology, University of Idaho, Moscow, Idaho 83843

Richard Cronn, Department of Zoology, University of Montana, Missoula, Montana 59801

John C. Grant, Department of Zoology, University of Montana, Missoula, Montana 59801

Bruce F. Goff, Department of Forest Resources, Utah State University, Logan, Utah 84322

Frank P. Howe, Department of Wildlife and Fisheries Science, South Dakota State University, Brookings, South Dakota 57007

Steve T. Knick, Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana 59801

William E. Moritz, Department of Biology, Montana State University, Bozeman, Montana 59717

Mark L. Shumar, Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

Michael P. Stafford, Department of Plant, Soil and Entomology, University of Idaho, Moscow, Idaho 83843

Nancee L. Toft, Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

Martha C. Wackenhut, Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209

Mark Wheeler, Biology Department, Northwest Nazarene College, Nampa, Idaho 83651

LONG TERM VEGETATION STUDIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Vegetation studies were initiated at the INEL in 1950 with the establishment of 94 permanent sample plots at systematic intervals along two perpendicular transects that totaled 120 km in length. Two plots were destroyed prior to 1957, but the remainder have been maintained for ecological studies.

Livestock have been excluded from the central portion of the INEL since 1950, which provides a unique opportunity to study long-term dynamics of sagebrush steppe in the absence of grazing. For this purpose, we chose 35 of the original plots based on their floristic similarity. We assumed that these plots represented a random sample from a relatively homogeneous plant community. These plots have been free from grazing or major disturbances such as fire since 1950. Earlier investigators concluded that the area was heavily grazed prior to 1950.

Data were collected in 1950, 1957, 1965, 1975, 1978, 1983 and 1985. Crown cover of shrubs and basal cover of perennial grasses were measured by line interception on two 15.2-m transects, and density of all vascular plants was recorded for 20 0.3- x 1-m quadrats, at each plot.

In 1950, the 35 sample plots were dominated heavily by big sagebrush. Perennial grass cover amounted to only 0.3%; shrub cover was 18%, with big sagebrush contributing 89% of that total. By 1975, total cover of shrubs and perennial grasses was 32%, nearly double that of 1950; shrub cover was 154% of the 1950 value, and grass cover had increased about 17-fold. Shrub cover increased by about 50% between 1957 and 1965, but then remained constant through 1975. Perennial grass cover increased exponentially from 1950 to 1975 (1981: J. Range Manage. 31:25-29).

Since 1975, cover of both perennial grasses and shrubs on the 35 plots has decreased markedly. Total shrub cover decreased from 27% in 1975 to 19% in 1983; it was 24% in 1985. These changes are largely attributable to sagebrush; the density of big sagebrush has decreased, particularly during the last decade. These data are substantiated by casual observation and data from other studies that show widespread mortality of sagebrush at the INEL. The second most abundant shrub, green rabbitbrush, has shown a modest but steady increase in cover from 1.3% in 1950 to 6.2% in 1985. Cover of perennial grasses decreased from 5.3% in 1975 to 3.3% in 1983 and 1.4% in 1985. All of the common perennial grasses have shown parallel declines in cover. However, the density of these grasses has increased, particularly during the last decade.

The highest coverages of perennial grasses occurred on plots having relatively low shrub cover. Cover of perennial grasses was negatively correlated with shrub cover during those years in which perennial grass cover was highest. The relative year-to-year variation in grass cover was much higher than in shrub cover.

The average number of species recorded per plot has increased steadily over the 35-year period. With the exception of the density data for shrubs, this pattern was apparent for all growth forms. This increase in average species richness suggests that species which were rare on the study area in 1950 are becoming more common and widespread.

REVEGETATION OF DISTURBED AREAS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

The goal of revegetation is to establish on disturbed sites a relatively stable community of desirable plants that will 1) stabilize the soil and minimize erosion, 2) resist invasion by undesirable species, 3) have a low maintenance requirement, 4) provide forage for wildlife or domestic stock, and 5) be aesthetically pleasing. The relative emphases of these items depend on the objectives of individual projects. Often it is desirable to re-establish native species on the site.

Revegetation research at the INEL includes 1) the establishment of an experimental garden, 2) trial seeding of decommission/decontamination sites, 3) seeding of a 2-ha demonstration plot, and 4) seeding grasses and transplanting shrubs onto areas disturbed by the excavation of three trenches across the principal linement.

The experimental garden was established in the fall of 1983 at the INEL Experimental Field Station to evaluate the establishment and growth of plant species that are commonly used for reclamation in the Intermountain West. Thirty varieties (15 grasses, 8 forbs, and 6 shrubs) representing 24 species were planted; 14 of the species are native to the INEL. Numerous cultivars for which seed are commercially available were included. Establishment and cover were evaluated by line interception in 1984 and 1986. Three species, two forbs and one shrub, failed to establish initially; two species of grasses were lost between 1984 and 1985. Vigorous stands of most of the others became established and increased in coverage between 1984 and 1986.

Based on their establishment and apparent vigor in the experimental garden, species were chosen for planting at two decommission/decontamination sites in the fall of 1984. At the Borax V site, various species of grass were seeded along with several species of forbs into test rows. Grass cover was measured and the number of forbs counted in each row in 1986. Exotic grasses such as crested wheatgrass consistently had higher cover than the native species. In most test rows, low cover of grasses was associated with a high number of forbs; however, three of the exotic grasses had high coverage despite the presence of a large number of forbs.

In November of 1982, a 2-ha plot of sagebrush steppe near the INEL Experimental Field Station was severely disturbed by disking and then tilling with a "Rotovator". Three sections were planted with different mixtures of seeds of native species; two strips were left unseeded as controls. Seven of eight species of grasses and two shrubs, winterfat and four-wing saltbush, that were seeded became established. There was also substantial recruitment from the residual seed bank on all plots. By 1986, vascular plant cover was about 20% in all sections, which approached that of natural sagebrush communities in the area.

In the fall of 1985, a revegetation project was initiated on an area that had been disturbed by the excavation and back-filling of three trenches across the principal linement. Various combinations of grasses were seeded in replacement series to study potential competitive interactions. Two species of shrubs were transplanted onto four plots; the results of these transplant trials are discussed in the summary "Transplanting Wild Plants."

TRANSPLANTING WILD PLANTS FOR REVEGETATION OF DISTURBED SITES

The use of transplants to establish cover on harsh sites is an important technique for reclaiming arid land disturbances. Typically, container stock or bare-root stock from greenhouses or nurseries is used. On the INEL, we have found that for small disturbances such as construction sites, decommission-decontamination sites, and hazardous waste disposal sites, transplanting wild plants from nearby native communities may be a convenient, economical method for establishing plant cover.

Approximately 400 giant wildrye, 600 crested wheatgrass, 2,000 green rabbitbrush, and 3,000 big sagebrush individuals were transplanted between 1983 and 1985 for various research projects. Plants were moved in the late fall when they were quiescent, but before the ground was frozen. Bunchgrasses, 15-20 cm in basal diameter, and shrubs, 15-30 cm tall, were removed from the soil by driving the length of a spade-point shovel into the ground next to the plant and lifting out the plant and a shovel full of soil. Shrubs were placed into a 15-20 cm plastic or metal pot. The bunchgrasses typically had a root mass that held the soil in place; thus they were usually moved without the use of a pot. Plants were taken to the revegetation site and placed in holes large enough to hold the plant and all the soil transported with it. The root masses of the bunchgrasses were covered with loose soil. Shrubs required a little care in transferring them from the pot to the hole to prevent all the soil from falling away from the roots. This was done by holding one hand over the top of the pot, turning the pot over, pulling off the pot and quickly turning the plant and soil right side up into the hole.

Survival of transplanted crested wheatgrass plants was near 100%, and there was no evidence of any negative impacts of transplanting. Phenology, growth and reproduction were comparable to that in the "parent" stands. Survival of giant wildrye and big sagebrush plants was lower than that of crested wheatgrass, but it was still excellent (about 85-90%). Both species appeared to suffer considerable "transplant shock" the first year after transplanting. Growth, flowering and overall vigor of wildrye plants were much lower by comparison than that of crested wheatgrass. However, wildrye plants grew vigorously, and sagebrush plants appeared normal two years after transplanting. Green rabbitbrush appeared to suffer the most transplant shock (70% survival) of the four species. These plants grew well in the second year after transplanting.

In conjunction with a study on evapotranspiration from waste disposal sites (see summary "Control of the Soil Water Balance in a Cold-Desert Environment"), we have data on soil moisture extraction by three of the four species transplanted. Both bunchgrasses removed water from the soil down to 1.6 m in the first year after transplanting. Sagebrush extracted water down to 1 m. By the end of the second growing season, all three species were removing water from a depth greater than 2 m. These data suggest that there was a tremendous proliferation of roots from these transplanted wildings in a relatively short period of time.

The use of wild plants offers a fast, economical, and effective means for establishing plant cover on severely disturbed sites. The technique takes advantage of locally adapted populations and does not introduce new species or foreign genetic material to the area.

SOIL EROSION STUDIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Shallow land burial of low energy wastes can create a major disturbance and erosional problem at western DOE sites. The main goals of these studies are to evaluate native grasses as erosion controlling mechanisms and to develop improved prediction technology for semi-arid sagebrush ecosystems.

A series of runoff-erosion plots were installed for measuring erosion both from natural precipitation and from simulated summer rainfalls. Seven plots on simulated trench caps of lake-bed sediments have been vegetated with streambank wheatgrass and with crested wheatgrass. Nine other plots on native silt loam soil were treated so that three are undisturbed sagebrush/grass; three are completely bare with both canopy and litter removed, and three are clipped so that only litter is present.

Erosion from snowmelt and natural rainfall has been monitored since winter 1986. The 1986 and 1987 snowmelts were small and yielded only minute amounts of erosion. Natural rainfalls were also small, under 1.27 cm/day, and failed to produce much erosion. Rainfall of 5.08 cm over 4 days in May 1987 did give substantial soil loss, particularly from the lake-bed sediment plots.

A series of rainfall simulator runs representing "dry," "wet," and "very wet" moisture conditions were made in August 1986. Average values of runoff and erosion from three plots are given below:

Treatment	Rainfall Condition	Moist (%)	Rain (cm)	Runoff (cm)	Erosion (T/a)
Streambank WG	30 min @ 5.6 cm/hr	4	3.0	0.711	.540
Crested WG	30 min @ 5.6 cm/hr	4	3.0	0.003	.009
Sagebrush	60 min @ 5.6 cm/hr	2	5.6	0.038	.004
Bare	60 min @ 5.6 cm/hr	2	5.7	0.282	.268
Sagebrush	30 min @ 5.6 cm/hr	17	2.9	0.079	.018
Bare	30 min @ 5.6 cm/hr	20	2.9	0.577	.486
Sagebrush	30 min @ 5.6 cm/hr	28	3.0	0.119	.022
Bare	30 min @ 5.6 cm/hr	29	3.0	0.795	.723

The results are tentative because the treatments have been in effect for only several months. There appears to be greater erosion from the streambank wheatgrass than from the crested wheatgrass plots. However, the streambank grass had not become fully established (25% canopy cover vs 49% canopy and litter on the crested wheatgrass). In addition, surface cracks and fissures were observed more frequently on the crested wheatgrass plots, and these have resulted in much less runoff and erosion than from the streambank plots.

The plots with sagebrush vegetation on native soil had low erosion rates--never exceeding 20 kg (.022 tons)/acre. This reflects the high degree of protection provided by canopy (46% cover density) and surface litter (41% cover density). The bare plots, with no canopy or litter, yielded greater erosional losses: 245 kg (.27 ton)/acre with "dry" conditions, 445 kg (.49 ton)/acre under "wet" conditions, and 653 kg (.72 ton)/acre under "very wet" conditions. These bare plots responded quite differently and we believe that microtopographic relief, presence of vesicular soil crusting, and different initial amounts of grass/forb biomass may be responsible, in part, for the variation in erosion from bare plots.

ROOT DEPTH OF SPECIES ON THE IDAHO NATIONAL ENGINEERING LABORATORY

The use of shallow land burial is one method of waste disposal for nuclear and some other types of toxic waste materials. After burial, the soil covering the wastes is normally seeded and the area managed for a few ten's of years. Maximum stability of the site and minimum movement of the waste from its buried location are primary management goals. These criteria are for the short-term, i.e., during active site management, and long-term, i.e., after active site management ceases. Vegetation plays an important role in both objectives and over both time periods.

One aspect of vegetation is root growth and distribution. This is important because it affects soil stability, water and nutrient balance, and potential root penetration into, and transport of, the buried wastes. Little information is available on root dynamics of most native species - the species that will ultimately invade a waste burial area.

A research project was initiated to determine the root depth and spread of native and exotic species that presently, or will ultimately, occupy the Subsurface Disposal Area on the Idaho National Engineering Laboratory.

The root depths of big sagebrush, green rabbitbrush, birdbeak, squirreltail bottlebrush, and giant wildrye were determined at an undisturbed site using P-32 and Rb-86 as radiotracers. At the disturbed site, the species were big sagebrush, green rabbitbrush, giant wildrye, Indian ricegrass, and crested wheatgrass. The soil was spiked with the tracer at a specified depth, the hole was partially backfilled, and the plant sampled after the roots had an opportunity to regrow in the spiked soil.

Maximum measured root depth and horizontal spread were:

Species	Undisturbed Depth and Spread (cm)		Disturbed Depth (cm)
big sagebrush	225	100	200
green rabbitbrush	190	40	200
birdbeak	160	80	---
giant wildrye	160	100	200
squirreltail bottlebrush	100	40	---
Indian ricegrass	---	---	150
crested wheatgrass	---	---	150

In 1987, a more intensive study was started using plants that were set out or seeded in a backfilled trench. An undisturbed area, adjacent to the trench, planted with the same species will be used for comparison.

Results of this study have application in determining the depth of soil necessary to cover buried wastes, the potential for buried waste penetration by roots over long time periods, and the potential for uptake and transport of the buried wastes.

ROOT DEPTHS AND LATERAL SPREAD OF SELECTED NATIVE PERENNIAL SHRUBS AND GRASSES IN DISTURBED AND UNDISTURBED SOUTHEASTERN IDAHO SOILS

The root distribution of seeded and successional shrubs and grasses at shallow land burial waste sites will affect the sites' soil stability and soil moisture level. In addition, deeply penetrating roots may contact and translocate certain types of waste material to the aerial portions of the plant enhancing the probability of contamination spread.

A study was initiated in May 1987 to determine the root depths and lateral spread of two native shrubs and four grasses that were set out or seeded in 1985 in the disturbed soil of a backfilled trench. For comparison, root distribution of the same species planted in an adjacent undisturbed area will also be determined. The species under study are Wyoming big sagebrush, green rabbitbrush, 'Sodar' or streambank wheatgrass, 'Ephraim' crested wheatgrass, basin wildrye, and squirreltail bottlebrush. Each species was set out or seeded in 12.2 by 15.2 m plots. Half of each plot consists of the deeply disturbed soil of the backfilled trench, while the other half was only shallowly disturbed for planting.

The root depths and lateral spread will be determined by using I-131 as a soil injected radiotracer. Iodine-131 has been shown to be rapidly absorbed by plant roots from the soil-water solution and translocated to the aerial portions of the plants. It emits gamma and beta radiation that is readily detectable either in the field or in the laboratory using simple counting techniques. An experiment conducted in the Spring of 1987 determined the diffusion and stability of an injected I-131 solution in the study plot soil. In addition, field trials were conducted with sagebrush to determine the optimum concentration and quantity of the tracer solution.

Holes are drilled into the soil in each species plot to six different depths and metal conduit is inserted. The I-131 solution is injected into each conduit and root uptake is allowed to occur for 5 days. Plants at various lateral distances to the tracer injection point are then sampled and counted to determine if I-131 uptake has occurred. Tracer activity that is significantly greater than background samples indicates minimum root extension to the tracer injection location at the bottom of the conduit.

ROOTS IN SIMULATED WASTE DISPOSAL TRENCHES

The broad goal of the research program is to examine vegetative factors that affect the integrity of shallow-land waste disposal trenches. This specific project primarily involves two investigations: 1) the relationship between rooting characteristics of plants and water extraction from the soil profile; and 2) the development of a plant-based, ecophysiological model of the transpirational component of the hydrologic water balance.

Root growth has been monitored in the native plant community as well as in monoculture plots of four species: Basin wildrye (Leymus cinereus), crested wheatgrass (Agropyron desertorum), Sodar, a cultivated variety of streambank wheatgrass (Elymus lanceolatus var. Sodar), and Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis). Monoculture plots were established on simulated waste disposal trenches in the fall of 1983 and spring of 1984. Root intensity along the glass windows in root boxes was measured periodically during the growing seasons of 1984 to 1986. In 1986, soil cores were extracted from the soil at the same time that root intensity measurements were taken in order to measure root density.

Roots of plants in the monocultures quickly explored the entire soil profile. By the end of the first growing season after transplanting, all species except Sodar had roots as deep as they could be observed (1.9 m). Sodar only produced roots to a depth of 1.6 m, but it was the only seeded species and the only species planted in the spring of 1984.

Roots of Sodar and crested wheatgrass were more uniformly distributed in the soil profile than Basin wildrye and big sagebrush. Root distribution of Sodar and crested wheatgrass tended to be bimodal, with slightly greater roots at shallow (near 0.4 m) and deep depths (1.2-1.6 m). Root intensity of Basin wildrye peaked at about 1.0 m whereas big sagebrush peaked deeper within the soil profile.

Basin wildrye produced the greatest total amount of roots in the soil profile. Big sagebrush, crested wheatgrass, and Sodar had progressively lower allocation of resources to roots. Although differences existed among the species in their rooting characteristics, the amount of water extracted from the soil profile was similar among the species. Thus, the root systems of Basin wildrye and big sagebrush were less efficient than those of Sodar and crested wheatgrass in terms of the amount of water extracted from the soil profile relative to the amount of root length produced in the soil profile.

The development of a plant-based, transpiration model has consisted of data collection, analysis of gas exchange data, and parameterization and verification of a transpiration model. Data collected include meteorological conditions, response of stomates to individual and diurnal environmental conditions, and seasonal changes in biomass production. Gas exchange data for crested wheatgrass has been analyzed and initial parameterization of a conductance model completed. Verification of the model will occur at two levels of resolution: 1) diurnal measurements of conductance; and 2) whole-plot transpiration using productivity and soil water content measurements.

ROOT DISTRIBUTION AND EFFECTIVENESS OF BIOBARRIERS

Maintaining the integrity of the soil cover is of primary importance in the management of waste materials at shallow land burial sites. Reduced erosion and withdrawal of moisture from the soils over interred wastes are two benefits of planting vegetation on shallow land sites. A potential drawback of having vegetation over wastes is the possibility of root intrusion into wastes or contaminated soils, and subsequent translocation of some types of contaminants to above ground tissues. Because many arid and semi-arid plant species have deep roots, a physical barrier to prevent root intrusion may be needed at shallow land burial sites for some contaminants in xeric communities.

An experiment was implemented at the DOE Experimental Field Station to assess the effectiveness of these biobarriers on the root distribution of four plant species. Moreover, the experimental design allowed an indirect assessment of the evapotranspiration of the four plant species. The barriers were lake-bed soil, a mixture of gravel and cobble, and scoria (highly vesicular basalt). Plants species were big sagebrush (Artemisia tridentata), Great Basin wildrye (Leymus cinereus), streambank wheatgrass (Elymus lanceolatus), and crested wheatgrass (Agropyron desertorum). The combination of lake-bed soil and crested wheatgrass mimics the situation at the SDA and was the benchmark against which all other combinations were to be compared.

There were seven replicates of each of the 12 possible combinations of barrier and plant species. Biobarriers and plants were placed in 25 cm by 1.2 m PVC cylinders capped at one end. Each cylinder was placed within a larger diameter (30 cm) PVC sleeve buried vertically in the ground. About 10 cm of soil was placed in the bottom of every cylinder. This was covered with nearly 50 cm of barrier material, which in turn was covered with over 60 cm of lake-bed soil. A resistance-type soil moisture unit was placed just above the barrier/lake-bed soil interface. Plants were transplanted from native or cultivated stock in the fall of 1984.

Although the analysis of moisture data is not complete, it appears that all four plant species can reduce soil moisture from about 35% (by volume) to 13% over the growing season; effectively withdrawing most, if not all, of the available soil moisture.

Root distribution and depth will be determined in the summer of 1987 after the plants have had 3 years of growth. The inner PVC cylinders will be withdrawn from their sleeves and laid horizontally. A saw will be used to remove the upper surface of the cylinders, and root penetration into barriers will be assessed. In addition, root material will be removed from 20 cm increments of each cylinder soil profile, dried and weighed. These data will provide information on the vertical root distribution of each species.

CONTROL OF THE SOIL WATER BALANCE IN A COLD-DESERT ENVIRONMENT

A major problem associated with the burial of hazardous materials is intrusion of water into the waste zone. The presence of water may result in the growth of plant roots into the waste zone and the subsequent transport of toxic materials to aboveground foliage. Percolation of water through the waste zone may transport toxic substances into ground water.

Vascular plants play a unique role in the hydrologic cycle by extracting water from soil below the shallow depths affected by evaporation. Thus, the potential exists to control the soil water balance by manipulating the vegetation. In semiarid regions, where potential evapotranspiration (ET) greatly exceeds precipitation, it is theoretically possible to preclude water from reaching interred wastes by providing a sufficient cap of soil to store the portion of the annual precipitation that falls outside the growing season and an adequate plant cover to deplete soil moisture reserves during the growing season.

This study was initiated to examine the capacity of different types of plant cover to deplete soil moisture and prevent deep percolation. The objectives were to 1) compare ET and patterns of soil water extraction among four species when grown in monoculture, 2) determine the effective water storage capacity of the soil under different vegetation types, and 3) recommend a minimum depth of soil for waste-trench caps that would be adequate to store the annual precipitation and preclude deep drainage.

Eight simulated waste trenches were established in the fall of 1983. Each 3- by 10.7-m trench was excavated to a depth of 2.4-m and then filled with the soil that is used for capping trenches at the INEL Subsurface Disposal Area. A monoculture of each of four species was established on two trenches. Sagebrush, crested wheatgrass, and giant wildrye plants were transplanted from adjacent natural stands in November 1983. Streambank wheatgrass was seeded onto two trench plots in March 1984. Volumetric soil moisture was measured by neutron scattering. ET was estimated by summing precipitation and the change in soil moisture; runoff and deep drainage were assumed to be negligible.

Transplanted crested wheatgrass extracted 276 mm of water from the soil during the first growing season, using virtually all of the plant-available water. The other species extracted less water, but ET from all stands was well over the average annual precipitation for the study area (224 mm). In the second year, all four species extracted water from the entire 2.4-m profile and used most of the available water. Despite phenological and morphological differences among species, patterns of water depletion were generally similar. The grasses depleted soil water content to a lower limit of about 11%; the lower limit for sagebrush was 12%. The effective water storage capacity of the soil was 20% by volume. A trench cap of 1.4-m of soil should be adequate to store precipitation received outside the growing season and preclude drainage into interred wastes, provided that the site is contoured such that no runoff is received from adjacent areas and no ponding occurs. Stands of any of the perennial grasses included in this study, or sagebrush, will use all of the plant-available soil water during a growing season, thereby resetting the water storage capacity of the soil.

PHOTOSYNTHETIC AND STOMATAL RESPONSES OF CRESTED WHEATGRASS AND GIANT WILDRYE TO WATER STRESS

Physiological responses of two perennial bunch grasses to water availability were studied under field and laboratory conditions. Crested wheatgrass is a naturalized species in the Great Plains and Intermountain Region of North America. Giant wildrye is an indigenous perennial bunch grass of the Intermountain West. Based on current hypotheses regarding the responses of photosynthesis and stomatal conductance to conditions that occur in a semiarid environment, we predicted that: 1) stomata would respond to humidity such that stomatal conductance to water vapor would decrease with increasing water vapor gradient (WVG), leading to a midday depression in conductance and photosynthesis; 2) photosynthesis and conductance would remain high over a wide range of soil water availability and then decline when most of the soil water is depleted and plant water stress develops; 3) conductance would be correlated to maximum photosynthesis (under favorable conditions of temperature, light and WVG) for plants differing in water status; 4) there would be no difference between species in their responses.

Field studies were conducted at the INEL. The plants were grown in monocultures on 3 m by 10.7 m plots that contained a homogeneous clay-loam soil to a depth of 2.4 m (simulated waste trenches). In laboratory studies, plants were grown in pots 1 m in height that contained about 44 kg of dry soil and 18 l of water at field capacity. Water stress was induced in one-half of the plants by withholding water from the pots. Physiological characteristics monitored were photosynthesis, transpiration, conductance, and plant and soil water status.

In field studies, the diurnal courses of photosynthesis, conductance, and transpiration were similar for crested wheatgrass and giant wildrye. When soil water availability was high, conductance remained high during the day, resulting in substantial losses of water through transpiration in the afternoon. When the availability of water was low, both species showed a strong depression in conductance, which greatly reduced water loss. Photosynthesis and conductance decreased with decreasing leaf water potential for both species. However, crested wheatgrass had lower photosynthetic rates and conductance than giant wildrye at a given water potential when the plants were under severe water stress.

In the laboratory experiment, water stressed plants of giant wildrye extracted more water from the soil than crested wheatgrass. Photosynthesis and conductance remained high over a wide range of soil water content and then declined at 15 to 20 % of extractable soil water. Giant wildrye had higher photosynthetic rates and conductance than crested wheatgrass when well watered. However, the responses of these gas exchange parameters to water availability were similar at low soil water contents. Stomatal conductance decreased with increasing WVG for both species.

The magnitudes of conductance and maximum photosynthesis for field and laboratory plants were correlated. As photosynthetic capacity decreases due to increasing water stress, the corresponding reduction in conductance leads to conservation of water.

These results are consistent with the first three predictions given above. Although the physiological responses of the two grasses were generally similar, giant wildrye was able to extract more water from the soil in pots and maintained higher transpiration and photosynthetic rates to lower water potentials than crested wheatgrass.

A COMPARISON OF GAS EXCHANGE CHARACTERISTICS OF TWO SUBSPECIES OF BIG SAGEBRUSH GROWN IN A COMMON GARDEN

Sagebrush, genus Artemisia, is a common element of the plant communities in the arid Intermountain West. Several species and subspecies within this genus have distributional patterns that reflect microhabitat differences. Subspecies of big sagebrush (A. tridentata) are sympatric on the upper Snake River Plain of Idaho. Basin big sagebrush (A.t. tridentata) is restricted to relatively mesic sites with deep soils, while Wyoming big sagebrush (A.t. wyomingensis) dominates the more abundant drier sites with shallower soils. The two subspecies are similar phenologically although A.t.t. plants are larger where the two grow together. There are hybrids of the two subspecies in some locations but these are not common. Genetic studies have shown that while populations of basin big sagebrush (A.t.t.) are diploids (2n), populations of Wyoming big sagebrush (A.t.w.) are frequently tetraploids (4n).

To examine the possible physiological bases for the observed distributional differences between these subspecies, individual from local populations were transplanted into plots in a common garden at the INEL in the fall of 1983. Plots were assigned to receive one of three watering treatments: unirrigated (natural precipitation only), light irrigation (natural precipitation and light supplemental additions), and heavy irrigation (natural precipitation and heavy supplementation). Soil moisture was monitored on all plots with a neutron probe. Gas exchange data were collected on individuals in both the unirrigated and heavily irrigated treatments. Changes in canopy dimensions were monitored for all treatments.

Although all individuals were about the same size when the plots were established, by the end of 1985 A.t.t. plants were larger than A.t.w. plants for all treatments. For each subspecies, plants in irrigated plots were larger than plants in unirrigated plots. Under natural precipitation, A.t.t. plants developed more severe leaf water deficits than did A.t.w. plants, presumably because the larger A.t.t. plants depleted the available soil moisture more rapidly. Gas exchange responses to standardized diurnal protocols were similar for both subspecies within watering treatments early in the summer although A.t.w plants had slightly higher assimilation rates. Irrigated plants of both subspecies continued to show similar responses throughout the season but unirrigated plants differed by midsummer as plant water stress increased. Conductance in both subspecies decreased as leaf-air water vapor gradient increased, and a midday depression of assimilation was observed in stressed plants of both subspecies. However, the magnitude of the depression was greater in A.t.t. plants. Additionally, stressed A.t.w. plants exhibited more complete afternoon recovery in response to decreased water vapor gradient than did A.t.t. plants. The physiological responses to unfavorable conditions of the two subspecies are similar; therefore, we suggest that genetic limitations on plant size are an important factor in conferring an advantage to A.t.w. plants on drier sites.

WATER AND NITROGEN AMENDMENTS IN SEMI-ARID ECOSYSTEMS

The overall goal of this research program is to investigate functional and mechanistic processes in semi-arid ecosystems in order to predict the influence of disturbance on three major ecosystem processes: production, nitrogen cycling, and water dynamics. The program utilizes a two-factor field experiment: control plots that have natural precipitation and soil nitrogen levels, plots that receive supplemental irrigation, plots that are fertilized with nitrogen, and plots that are both irrigated and fertilized. This specific project will investigate the effects of these water and nitrogen treatments on water use efficiency and resource (carbon and nitrogen) allocation.

Field measurements of water use efficiency and resource allocation will start during the 1987 growing season. Instantaneous measurements of water use efficiency will be made with gas exchange techniques. Nitrogen concentrations of individual leaves used for gas exchange will be determined in order to estimate how efficiently the plants use nitrogen to fix carbon. Aboveground and belowground biomass production and nitrogen concentrations will be measured to investigate carbon and nitrogen allocation to different plant parts. Soil properties (texture, pH, etc.) have been measured, and soil nitrogen pools will continue to be sampled.

A greenhouse experiment was conducted during the 1985-1986 winter to determine the effects of nitrogen concentration and form on carbon and nitrogen allocation in Indian rice grass (Oryzopsis hymenoides) and Sodar, a cultivated variety of streambank wheatgrass (Elymus lanceolatus var. Sodar). To examine plant response to nitrogen concentration, a 3:1 ratio of nitrate-N to ammonium-N was applied at two different levels of total nitrogen. To determine if plants were sensitive to the form of nitrogen, nitrate-N only and ammonium-N only were applied at the lowest and highest concentration level of total nitrogen.

For Indian rice grass, biomass production per tiller was not affected by the form or concentration of nitrogen. However, biomass production per tiller for Sodar was affected by nitrogen concentration. The effects of nitrogen concentration on tiller biomass of Sodar were dependent on the form of nitrogen: although biomass per tiller increased with increased nitrogen concentration when either both forms of nitrogen or nitrate-N only were applied, production was smaller at high concentrations of the ammonium-N only treatment.

For both species, the average number of tillers per plant at the lowest nitrogen concentration was significantly lower than that at the highest concentration. This result was independent of the form of nitrogen applied.

The form and concentration of nitrogen significantly affected reproductive allocation in Indian rice grass. The highest number of reproductive tillers and seed heads occurred at the second lowest nitrogen concentration. If nitrogen was applied as ammonium-N only, reproductive output was almost completely suppressed.

Further data analysis from this experiment will examine soil nitrogen concentrations, root production, and plant nitrogen concentrations.

WATER AND NITROGEN DYNAMICS IN A SAGEBRUSH-STEPPE ECOSYSTEM

The soil water balance and nutrient cycling in semiarid ecosystems is strongly influenced by the plant community. The vegetation exerts biotic control over water balance by extracting soil moisture for transpiration. Transpiration is intrinsically tied to photosynthesis; plants gain carbon only at the expense of losing water. The availability of nutrients, especially nitrogen, may limit photosynthetic capacity, which may, in turn, limit transpirational losses. Nutrient availability may also affect the amount of carbon gained for a given amount of water transpired, i.e. water use efficiency.

Under the framework of the DOE Arid and Semiarid Lands Research Program and in cooperation with investigators at Pacific Northwest Laboratories, the Nevada Test Site, and the Piceance Creek Basin in Colorado, we have initiated a study of the effects of water and nitrogen amendments on carbon and nutrient cycling and soil water dynamics of a sagebrush steppe ecosystem. The intersite research program will allow comparisons of processes and responses to disturbance among different arid ecosystems. A major objective of the project at INEL is to examine both water use and water use efficiency in the context of current hypotheses that link transpiration and photosynthesis.

The study design calls for four treatments: 1) addition of water to simulate a maximum precipitation year, 2) addition of nitrogen (100 kg/ha), 3) addition of both water and nitrogen (same levels as 1 and 2), and 4) control (no added water or nitrogen). During the summer of 1986, we randomly identified and permanently staked 16 25-m^2 plots at the INEL Experimental Field Station. Baseline data on vegetation and soils were collected, and neutron access tubes for monitoring soil moisture were installed. Monitoring of soil moisture levels began in the fall of 1986 and will continue at monthly or biweekly (during the growing season) intervals. A drip-irrigation system was installed on each plot. In April 1987, the nitrogen treatments were applied and supplemental watering was begun. Additional water will be added at the beginning of each month, through the growing season, to bring the monthly total precipitation up to the maximum observed in the past 34 years. Estimates of peak biomass will be obtained for each of the plots. Leaf tissues from three of the dominant species of grasses and shrubs will be sampled periodically for carbon-isotope composition.

The carbon-isotope composition of a leaf provides an index of water use efficiency integrated over the lifetime of the leaf. Water use efficiency is a consequence of stomatal conductance and photosynthetic capacity. Stomatal conductance is influenced by the availability of water; photosynthetic capacity is influenced by the availability of nitrogen. Consideration of these interactions within the framework of the "stomatal optimization hypothesis" leads to the following specific hypotheses that we will test: 1) the plant community on all plots will use all of the plant-available soil water during the growing season; addition of water will increase water use and decrease water use efficiency, 2) if nitrogen or both water and nitrogen are limiting to plant growth, addition of nitrogen will increase water use efficiency, and 3) patterns of water use and water use efficiency will be consistent across species.

COMPUTER MODELING OF WATER FLOW AND EROSION ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Several computer models have been designed to aid in predicting water flow patterns and erosion for watersheds. All of these models have been initially designed for specific geographic areas with unique soil characteristics and climatological patterns. Before the models can be used for predictive purposes in other parts of the U.S., climatological data bases need to be compiled for the region of interest. The models then need to be verified by running them under soil and vegetation parameters specific to that region. Results of such runs need to be compared with existing information on soil water movement and erosion. Once realistic patterns are postdicted by the model for known conditions, it then can be used as a predictive tool for that region.

To aid in predictive efforts on the INEL, two computer models, CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) and ERHYMII (Ekalaka Range and Hydrology and Yield Model), were chosen for verification and modification. The goals of this project were to 1) compile the necessary data needed to verify the chosen computer models, 2) make any modifications in the models necessary so they are applicable to climatic conditions on the INEL, and 3) modify models to incorporate findings from the project on water flow relative to mammal burrows.

Climatic and watershed data bases pertaining to the INEL were compiled for each model. These data bases were used to generate model outputs which were then compared with information on actual soil moisture estimates for the years simulated. Tabulated watershed values supplied in the user's manuals for each model were used for initial runs of the models.

Initial outputs by both models did not concur closely with empirical data. Predicted soil moisture based on the CREAMS model was consistently higher than field estimates. Onset of recharge was also much later than field data indicated. Wilting points recommended by the CREAMS user's guide are based on standard -15 bars pressure. Plants on the INEL are able to extract water to a much lower level. Subsequent runs relied on wilting points based on the lowest moisture levels recorded for the particular soil under consideration. This alteration in the data base brought the predicted and actual seasonal lows in soil moisture in concurrence.

The CREAMS model initiated snow melt when the average daily temperature was above $0^{\circ}C$. Although the average daily temperature can be below freezing, the daily maximum temperature can be well above freezing and snow melt can occur. Based on 30 years of temperature data, the maximum daily temperature will rise above freezing when the average temperature is $-6^{\circ}C$. When the snow melt subroutine in CREAMS was changed to initiate snow melt at -6 rather than 0°, model output patterned field data more closely.

Similar changes in wilting point and snow melt are being made with the ERHYMII model. Work is also continuing on comparing evapotranspiration and erosion output with field data as they become available from other ongoing projects. Data on the effects of small mammal burrows on water infiltration will also be incorporated into model subroutines.

RELATIONSHIPS BETWEEN ANTS, APHIDS AND INSECT HERBIVORES ON SAGEBRUSH

Sagebrush plants used as aphid pasture and foraged by Formica workers generally had lower densities of insect herbivores (excluding aphids) than ant-excluded plants. Populations of the exposed larval defoliator, Bucculatrix tridenticola, were reduced to a greater degree by ants than were populations of Lepidoptera species which feed in protected environments, e.g. leaf-tiers or case-bearers. This suggests that feeding adaptations can influence the survival of larvae on ant-foraged sagebrush. Excluding aphids, fluid-feeding insects, especially Cicadellidae, were less abundant on ant-foraged plants. Aphids, however, form a mutualistic relationship with the Formica species in which the ants protect the aphids in return for honeydew. Only individual aphids were observed on the ant-excluded plants as aphids were not able to colonize sagebrush plants in the absence of Formica. The numbers of predators, including spiders, were somewhat lower on the ant-foraged plants. In most cases, the abundance of flies on the ant-foraged plants was greater as a result of their attraction to aphid honeydew. Species richness did not differ between the controls and treatments but species diversity was higher on the ant-excluded plants.

Sagebrush plants supporting aphid colonies could benefit from decreased levels of herbivory resulting from ant predation. Benefits should be directly related to herbivore densities. At some point, the costs of supporting the aphids outweighs the benefits due to lower rates of herbivory, and the aphids would become a liability to the sagebrush. Aphid colonies usually declined and disappeared in July as the plants became water stressed. It is suggested that the seasonal pattern of water stress observed in sagebrush could provide a mechanism preventing aphids from overexploiting their host and that the ant-aphid-sagebrush interaction could be beneficial for all three species involved.

INTERACTIONS OF THE HARVESTER ANT WITH SOIL, WATER AND VEGETATION

Cursory observations indicate that the INEL supports an abundant ant fauna (ca. 38 species) of which the harvester ant could be considered the most obvious member. This investigation explores the direct and indirect impact the harvester ant could have on movement of radionuclides and water in both areas of nuclear waste disposal or contamination and in native habitat.

Soil of nine harvester ant nests within the perimeter of the SL-1 waste storage area were sampled, processed and analyzed by gamma spectrometry. Preliminary results suggest that mounds have a higher level of contamination than 3-m distant control soils. Further, levels in the clearing soils, presumably due to secondary transport of the contamination by erosive forces, are generally higher than those found in the mound. Soil beneath the mound also appears to have higher concentrations than the control soil, though lower than the mound and decreasing with depth. We are sampling two additional sites which differ in contaminative characteristics. Test Reactor Area radioactive leaching ponds present a situation for potential soil contamination through lateral leaching with subsequent vertical transport by the ants to the surface environment. The Borax reactor is an area where surface soils are contaminated with large particles and covered with a shallow covering of gravel and soil.

The western harvester ant has been shown to be important in the process of soil formation. In addition, they have the potential to alter soil microclimate characteristics which may affect waste management areas. Comparisons of soil water and temperatures in the nest soils (below mound and clearings) and adjacent vegetated and naturally denuded soils are under way. Preliminary results show a trend toward differences between the mound, clearing and vegetation profiles in the upper 60 cm. Experimentation with infiltration rates for the same profiles under various levels of artificial precipitation are planned for the coming season.

Supplementing the moisture and temperature information will be a comparative description of the nest and adjacent soils with an analysis of particle size and exchangeable ion distribution.

Nesting behavior of the harvester ant involves excavation of subterranean galleries and chambers. Utilizing resin and latex casting materials volume to depth relationships for the ant's tunneling is being investigated.

As the NERP hosts a diversity of plant communities and soil types, data is being gathered on harvester ant densities and colony size in several of these major areas.

USE OF HONEYBEES FOR MONITORING CONTAMINANTS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Honeybees collect nectar, pollen, water, and resin from up to several kilometers from the hive. The overall pattern of bee foraging is a rapidly changing mosaic of forage patches (1985: Honeybee Ecology). During these foraging flights, bees accumulate from various sources many kinds of pollutants, including radionuclides, trace elements, pesticides, and various organic compounds (1987: in press, Nat. Bur. of Stand.; 1985: Science 227:632-634; 1982: Amer. Bee J. 122:770-782). Thus, bees can be deployed to provide spatially and temporally integrated samples of air, soil, and water. They concentrate some pollutants, for example fluoride, by several orders of magnitude over ambient concentrations. Chemical residues in bees and pollen have been used to map, over large geographical areas, variations in trace element distribution resultant from natural geochemical sources as well as gradients and hot spots resultant from point and area sources of pollutants.

During June 1986, 44 miniature colonies of bees were placed at 24 sites across the INEL, including sites near several facilities, ICPP, TAN, CFA, SDA, and Highway 20/26. Samples of forager bees were collected at intervals of 48 to 340 hours from June 21 through August 28. In addition, bees were collected from full-size hives at beeyards in communities surrounding the INEL, including Aberdeen, American Falls, Arco, Blackfoot, Butte City, Howe, Inkom, Mud Lake, Pingree, Pocatello, Springfield, and Wapello. The objectives of this sampling were to 1) determine exposure levels as indicated by accumulation in bees and variability of biologically available trace elements at various sites on and off the INEL: 2) address the sources of these materials; 3) compare trace elements in these bees with other INEL media; and 4) evaluate the suitability of bees as monitors of trace elements and other contaminants at the INEL.

Analysis of gamma-emitting radionuclides and of fluoride in whole bees has been completed. Bees from TRA, CPP, and NRF contained significantly elevated levels (three S.D. above background) of radionuclides such as Cs-137, Co-60, and Cr-51. Radionuclide levels in bees at the TRA pond varied markedly from one sampling date to the next. Honey, pollen, brood, and field blanks taken from the hive at the TRA pond showed no elevated levels of radionuclides. Fluoride concentrations in bees were approximately 80-90 ppm near Pocatello; above 20 ppm at Blackfoot, Inkom, American Falls, and Wapello; and generally below 15 ppm at sites across the INEL. This data suggests that INEL related activities contribute little fluoride to the region. Currently, bees are being analyzed by ICAP for Al, As, Ca, Cd, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, P, Si, Ti, and Z. This project, which will be continued during FY-88, should provide a cost-effective means of monitoring and differentiating onsite versus offsite sources of contaminants via source fingerprinting techniques.

CADMIUM METALLOTHIONEIN PRODUCTION IN HONEYBEES AS AN INDICATOR OF METAL EXPOSURE

Previous studies have shown that honeybees can accumulate contaminants as varied as trace elements, synthetic organic chemicals and radionuclides (1985: Science 227:632-634; 1982: Am. Bee J. 122: 770-782). Biomonitoring studies with honeybees to date have made no distinction between the concentration of external versus internal pollutant burdens, which makes it difficult to assess the physiological and behavioral effects of xenobiotic substances on bees in a field setting. One possible method to address the physiological activity of a pollutant is to isolate and examine specific metabolic components that interact with pollutants of interest. Metal-binding biomolecules called "metallothioneins" may provide such a metabolic marker in heavy-metal exposure.

Metallothioneins (MT) are a group of low molecular weight protein (6,000-10,000 Daltons) that are rich in cysteine (35%) and bind group 1a and 11a elements including Bi, Cd, Co, Cu, Au, Pb, Hg, Ag and Zn (1960: J. Biol. Chem. 235:12:3460-3465; 1986: Ann. Rev. Biochem. 55:914-946). Metals are associated with MT exclusively through cysteine-thiolate bonds, and past research shows the protein to bind 6-12 metal atoms per molecule of protein. Metallothioneins are hypothesized to play a role in essential element metabolism/regulation and in detoxification of nonessential metals. Recent studies on mammalian and invertebrate cell lines in vitro appear to support the role of detoxification, as MT-mRNA increases 25-fold within 1 hour of Cadmium exposure, cellular MT-protein levels reach 90% of maximum within 4 hours, and cellular resistance to cytoxic effects of the metal can increase more than three-fold. Studies in vivo have shown MT-production to occur within 12 hours of exposure.

To examine this protein, caged honeybees will be fed two concentrations of Cd-containing sucrose solution for 0.5, 1, 7 and 14 days. Protein isolation, characterization and quantitation will be performed at the Idaho Research Center Biotechnology Division. The objectives of this project are to (1) determine if honeybees produce metallothionein in response to oral Cd-Exposure, (2) determine the quantity of protein produced under different oral doses, (3) characterize the physiochemical properties of the protein, and (4) determine if metallothionein can be induced by Cd-exposure in a field setting. Field samples will be collected from mini-hives located SE of the ICPP percolation ponds and from a superfund site in western Montana. "Low exposure" control honeybees will be collected from an agricultural area NE of Missoula, MT. This research was initiated in June 1987.

TRACE ELEMENT DISTRIBUTION AND CYCLING ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Enhanced levels of trace elements in the general environment have been linked to sources from ore smelters, municipal incinerators, automobiles, fossil-fuel powered facilities and solid waste disposal. The start-up of a coal-fired steam generation facility at the Idaho Chemical Processing Plant (ICPP) in 1984 provided the impetus to collect preoperational data on the status of trace elements in the INEL environment. In addition, studies were designed to evaluate any effect on trace element concentrations due to past ICPP emissions.

Concentrations of 30 elements were measured in strong-acid extracts of soil, sagebrush leaves, and perennial grasses from the INEL and two control locations in southern Idaho. A bicarbonate-chelating extract of soil was used to estimate plant-available concentrations. Based on the spatial distribution of element concentrations, as well as comparison with controls, we concluded that concentrations of Zn, and perhaps Ni, Cd, and V, were elevated around the ICPP prior to start-up of the coal-fired steam generation facility [Rope et al., submitted manuscript]. Concentrations of B, Cr, Na, Ca, Hg, Sr and Se were 10-50 times higher in coal fly ash and bottom ash than in surrounding soils, suggesting that these elements are most likely to be elevated in the future due to particulate releases from the coal-fired facility.

The lichen Lecanora melanophthalma appears promising as a biomonitor for atmospheric trace elements (see separate summary on this topic). The spatial pattern of lead and boron in lichen samples collected 3 months after the start-up of the coal-fired facility implicated the ICPP complex as the source. Concentrations of both elements were significantly less than in samples from Idaho Falls.

Trace element data from soil, vegetation, and animal feces were used to evaluate the soil ingestion rate of two herbivores on the INEL: pronghorn and black-tailed jackrabbits [Arthur et al., submitted manuscript]. The soil ingestion rate is necessary for evaluation of transport by physical processes and the food chain. Soil comprised 5.4% and 6.3%, respectively, of the pronghorn and jackrabbit total dry matter intake. For both species, the estimated percentage of elemental intake attributable to soil was 75% for Na, Fe, V and F, and 10-50% for Mn, Cr, Mg, Ni, K and Zn.

A deposition station measuring dry fall and wet deposition of elements and compounds in rain and snow was established at the Experimental Field Station on the INEL in May 1985. The effect of precipitation event frequency and duration, as well as other factors, on the chemical characteristics of precipitation is being evaluated. In addition, approximately 2 years of baseline data will be compared with data collected after resumption of operations at the ICPP waste calciner, the major source of NO_x emissions at the INEL.

LICHENS AS AIR POLLUTION BIOMONITORS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Because lichens are especially sensitive to air pollution, they have been used to study the effects of pollution, especially SO_2, on plants. Various measures of response include presence or absence of species, the photosynthetic or nitrogen fixation rate, morphology, accumulation of non-essential elements, and cell death or damage. In humid climates, a high correlation generally exists between pollution level and damage to living cells and tissues (1965: Science 148:1600-1602; 1985: Atmos. Envir. 19:209-212). In dry climates, other environmental factors, such as available moisture, may interact with pollution level in causing damage; however, few data have been obtained on the use of lichens as bioindicators or biomonitors in semiarid climates (1974: Envir. Pollution 7:283-301; 1979: Bryologist 82:20-28).

In 1984, we initiated a study to evaluate the feasibility of using lichens as pollution indicators at the Idaho National Engineering Laboratory. Three kinds of measurements were chosen for evaluation of our results: species diversity, membrane permeability, and trace element accumulation. The ICPP and associated facilities emit SO_2, NO_x trace elements, and radionuclides. The effects of these pollutants were evaluated at 16 sites which were chosen based on prevailing wind patterns with respect to the ICPP.

Lichen species diversity was highly correlated with distance from the ICPP; however, diversity of substrates was also correlated with distance. Several widely distributed species were selected for further laboratory analysis and for field transplant experiments.

Permeability of lichen membranes was evaluated by a simple electrolyte leakage test, which has been shown to be correlated with degree of exposure to SO_2 (1981: Bryologist 84:515-520; 1982: Phyton 22:329-337; 1985: Atmos. Envir. 19:209-212). Results suggest that in a dry climate, damage from atmospheric pollution is greater when the plants are moist, as a result either of dew or of recent rains, than when they are dry. TEM micrographs revealed visible tears in the membranes and severe damage to the plastids.

Because lichens grow slowly, obtaining the majority of their nutrients from the atmosphere, lichens reflect long-term exposure to atmospheric pollutants. A widely distributed foliose species from the INEL Lecanora melanophthalma was chosen for trace element analysis by means of energy dispersal analysis of X-rays (EDAX) using the SEM to zero in on specific cells and tissues. Results indicated that trace elements accumulated in the algal layer and medulla to just as great a degree as in or on the cortex. The total trace element of this species was also measured. Although concentrations were generally higher than those previously measured in vascular plants on the INEL, there were no unusually high values compared to those in the literature, suggesting that emissions of trace elements and heavy metals from the ICPP has been at relatively low levels over the years. Controls collected at two sites in Idaho Falls gave significantly higher levels of lead, mercury, and other elements than the INEL sites.

SEASONAL CHANGES IN RELATIVE DENSITY OF RODENT COMMUNITIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Significant geographical variation occurs in the species composition, diversity, and density of small mammal communities on the INEL. Because the potential number of small mammals estimated to occupy the INEL Subsurface Disposal Area at the Radioactive Waste Management Complex proved to be large (1983: Amer. Midl. Natur. 109:253-265), a program was designed to monitor the relative density of rodent communities with reference to an undisturbed site near the RWMC. Two additional undisturbed sites and one site proposed for prescribed burning were initially selected for monitoring. All are dominated by big sagebrush (Artemisia tridentata). Two additional sites dominated by grasses and of different soil composition were added later in the study. Trapping has been completed at fixed points spaced at 10-m intervals along three transects spaced at 0.2-km intervals over 3-day periods at each area. Prebaiting and standardized trapping techniques have been employed based upon experimental designs tested previously on the INEL (1983: Northwest Sci. 57:194-204; Canad. J. Zool. 61:403-410). The objectives of this project are to: 1) develop fall and spring estimates of relative density and composition of rodent communities at fixed sites over a period of years, 2) contrast indicies of relative density of rodents trapped at widely-separated independent sites with data obtained near the RWMC, and 3) provide students enrolled in university courses with field experience that generates real data matrices that can be analyzed and summarized as a class project.

In 54,328 snap-trap nights, 7,901 specimens of 11 species of rodents have been collected since the fall 1980. The mean relative density of rodents collected during fall periods at the RWMC site (209.4 $\pm$ 20.7; $\pm$ S.E., n = 7) per 1,000 snap-trap nights has exceeded spring values at five localities, and all fall values excepting the area receiving a partial prescribed burn (223.8 $\pm$ 35.2, n = 7). But the later difference is not statistically different.

The grand mean relative density of rodents per 1,000 snap-trap nights, obtained from samples for the first fall (207.2 $\pm$ 26.3) for the initial four areas sampled was not significantly different ($p \leq 0.05$) than 1986 (201.1 $\pm$ 18.1) densities. Three of the sampling sites represented by two seasons of data show a consistent pattern of decline until the spring 1982, but not all individual species were subject to decline. In general, communities have fluctuated in synchrony. The highest single relative density, 347.6 individuals per 1,000 trap nights was observed on the burn site following a partial prescribed burn. The lowest total relative density, 23.5 individuals per 1,000 trap-nights, was observed on a site dominated by crested wheatgrass (Agropyron cristatum). The grand mean relative density, calculated from the pooled data is 165.6 $\pm$ 21.2 individuals per 1,000 trap-nights for fall samples and 123.5 $\pm$ 10.2 for spring samples.

SMALL MAMMAL MOVEMENT PATTERNS AROUND THE SUBSURFACE DISPOSAL AREA, IDAHO NATIONAL ENGINEERING LABORATORY

Research conducted on the Subsurface Disposal Area (SDA) of the Idaho National Engineering Laboratory has revealed that small mammals are the most frequently occurring wildlife. Small mammal densities on the SDA were as high or higher than those in the adjacent native sagebrush vegetation (1983: Amer. Midl. Natur. 109: 253-265). This may be attributable to certain waste disposal practices that could potentially attract small mammals. The disturbed soil cover placed over the waste material may facilitate burrowing. Also, crested wheatgrass which is planted on the SDA for soil stabilization and hydrologic benefits provides a readily available seed source for granivorous rodents. Studies have indicated that a large portion of the small mammals inhabiting the SDA are receiving radiation doses greater than background rates (1986: J. Applied Ecol. 23:13-26). The shallow burial of radioactive waste materials enables burrowing small mammals to come into direct contact with contaminated materials (1983: J. Environ. Qual. 12:117-122). Thus, the potential exists for rodents to serve as vectors of radionuclide dispersal through their daily movements.

The main objective of this study was to determine small mammal movement patterns on and adjacent to the SDA. Efforts were concentrated on the four most abundant species: deer mouse, montane vole, Ord's kangaroo rat, and Townsend's ground squirrel. Small mammal movement data were collected by radio-telemetry and multiple capture live trapping techniques. Food habits and habitat use (specifically the importance of crested wheatgrass) were also evaluated.

Radio-transmitters were surgically implanted intraperitoneally in these small mammals. Movement data were obtained on 18 deer mice, 12 montane voles, 5 Ord's kangaroo rats, and 5 Townsend's ground squirrels over the course of the study. Many of these animals were radio-tracked over several monthly tracking periods. All four species used the crested wheatgrass within the borders of the SDA. Montane voles used the crested wheatgrass habitat type almost exclusively while the other three species commonly moved back and forth between the crested wheatgrass and the surrounding native sagebrush vegetation. Maximum linear distances moved from the SDA out into the sagebrush for deer mice, montane voles, Ord's kangaroo rats, and Townsend's ground squirrels were 250 m, 20 m, 100 m, and 250 m, respectively.

Food habits analysis indicated that crested wheatgrass is an important food item at least seasonally for all four species. Crested wheatgrass was the major food item throughout the summer for both montane voles and Townsend's ground squirrels. Deer mice and Ord's kangaroo rats also used crested wheatgrass but its importance increased greatly after seed heads formed. Crested wheatgrass was found in stomachs of deer mice that were trapped up to 250 m from the crested wheatgrass-sagebrush interface. This may indicate that the crested wheatgrass planted in the SDA is attracting small mammals from relatively long distances and may be, at least partially, responsible for the small mammal densities on and immediately adjacent to the SDA.

STRUCTURAL CHARACTERISTICS AND SOIL MOISTURE DYNAMICS OF SMALL MAMMAL BURROWS IN DISTURBED AND UNDISTURBED SOILS

The purposes of this study were to 1) investigate the effect of soil disturbance on burrowing habits of small mammals and 2) determine if small mammal burrows alter water infiltration rates into the soil. Data on both these factors will aid in increasing our understanding of the ecological relationship between burrowing mammals and their environment. These data could also be helpful to the reclamation and management of disturbed areas such as hazardous chemical or radioactive waste disposal sites.

To assess effects of soil disturbance on burrow characteristics, physical dimensions of burrows in disturbed and undisturbed soils were compared for five common species of small mammals, Townsends ground squirrel (Spermophilus townsendi), Wyoming ground squirrel (S. elegans), deer mouse (Peromyscus maniculatus), kangaroo rat (Dipodomys ordii), and montane vole (Microtus montanus). Burrows were located at various areas on the Idaho National Engineering Laboratory as well as mine reclamation areas near Soda Springs, Idaho. Burrows were injected with polyurethane foam, excavated, and mapped. Maximum depth, length, diameter, and volume of each burrow were measured. Detailed analyses of soil texture and structure were also made.

Effects of burrows on water movement were studied by comparing annual cycles in soil moisture in areas adjacent to burrow openings to cycles in areas without openings. Three study sites were chosen, two in the Soda Springs area and one on the INEL. Water patterns were assessed with the use of a neutron probe. Pairs of access tubes were placed in reclaimed (disturbed) areas and adjacent native (undisturbed) areas. Within each pair, one tube was placed adjacent to a burrow opening (burrow tube) and one control tube was placed approximately 3-5 m from the burrow tube. Ten pairs of tubes were set up per soil type at each study site.

To quantify effects of burrow density on water infiltration a 4 x 7 grid system was set up. Neutron access tubes were placed in the center of each 9 m^2 grid cell. Four treatments were set up: a control (no openings), two openings (0.2 holes/m^2), four openings (0.4 holes/m^2) and six openings (0.7 holes/m^2). Two opening sizes were used: ground squirrel size (4-cm diameter) and small mammal size (2-cm diameter).

Data on burrow characteristics indicate that deer mice dig deeper and have longer burrows in undisturbed soil and kangaroo rats dig deeper in disturbed soils. A difference was noted in the depth of montane vole burrows among three sample subsets but that difference was not due to the disturbed or undisturbed nature of the soil but to bulk density and soil texture differences. No differences were found in burrow characteristics for either species of ground squirrel. However, the vertical distribution of burrow volume differed between disturbed and undisturbed soils for Townsend's ground squirrels. The species removed proportionally more soil from below 50 cm in disturbed soils than in undisturbed soils. Townsend's ground squirrels also had a greater proportion of their burrows extending below 100 cm in disturbed soils than in undisturbed sites.

Analysis of moisture data indicate that areas adjacent to burrow openings contain significantly higher levels of water at peak recharge in the spring. The difference between burrow and non-burrow areas is most evident at low spring recharge levels. Based on data from the experimental grid, there is a significant correlation between hole density and recharge amount. These results are being used to develop a predictive equation that can be incorporated into hydrologic simulation models.

COLONIZATION AND HABITAT USE BY SMALL MAMMALS

Biological intrusion has been identified as a potentially significant transport mechanism of contaminants at shallow land hazardous waste burial sites (1982: PNL-4241, NTIS; 1985: Health Physics 49:11-24). Although the impacts of small mammals on waste management systems are not completely known, elevated levels of radionuclides have been reported in small mammals (1986: J. Appl. Ecol. 23:13-26) and soils excavated by small mammals (1983: J. Environ. Qual. 12:117-122) at the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory.

Other studies (1983: Filipovich MS Thesis, Idaho State University; Koehler, in progress) suggest that the exotic vegetation planted for soil stabilization influences small mammal abundance on and use of the SDA, particulary at the interface between the crested wheatgrass and the native vegetation. Because the habitat preferences and rates of colonization of vegetation types are unknown for most small mammal species on the INEL, a study was initiated to determine the colonization and habitat use by small mammals of 14 habitat types on disturbed and undisturbed soils. Two trenches, each about 7.5 m wide and up to 2.5 m deep, were backfilled in the summer of 1985. Trenches were about 146 m and 195 m long. Backfilling from the soil stockpile removed all the vegetation 7.5 m to one side of each trench. Twenty-eight 15.2 x 12.2 m study plots were established. Half of each plot was on highly disturbed soils (former trench), with the remainder on "undisturbed" soils (where overburden had been stored). Besides a control area which was not revegetated, plantings included two pure stands of big sagebrush (Artemisia tridentata), rabbitbrush (Chrysothamnous vicidiflorus), Indian ricegrass (Oryzopsis hymenoides), needle and thread grass (Stipa comata), squirreltail (Elymus elymoides), streambank wheatgrass (Elymus lanceolatus), ephraim crested wheatgrass (Agropyron cristatum var. ephraim), and replacement series ratios of 75:25, 50:50, and 25:75 for sodar:Great Basin wildrye, sodar:ephraim, and Great Basin wildrye:emphraim. Seeding and transplanting took place in the fall of 1985 and the spring of 1986.

Fifteen permanent small mammal trapping stations were established on each plot. Live-trapping (mark-recapture) for 3 days each summer month was initiated in June 1986. This provided data on the use of each vegetation type by small mammals. Small mammal burrows were counted within a centare of each trapping station, excluding those at the soil disturbance interface, in August. This provided data on the colonization of each habitat and soil type.

First-year results were inconclusive. Plots with the greatest number of small mammals captured also had the greatest canopy cover. However, seedings of grasses were not fully successful, with many plots exhibiting less than 10% canopy cover. Likewise, conclusions regarding colonization are also not warranted at this time.

THE INFLUENCE OF SIMULATED TOWNSEND'S GROUND SQUIRREL BURROWS ON SOIL MOISTURE

Burrowing by small mammals is one of the biotic transport mechanisms identified as contributing to the potential and unwanted movement of toxic substances from shallow land burial sites (1982: PNL-4241, NTIS; 1985: Health Phys. 49:11-24). One scenario is that burrows may enhance the potential for transport via water by modifying the soil matrix.

Of the four most abundant species of small mammals using the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex on the Idaho National Engineering Laboratory, (1983: Am. Midl. Natur. 109:253-265), the Townsend's ground squirrel has the deepest, longest, and largest average burrow system (Reynolds and Wakkinnen, in press. Am. Midl. Natur.) and, consequently, the greatest likelihood to alter shallow water movements. The objective of this study was to compare the moisture content between soils used to cover wastes at the SDA in the presence and absence of ground squirrel burrows.

Because the exact configuration and depth of burrows is not known until the burrow is excavated, average-sized artificial ground squirrel burrows were fabricated using a Mirafi (a non-woven, not-wetting, polypropylene fabric) sock filled with washed pea gravel. Because radioactive wastes are buried under a shallow mantle of soil at the SDA, the 15 artificial burrow systems were buried to the average depth in test trenches distant from the SDA. These were covered with the same lake-bed soils used to cover wastes at the SDA. Resistance-type soil moisture sensors, equipped with thermistors, were placed 10 cm above, and 10- and 50-cm below each artificial burrow system. Actual depths below the soil surface were about 30, 50, and 100 cm. Moisture sensors were placed at the same depths in control area, lacking burrows, adjacent to each test burrow. To eliminate any confounding effects of evapotranspiration on soil moisture, plants were chemically excluded from the study areas.

Soil moisture and soil temperature were determined fortnightly (usually) with resistance-type soil moisture units beginning in the spring of 1984. Soil moisture followed similar trends each year in the control and test plots. Shallow recharge was associated with the thawing of soil and spring melt in March and April. Soils at 30 cm depth were wetted approximately 1 and 2 weeks earlier, respectively, than soils 50 and 100 cm below the surface. Maximum annual moisture content (by volume) was equal (31-36%) at all depths with or without burrows. There were few significant differences in moisture content between test and control areas. After significant precipitation events, soils below burrows occasionally were wetter sooner than control counterparts. This suggests that burrows can act as funnels. Contrariwise, following periods without precipitation, soils below burrows were occasionally drier than control soils. This suggests that burrows may also act as chimneys, and serve as an avenue for moisture to evaporate from beneath the soil surface.

ECOLOGY OF BLACK-TAILED JACKRABBITS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

The black-tailed jackrabbit is a widely-distributed herbivore on rangelands of western North America. On northern portions of the species range, populations are cyclic, reaching high densities at approximately 10-year intervals. High densities have been recorded in southern Idaho during almost every decade since 1832; peak numbers occurred at the INEL in 1949, 1959, 1971, and 1981. Because of the magnitude of a population's fluctuation during a cycle, jackrabbit numbers may have a dramatic effect on predator populations and the availability of forage. Crop depredations can result in economic impacts during years when population levels are high. During the winter of 1981-82, concern was expressed that the INEL might provide a refuge from which jackrabbits raided crops and haystacks on adjacent farmlands.

Studies of black-tailed jackrabbits at the INEL were initiated in the 1960's and include investigations of reproductive biology, age structure and sex ratios of the population, population trends and relationships to predator numbers, food habits, and impacts on vegetation. These hares are generalist herbivores that consume a wide variety of plants. Diets vary seasonally in response to forage maturity and availability. At INEL, winterfat and perennial grasses comprised about 80% of the spring-early summer diet; jackrabbit densities were higher in areas having higher proportions of grass cover (1984: J. Range Manage. 37:79-83). Forbs typically become more important in late summer and early fall, and shrubs are the staple during late fall and winter.

During the population peak of 1981-1982, the impacts of jackrabbits on vegetation at INEL was examined. Total vascular plant cover was lower on plots open to jackrabbits than on exclosure plots. The most severe impacts were on shrubs during winter, but these impacts were largely ameliorated by rapid growth during the next growing season. Although the cumulative effects of herbivory reduced total plant cover, no single species was irreparably impacted. Over a year, jackrabbits feed on nearly all of the important species in these communities and, therefore, do not appear to apply differential grazing pressure that would alter community composition over the long term (1986: J. Range Manage. 39:152-156). It is possible, however, that jackrabbits may significantly affect nutrient cycling in this ecosystem. During a peak in the cycle, fecal pellets are ubiquitous, accumulating to densities of several hundred/m^2. We plan to investigate this aspect of jackrabbit ecology during the next population peak.

Since 1980, population trends have been monitored by nighttime counts of all jackrabbits within a 50-m strip on both sides of a 45-km backroad routes. June counts for 1980 through 1987 were 348, 1194, 450, 175, 4, 0, 1, 2 jackrabbits, respectively. These data document the amplitude of density changes during a cycle. In 1981, the distribution of jackrabbits along the 45-km route changed markedly between June and September. A separate study using radiotelemetry indicated that jackrabbits rarely moved more than 1 km during summer, but movements of about 35 and 45 km were documented for two individuals in fall. Census data taken by the U.S. Fish and Wildlife Service suggested a large immigration of jackrabbits onto the INEL during the winter of 1981. It is clear that more data on movement patterns are needed to understand the dynamics of this population.

ECOLOGY OF BLACK-TAILED JACKRABBITS AT THE INEL RADIOACTIVE WASTE MANAGEMENT COMPLEX

Research on the ecology of black-tailed jackrabbits was conducted near the INEL Radioactive Waste Management Complex between June 1982 and July 1985 to evaluate the role of this species in radionuclide transport. Seasonal and annual variation in RWMC jackrabbit population was evident. Peaks in density occurred during the summer months. Highest density occurred in 1982 with peaks reaching progressively lower levels in the following summers. Essentially no jackrabbits inhabited the RWMC during the winters of study. Low densities were attributed to emigration from the area in fall in addition to mortality. Immigration in spring provided breeding stock to permit increases through reproduction during the breeding season.

A mosaic vegetation pattern appeared to be the attractive feature of the RWMC. Native sagebrush provided hiding cover during the days, whereas plants growing in the interspersed disturbed sites (SDA and borrow pits) were a source of forage during nocturnal feeding periods. Crested wheatgrass which contained elevated concentrations of radionuclides in the SDA (1982: J. Environ. Qual. 11:394-399) and summer cypress, an invader species, were the most common plants detected in jackrabbit diet samples. No significant differences ($P>0.05$) were observed for radionuclide concentrations between RWMC and control area jackrabbit tissue samples.

Radiotelemetered jackrabbits inhabiting the RWMC during summer demonstrated a high degree of site fidelity and rarely moved more than 1 km from the complex. In the fall, however, the animals moved from the area. Mortality was quite high during this movement, but one radioed jackrabbit was observed near Mud Lake approximately 45 km NE of RWMC. A rabbit that summered at RWMC moved to CFA in the fall then returned to RWMC the following spring.

ECOLOGY OF BOBCATS RELATIVE TO EXPLOITATION AND A DECLINE IN BLACK-TAILED JACKRABBIT POPULATIONS IN SOUTHEASTERN IDAHO

Bobcat (Felis rufus) population responses to exploitation and a decline in black-tailed jackrabbit (Lepus californicus) populations were studied in southeastern Idaho from 1982 through 1985. Bobcat social organization during peak jackrabbit densities consisted of a territorial system with little intra- and much inter-sexual range overlap. Possession of a territory appeared to be necessary for females to raise young. None of the 12 marked females <15 months of age raised kittens even though some were physiologically capable of breeding. Kittens moved independently from their mother within the natal range by 9 months of age and dispersed at a mean age of 14.5 months. Most dispersals (16/17) were <35 km from the natal range. Bobcats dispersed into sagebrush (Artemesia sp.) habitats similar to their natal range.

The functional and numerical responses by bobcats were studied during the second through fifth year of a decline in black-trailed jackrabbit numbers. Bobcats ate more cottontail rabbits (Sylvilagus nuttallii and S. idahoensis) during winters and small mammals during summers while the proportion of jackrabbits in the diet decreased. Bobcat recruitment essentially ceased because fewer females raised litters and kitten survival was reduced. As a result, bobcat densities declined at lambda = 0.52 between 1982 and 1985 in both study areas. Adult survival remained the same during the jackrabbit decline except for winter 1984-85 when two adult females starved to death. As jackrabbit populations declined, the average size of the home range increased approximately five times from 1982 to 1985. Bobcats made extra-territorial forays during winters of the decline to areas of jackrabbit aggregations or to lava flows. Inverse density-dependent predation on jackrabbits in aggregations during their decline could act to increase the amplitude of the cycle. To conserve energy, denning females stayed closer to the den, and traveled shorter total distances when small rodents were the primary prey in 1983 compared to 1982 when jackrabbits were eaten.

Harvest effects were determined by comparison of an unharvested population on the Idaho National Engineering Laboratory (INEL) with a harvested population in the Box Canyon region of the Big Lost River. The harvested population contained a higher proportion of yearlings and a lower proportion of adults than the unharvested population. Because yearlings did not reproduce, the harvested population was maintained solely by immigration from surrounding regions.

Computer simulations of female bobcat populations were used to determine yield at different harvest intensities. Recommended harvest rates were <20% of the fall population. Increases in mortality to productive females that orphaned kittens had a greater impact on yield than did increases in kitten mortality. The predicted size of refugia needed to maintain the population suggested that it was necessary to buffer some territories from the refuge edge.

SAGE GROUSE, PRONGHORN AND SMALL MAMMAL USE OF FIRE SCARS OF VARIOUS AGES ON THE IDAHO NATIONAL ENGINEERING LABORATORY

This study investigated wildlife use of nine fire scars of various ages and sizes on the Idaho National Engineering Laboratory. The objectives were to determine the relative use of these areas by sage grouse (Centrocercus urophasianus), pronghorn (Antelocapra americana) and small mammals relative to adjacent non-burned (control) areas. Vegetation sampling was conducted to determine the duration of any effect over time of fire in a sagebrush (Artemisia sp) community. The present study was initiated in 1984.

Canopy coverage and line intercept methods were used to estimate the plant community composition of each study area. Fecal pellet counts were used to determine relative use by sage grouse and pronghorn. A combination of snap traps and live traps were used to determine small mammal abundance and diversity.

Fire has a long-term and dramatic effect on the plant community. The sagebrush canopy was effectively removed for at least 75 years by intensive burns. Grass and forb canopy coverage was generally greater on burned areas than on adjacent areas. The vegetation found on fire scars can be characterized as rabbitbrush/perennial grass stands. Two of the four fire scars less than 6-years old were dominated by cheatgrass.

A total of 25,781 trap nights produced 1,989 captures of 11 species of small mammals. Total captures on fire scars were significantly lower than on non-burn areas in both fall 1985 and spring 1986 samples. Species diversity and evenness values were not significantly different in the fall sample, but were significantly greater in the non-burn areas in the spring sample.

The results of the pellet counts for sage grouse and pronghorn are tentative at this time. Because, the vegetation of the INEL is dominated by sagebrush, the creation of open grassy areas appears beneficial to sage grouse and pronghorn populations. The open areas are especially important to sage grouse during the spring courtship period. The removal of the shrub canopy and the resulting increase in grass and forb coverage is attractive to pronghorn during all seasons.

Use by elk (Cervus elaphus) and mule deer (Odocoileus hemionus) was noted on some study areas. Elk fecal pellets and other sign were found in all 1986 sampling periods on one study area located south of Twin Buttes. Elk were previously reported only as transients. A change in abundance may be occurring.

MOVEMENTS OF BAT POPULATIONS ON AND ADJACENT TO THE IDAHO NATIONAL ENGINEERING LABORATORY

Only a limited body of data exists on bat populations residing in lava-tube caves (1986: Great Basin Natur. 46:241-244). Information on the composition, location and movement patterns of the 14 species of bats known to occur in Idaho (1985: Tebiwa 22:57-63) is needed to develop management strategies to prevent a general pattern of population decline similar to that experienced elsewhere. Because the frequency of human disturbance of colonies may significantly reduce survival of bats (1979: J. Wildl. Manage. 43:1-17), a unique opportunity is available to institute mitigating measures to enhance populations of several species of bats residing on the Idaho National Engineering Laboratory (INEL). Controlled access measures could be adopted for sensitive caves because the INEL has NERP status.

Five species of bats are known to occur in the lava-tube caves on and adjacent to the INEL. Two species, Myotis leibii and Plecotus townsendii hibernate on the site, whereas three species, Myotis lucifugus, M. evotis, and Eptesicus fuscus are considered migratory. As a result of the seasonal movements of bats using lava-tube caves on the INEL, information on their local movements is needed to determine which caves are important roosting and hibernating sites to south-central Idaho populations.

A large number of lava-tube caves also exist on Shoshone District BLM lands in Lincoln and Gooding Counties. Personnel from the BLM will cooperate during this study by providing information on and access to caves on BLM lands known to have populations of bats. Interchange of species found at both sites may occur during formation of nursery colonies as well as during hibernation.

The objectives of this project are to determine the movement patterns of bat populations at the INEL and Lincoln-Gooding county lava-tube caves, and to determine if there is exchange of bat populations between these two areas. Bats will be captured at both sites in the summer of 1987 and 1988. Selected individuals will be marked with different colored bands to identify the site of initial capture. Caves in both areas will be re-visited in the late fall of 1987-88 and again in the early spring of 1988-89 to determine if interchange has occurred. This procedure should prevent unnecessary disturbance of individuals especially during sensitive periods. Additional information on temperature and relative humidity of caves used as hibernacula will be gathered as well as approximate densities of bats at specific distances from the cave opening for analysis and mitigation of sites important to bat survival.

RAPTOR AND PRONGHORN SURVEYS ON THE IDAHO NATIONAL ENVIRONMENTAL RESEARCH PARK

Personnel involved in the Radioecology and Ecology research program at the Idaho National Engineering Laboratory's Radiological and Environmental Sciences Laboratory have participated in the Midwinter Bald Eagle Survey sponsored by the National Wildlife Federation since 1983. In addition, starting in 1985, all raptors observed on these designated onsite routes were tallied. Table 1 shows the number of hawks, eagles, and falcons observed on the INEL during these midwinter counts. Several previous detailed studies have monitored raptor densities, both during nesting and winter seasons, over all of the INEL during both high and low jackrabbit densities. Since raptors are at the end of the food chain, and can be important indicators as to the general health of the environment, we will continue to do periodic detailed ecological studies on raptors in addition to the yearly surveys.

Table 1. Wintering raptors observed on the Idaho NERP

	YEAR				
SPECIES	1983	1984	1985	1986	1987
Bald Eagle	4	3	2	5	1
Golden Eagle	46	20	8	9	9
Prairie Falcon	--	--	3	2	0
Rough Legged Hawk	--	--	100	48	57
Red-tailed Hawk	--	--	5	0	0
Great Horned Owl	--	--	1	2	0
Ferruginous Hawk	--	--	4	0	0
Northern Harrier	--	--	6	0	0

Aerial surveys for pronghorn wintering on the Idaho NERP and pronghorn production counts (number of fawns per 100 does) have been conducted since 1985 in January and August, respectively. The number of pronghorn wintering on the NERP in 1985, 1986, and 1987 was, respectively, 1904, 1648, and 908. The number of pronghorn fawns per 100 does was 110 and 88 for 1985 and 1986, respectively.

1985 AND 1986 BREEDING BIRD SURVEYS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Baseline data on the vertebrate populations on the INEL are reported but records for breeding birds are limited. Although nesting studies have been conduced on the NERP for raptors, sage grouse and some passerines, an extensive survey of breeding birds on the INEL was needed. Five standard 40-km U. S. Fish and Wildlife Service Breeding Bird Survey (BBS) routes were established across major habitats of the Idaho NERP. Thirteen breeding bird survey routes were established and surveys were conducted on the INEL from 12 June to 3 July 1985 and 5 June to 17 June 1986. Eight shorter survey routes (mini-routes), ranging from 5.8 km to 19.2 km in length, were established within 0.16 - 2.0 km of the perimeter around major INEL facility complexes. Standard surveys were conducted following the U. S. Fish and Wildlife Service techniques. For mini-routes the duration of each session was the same as the standard routes, although the distance between survey points was reduced to 0.32 km. Surveys ranged in duration from 1 hour 29 minutes on mini-routes to 6 hours 28 minutes on standard routes.

More than 2900 birds representing 54 species were recorded during the 1985 surveys. Of those, 1411 (32 species) were observed along 200 km of the five standard survey routes and 1499 (45 species) were recorded along 74 km of the eight mini-routes. The most abundant species recorded on the standard surveys was the western meadowlark followed by the sage sparrow, horned lark, sage thrasher, Brewer's sparrow and mourning dove. on the mini-routes, the most abundant species recorded were the sage sparrow, western meadowlark, sage thrasher, brown-headed cowbird, horned lark and Wilson's phalarope, respectively.

In 1986, 3400 birds of 81 species were recorded during the surveys. Of those, 1594 (40 species) were observed along the five standard survey routes and 1818 (39 species) were observed along the eight mini-routes. The most abundant species recorded on the standard surveys was the western meadowlark followed by the Brewer's sparrow, sage thrasher, horned lark, sage sparrow and mourning dove. on the mini-routes, the most abundant species recorded were the western meadowlark, Brewer's sparrow, sage thrasher, horned lark, sage sparrow, yellow-headed blackbird and Canada goose, respectively. Results from mini-routes around facility complexes indicated a greater species diversity and density of birds than on standard 40-km routes. This was likely due to the presence of lawns, deciduous trees, several small ponds, marsh, and riparian habitat not as prevalent on standard surveys. Such habitat diversity provided several waterfowl marsh and shorebird species not recorded on standard survey routes. These site-specific habitats could yield misleading numbers such as those of the Wilson's phalarope (100) that were recorded at two stops near a single pond in 1985. Data analysis and manuscript preparation of the first 3 years' results are planned for fall of 1987.

RAPTOR USE OF TWO STYLES OF NESTING PLATFORMS ON THE IDAHO NATIONAL ENVIRONMENTAL RESEARCH PARK

Three species of raptors in the genus Buteo are known to nest on the sagebrush and grass dominated Idaho National Environmental Research Park (NERP): Ferruginous Hawk (B. regalis), Red-tailed Hawk (B. jamaicensis), and Swainson's Hawk (B. swainsoni) (1979: IDO-12089, NTIS). Although these species commonly occur in shrub-steep habitat, only 1-2 dozen pairs annually nest on the 2300 km^2 NERP (1984: Murrelet 65:91-93). During the peak phase of the jackrabbit cycle, when Buteo nests are most abundant on the NERP, nests are restricted in distribution. Most are in deciduous trees along the Big Lost River, with others located in juniper (Juniperus spp.) stands near Kyle Canyon in the northwest portion of the NERP or near the Twin Buttes to the southeast (1983: DOE/IDO-12098, NTIS). Because Red-tailed, Ferruginous, and Swainson's Hawks almost always nest in trees or on cliffs, bluffs, or man-made structures (1974: Olendorff and Stoddart, Proc. Conf. Raptor Conserv. Tech., Raptor Res. Rep. 2:44-88), it is possible that the nesting raptor population on the NERP is limited by the number of suitable nest sites.

The objectives of this study were (1) to encourage additional raptor nesting on the Idaho NERP by providing artificial nesting structures and (2) to compare the raptor use and nesting (fledging) success between two styles of artificial nest platforms. One style (FG) was a redwood version of the platform (1982: Proc. Workshop Raptors and Energy Dev., U.S. Fish Wildl. Serv, Boise, ID. pp. 117-122) and distributed by the Idaho Department of Fish and Game Nongame Species Program. This nest platform style lacks any shade producing structure, but has an horizontal perch. The other style (IP) was designed for the Idaho Power Company (1976: Idaho Power Co., Nest Platform Schematic 23-C-36155). This structure has a shading device but no perch.

About 30 sagebrush branches were wired to each platform to simulate nesting material and encourage nesting (1980: Raptor Res. 14:39-45). Nest platforms were placed atop decommissioned communication line poles by linemen during February 1985. Ten IP style and eight FG style platforms were alternated at approximately 1.6 km intervals along Lincoln Boulevard from the turnoff to the Experimental Field Station northward to TAN.

Platforms were surveyed for use during the incubation period (late May or early June) in 1985, 1986, and 1987 when breeding pairs are reported to be most conspicuous (1982: J. Wildl. Manage. 46:885-893). Raptors did not use the platforms for nesting any year. But, all three species of Buteos have used them for hunting perches or roosting sites. Other studies (1980: Raptor Res. 14:39-45; 1982: Blue Jay 40:208-213; 1984: J. Wildl. Manage. 48:1009-1013) indicate that 2 or more years of familiarization are needed before raptors readily nest on artificial platforms. Moreover, because the jackrabbit population on the NERP has yet to recover from its 1983 crash, the lack of nesting to date is not totally unexpected.

AN ECOLOGICAL STUDY OF MOURNING DOVES IN A COLD DESERT ECOSYSTEM ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Mourning dove (Zenaida macroura) use of and movements around man-made ponds, as well as dove nesting ecology, were studied from 1983 through 1985 on the Idaho National Engineering Laboratory (INEL). Relative dove use was higher ($P < 0.01$) on some ponds than others, and multiple regression revealed a positive association ($R^2 = 0.49$) between relative use and the geographic isolation of ponds. Two peaks in diurnal pond use were exhibited by doves on the INEL: the morning peak began around 0800 and lasted until approximately 1300, and the evening peak began at about 2030 and ended by 2150. Seasonal pond use fluctuated slightly through the summer then dropped rapidly in early September.

Average and average maximum movements indicated that the 41 mourning doves trapped and fitted with radio-transmitters at the Test Reactor Area (TRA) and the Naval Research Facility (NRF) did not move off the INEL on a regular basis. The average distance from mourning dove locations to TRA and NRF was <2.0 km, and the average maximum dove location was <3.5 km from either facility. Average (<2.0 km) and average maximum (<3.5 km) distances were also measured from dove locations to watering sites. Doves captured at both TRA and NRF moved, on average, 1.5 km from their nests; the average maximum distance from a dove's location to its nest was 2.8 and 5.4 km for doves caught at TRA and NRF. The average maximum distance between any two locations (for the same individual) at both TRA and NRF was <4.0 km.

Mourning doves on the INEL are primarily ground nesters. Nesting success averaged 68% per year, with 1.8 fledglings produced per successful nest. Nesting densities averaged 0.02 nests/ha during the study. Three peaks in hatching occurred on the INEL: one during the fourth week of June, another during the third week of July, and a third during the first and second weeks of August. Annual production estimates for the INEL ranged from 11,300 to 17,000 doves, based on a model using two and three nesting attempts per summer.

No differences ($P < 0.5$) were indicated in the percent coverage of shrubs, grasses, forbs, and bare ground, as measured with the line-intercept method, in the 5-m area surrounding dove nests and paired random sites. However, a difference in the percentage of grass cover and bare ground, as measured with a point-frame, was indicated in the 1-m^2 (microhabitat) centered on the nest or random site; nest sites contained more grass ($P = 0.02$) and less bare ground ($P = 0.02$) than random sites. No difference was found between nest and random site microhabitats in the percentage of shrub or forb cover. Also, no difference was indicated by chi-square analysis in vertical vegetation obstruction, as measured from 15 m, between nest and random sites. Twenty-three of the 28 ground nests on the INEL were located under big sagebrush (Artemisia tridentata).

AVIAN ECOLOGICAL STUDIES IN A SAGEBRUSH COMMUNITY

In 1980-1985, we (1) documented the responses of nongame birds to a prescribed fire (2-years preburn and 4-years postburn) in a southeastern Idaho sagebrush (Artemisia spp.) community, and (2) tested the hypothesis that territory shifts by sage sparrows (Amphispiza belli) represent adaptive adjustments in site use.

The prescribed fire produced a mosaic of burned (45%) and unburned habitat patches, and resulted in a decrease in sagebrush coverage and increases in coverages of forbs and bare ground. After the fire, experimental (burned) study plots consistently supported one more bird species than control plots. By the fourth postburn season, total bird densities on experimental plots were greater than those on control plots. Sage sparrows and Brewer's sparrows dominated the bird assemblages associated with both treatments. Sage sparrow densities were unaffected by fire; Brewer's sparrow (Spizella breweri) numbers declined in the two breeding seasons after fire but more than doubled thereafter. Sage thrashers (Oreoscoptes montanus) showed no response to fire, and western meadowlarks (Sturnella neglecta) increased slightly. Horned larks (Eremophila alpestris) and vesper sparrows (Pooecetes gramineus) colonized burned areas. The return rate of male sage sparrows was somewhat reduced 2 years after fire. Sage sparrow nest survival probabilities and clutch sizes varied annually on control plots but did not differ between treatments after fire. Mass growth rate of sage sparrow nestlings increased the first 2-years postburn. Sage sparrow mating success and fledgling production were not influenced by fire. Brewer's sparrow return rate, mating success, clutch size, fledgling production, and nestling growth were unaffected by fire. Nest survival probabilities of Brewer's sparrows varied among years on experimental plots, but treatments did not differ. Burning altered nest-site and nest-vicinity characteristics of both sparrows, and the changes generally paralleled those that occurred in habitat characteristics measured on the study area in general. Moderate, incomplete burns are not detrimental to nongame bird populations nor to important components of sage and Brewer's sparrow breeding biology. When giving consideration to nongame birds in range burning, we recommend mosaic-pattern, narrow-strip, or small-block burns and long-term monitoring of controls as well as treated sites.

With respect to territory shifts by sage sparrows, we predicted that shifts should (1) result in changes in territory characteristics, (2) be influenced by previous reproductive success and result in greater success, and (3) decline in magnitude for individual males over time. Habitat features of territories changed little as a result of shifts, but territory size increased. Correspondingly, habitat features of territories were unrelated to reproductive success, whereas territory size was positively related. The magnitude of territory shifts was negatively correlated with preshift fledging success, and after shifts, males experienced greater average reproductive success than before. Successive territory shifts by individual males became progressively smaller. Thus, territory shifting by sage sparrows seems to be adaptive behavior aimed primarily at increasing territory size.

EXPORT OF CONTAMINANTS BY WATERFOWL USING IDAHO NATIONAL ENGINEERING LABORATORY WASTE PONDS

Previous studies have shown that gamma-emitting radionuclides are incorporated into tissues of waterfowl using the Test Reactor Area (TRA) waste ponds. Radiation dose to ducks (1982: J. Wildl. Manage. 46:905-914) and to man (1981: Health Physics 40:173-181) from gamma-emitting nuclides has been evaluated. Subsequent analyses for Sr-90 and transuranic nuclides in tame ducks released on these TRA ponds indicate that dose to man from these nuclides is insignificant relative to the gamma-emitting nuclides, but dose to ducks is comparable (submitted: Health Physics). Although an improbable event, consumption of a duck immediately after leaving the TRA waste ponds would result in the predicted dose equivalent of about 10 mrem to an offsite individual from routine INEL operations [DOE/ID-12082(86)].

Studies are now in progress on two additional areas: 1) contaminant transport by waterfowl using other INEL waste water ponds and 2) uptake of non-radiological contaminants into waterfowl tissues. Although other waste water ponds currently receive effluent containing lower radionuclide concentrations than the TRA pond, some may attract a larger number of waterfowl, due to their larger size or more attractive habitat. In addition, certain non-radioactive contaminants are of interest at the other ponds, as well as at the TRA.

Data on waterfowl usage have been obtained for the TRA ponds and the percolation pond at the Idaho Chemical Processing Plant (ICPP) since March 1984, 2 weeks after the ICPP percolation pond was officially opened. In addition to these two, five other INEL pond complexes were observed between October 1985 and October 1986: 1) Argonne industrial waste and sewage lagoons, 2) Naval Reactor Facility (NRF) sewage ponds, 3) Loss of Fluid Test facility seepage pond, 4) Test Area North disposal pond, and 5) Test Reactor Area cold waste ponds. Most waterfowl use the waste water ponds mainly as a resting place. The NRF ponds receive the greatest amount of use, followed by the Argonne ponds.

The second phase of the project involves measuring the contaminant concentrations in waterfowl tissues and determining export. Fifty ducks whose time on the ponds could be estimated were collected from six INEL waste water ponds as well as control areas from November 1984 through October 1986. Analysis of non-radiological contaminants is pending, but analyses of gamma-emitting radionuclides have been completed for muscle, skin, feathers, gastrointestinal, liver and whole body. Twenty-one man-made radionuclides were detected in tissues from the INEL birds whereas only Cs-137 was detected in birds from control areas. Birds from the TRA warm waste ponds had the highest concentrations and largest number of radionuclides. The ICPP percolation pond was the next highest location; the maximum concentrations being observed in a wing-clipped coot that was allowed to remain on the pond for 11 days. The concentrations of ^{137}Cs (4.2 pCi/g wet weight) and Cs-134 (0.7 pCi/g) in muscle would result in a dose equivalent to a hunter of less than 0.1 mrem.

ANTIMONY-125 RELEASES FROM THE IDAHO CHEMICAL PROCESSING PLANT: CONSEQUENCES AND OPPORTUNITIES

The Fluorinel Dissolution Process (FDP) at the Idaho Chemical Processing Plant (ICPP) began dissolving fuel for uranium recovery in October 1986. The FDP, part of the Fluorinel and Fuel Storage Facility (FAST), is a major nuclear facility which replaces part of an older facility at the ICPP. A radioisotope of antimony, Sb-125, was determined to be escaping the FAST ventilation exhaust particulate filters, due to its presence as a stibene (SbH_3) gas. Stibene gas is unstable and rapidly undergoes chemical decomposition into a particulate form (Sb_2O_3) in an oxidizing environment.

Antimony-125 was detected in air at both onsite and offsite monitoring stations in the fourth quarter of 1986 and continues to be detected in 1987. Unlike previous years, in which the isotopes of the noble gases comprised the majority of hypothetical dose to an offsite person from the INEL, 78% of the calculated dose (0.11 mrem) to a maximally exposed individual in 1986 from routine operations was due to Sb-125 [1986: DOE/ID-12082(86), NTIS]. Approximately one curie of Sb-125 was released in 1986; the 1987 release is expected to be at least 10 times higher. Although the onsite and offsite radiation dose consequences of the Sb-125 are expected to be well below radiation protection standards promulgated by the Department of Energy (DOE) and the Environmental Protection Agency, careful review of control technology to reduce the Sb-125 effluent is underway by DOE and ICPP personnel.

The Sb-125 releases in 1986 and 1987 provide a unique opportunity for increased understanding of dispersion and deposition of pollutants from the ICPP. Since most INEL effluents are rarely measurable at air monitoring stations, it has been difficult to determine the adequacy of predictive models. Two atmospheric dispersion models are presently used by the Radiological and Environmental Sciences Laboratory (RESL) of DOE for evaluating radiological consequences of INEL operations. The MESODIF model, operated by the National Atmospheric and Oceanic Administration (NOAA) for the DOE at the INEL, has been used for 14 years to calculate ground-level concentrations of pollutants in air. In addition, the AIRDOS/EPA model has been used by RESL for the past 2 years to show compliance with the EPA Clean Air Act regulations. The two models predict quite different results for the 1985 and 1986 releases and meteorology. The Sb-125 releases from the ICPP may provide an opportunity for model validation, provided sufficient data on release dynamics are available. Personnel from ICPP and NOAA will be cooperating with RESL in this effort.

The most important pathway for dose to man from Sb-125 airborne effluents is deposition onto ground surfaces and external radiation exposure. Thus, it is important to know the rate of depositon from air to ground. Several techniques, including shallow-depth soil sampling, sticky-paper collection surfaces, wet-only deposition samples, and in-situ gamma spectroscopy are being evaluated and used to measure Sb-125 deposition. These site-specific measurements will allow us to determine more appropriate parameters for use in predictive models at the INEL.

I-129/I-127 RATIOS IN THE ENVIRONMENT AT THE IDAHO NATIONAL ENGINEERING LABORATORY

The radioisotopes of iodine are potentially the most environmentally important emissions from nuclear fuel reprocessing plants. We first reported Iodine-129/Iodine-127 ratios (the ratio of the long-lived isotope I-129 to stable iodine I-127) in the INEL environment in 1974 (Rad. Data and Reports 15:227-246). Subsequently in 1975, an extensive study was conducted on the INEL to determine I-129/I-127 atom ratios in rabbit thyroids (1982: Health Physics 43:251-258). The highest ratio in rabbit thyroids occurred near the ICPP and was 9.1×10^{-4}. Ratios from thyroids of rabbits collected offsite and adjacent to the INEL were higher than control area ratios ($< 4 \times 10^{-7}$).

During this same period, mule deer thyroids collected at Craters of the Moon National Monument (54 km west of ICPP) had average I-129/I-127 ratios of 4.4×10^{-6} and were significantly ($P < 0.01$) higher than ratios in control animals (3.3×10^{-7}) (1983: Health Physics 45:31-38). Thyroids of deer in the Medicine Lodge/Crooked Creek area (71 km northeast of Idaho Chemical Processing Plant) averaged 2.0×10^{-6}, and ratios of pronghorn thyroids collected near Monida Pass on the Montana border (71-116 km from ICPP) averaged 3.9×10^{-6}. Thyroids of a domestic sheep collected in August 1974 (116 km northeast of ICPP) had a I-129/I-127 ratio of 1.6×10^{-5}. From these data, it seems probable that the increased ratios obtained from samples northeast and southwest of the INEL are due to atmospheric releases from the ICPP.

In a related project (1985: McGiff MS Thesis, Colorado State University), sagebrush and grass samples were collected from 1 to 30 km from the ICPP along two transects which followed the predominant downwind directions. I-129/I-127 ratios in vegetation onsite ranged from 1.5×10^{-3} to 1.9×10^{-5}. The I-129/I-127 atom ratios in both vegetation and rabbit thyroids exhibit similar decreases with distance from the ICPP. Based upon the ratios in vegetation, estimates of maximum potential 50-year dose commitments to man from I-129 resulting from ingestion over 1 year of food items produced on or near the INEL were 0.07 mrem for milk consumption, 0.31 mrem for beef and 0.022 mrem for pronghorn. Actual dose rates would be less. Currently the data on I-129 in INEL vegetation is being prepared for the open literature.

Data on I-129 in tissues of ducks from the Test Reactor Area leaching ponds have been published (1984: Health Physics 46: 1259-1263). The relative amount of I-129 waterfowl muscle tissue is small compared to tissues of other species occurring around nuclear fuel processing plants.

The majority of data on I-129/I-127 atom ratios on the INEL were collected in 1975 or prior years (vegetation data 1978). In addition, modifications to the fuel reprocessing plant process will allow a greater throughput of waste with subsequent increases in the I-129 effluent. Thus, data are needed on the current levels and factors affecting long-term rates of change of I-129/I-127 ratios in the INEL environment. Study plans on these topics are currently being formulated.

PLUTONIUM DISTRIBUTION AND PHYSIOCHEMICAL CHARACTERISTICS IN TEST REACTOR AREA LEACHING PONDS

For over 30 years, Test Reactor Area (TRA) leaching ponds on the Idaho National Engineering Laboratory (INEL) site have received liquid wastes contaminated with radioactivity from controlled low-level and accidental releases. The objectives of this study were to (a) determine the distribution of Pu-239,240 and Pu-238 in sediment, water and net plankton in TRA leaching ponds, and (b) characterize the chemical and physical species of the plutonium isotopes in ponds water.

The highest plutonium concentration was found in net plankton. Plankton Concentration Ratios (CRs) ranged from $4x10^4$ to $4x10^5$ for the plutonium isotopes and varied with sampling dates. These values reflect the efficiency with which plutonium is taken up by plankton. The lowest plutonium concentrations were found in filtered water ($\sim$1 pCi/l). Plutonium concentration associated with sediment was inversely related to particle size. Distribution coefficients (K_d's) for Pu isotopes ranged from $1.3x10^4$ to $1.5x10^5$ reflecting the relative insolubility of plutonium in water. The lower oxidation states (III and IV) were dominant in water representing 65 to 72% of the total activity for plutonium isotopes. This is in contrast with other aquatic systems (Great Lakes) in which Pu is predominately in the upper oxidation states. The different Pu oxidation states can be expected to show markedly different chemical and biological properties. No significant differences between Pu-239,240 and Pu-238 concentrations were observed in pond components. This finding is contrary to what has been reported in an earlier study for various biotic components of the TRA ponds ecosystem. Most of the plutonium in solution (0.45 μm filtered) was associated with molecular attachment fraction of less than 0.22 μm in size. An order of magnitude difference in plankton cell counts was observed between the leaching ponds and was attributed to differences in water pH and nutrient concentrations.