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IDAHO NATIONAL ENGINEERING LABORATORY RADIOECOLOGY AND ECOLOGY PROGRAMS 1983 PROGRESS REPORT

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U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
RADIOLOGICAL AND ENVIRONMENTAL SCIENCES LABORATORY
O.D. Markham, Editor

MASTER

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DOE/ID--12098

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Date Published -- June 1983

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ECOLOGICAL VECTORS OF RADIONUCLIDE TRANSPORT
AT A SOLID RADIOACTIVE WASTE DISPOSAL FACILITY IN SOUTHEASTERN IDAHO^a

W. John Arthur and O. Doyle Markham

ABSTRACT

Radioecological research conducted at the Idaho National Engineering Laboratory Subsurface Disposal Area (SDA) in southeastern Idaho has estimated the quantity of radionuclides transported by various ecosystem components and evaluated the impact of subsurface disposal of radioactive waste on biotic species inhabiting the area. Two reptilian, 18 mammalian and 31 avian species were observed in the waste disposal area between October 1977 and August 1979 of which cottontail rabbits and rodents were the most frequently occurring wildlife. A total of 23 μCi (^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am) was estimated to occur in SDA deer mice tissues over a 1-year period, with 0.01 μCi estimated to occur in rabbit tissues over a similar time period. Radiation dose rates received by small mammals at the SDA ranged from 0.4 to 41790 mrad/day. Comparisons of the radiation dose rates received by individual rodents to the ambient radiation dose rates on the SDA surface indicated that 48% of the small mammal population had encountered areas of disposed gamma-emitting radioactive waste and/or contaminated soil. Small mammal soil burrowing was an upward transport mechanism for transuranic radionuclides, with an estimated total of 11700 kg of soil containing 45 μCi of activity excavated to the 36 ha SDA surface over a 1-year period. Statistically greater plutonium and americium concentrations were detected in crested wheatgrass and Russian thistle samples collected at the SDA. Seventy-seven μCi of radioactivity occurred in SDA vegetation annually. Even though soil, vegetation, and small animal tissue samples collected at the SDA had elevated radionuclide concentrations, none of these ecological vectors contributed appreciable quantities of radioactive contamination to the environment surrounding the SDA. More important may be the effects of factors such as small mammal soil burrowing and deep rooting vegetation on the integrity of soil covers over the disposed waste. Research currently being conducted at the SDA will relate results of these radioecological studies to management considerations associated with stabilizing shallow land radioactive waste disposal sites.

^a A brief version of this report appeared as a paper of the same title: 1982. p. 574-580 In M. A. Feraday, ed. Proceedings of International Conference on Waste Management held at Winnipeg, Manitoba. Canadian Nuclear Society, Toronto, Ontario, ISBN: 0-919784-01-1.

INTRODUCTION

Since 1953 the Idaho National Engineering Laboratory in southeastern Idaho has been used to test nuclear reactors under a variety of experimental conditions which include evaluating fuel, coolant, and moderator characteristics and accelerated testing of safety features. Reactor operations, supporting laboratory facilities, and a nuclear fuel reprocessing plant have generated solid and liquid radioactive wastes.

Between 1952 and present, 8.8×10^6 curies of solid activation, fission, and transuranic radioactive wastes have been disposed at the Subsurface Disposal Area of the Idaho National Engineering Laboratory (INEL) Radioactive Waste Management Complex (RWMC). Due to deterioration of some waste containers and degradation of other uncontained wastes, radionuclide contamination has occurred in SDA subsurface soils (Card, 1977). Additionally, flooding due to snowmelt in 1962 and 1969 caused transuranic radionuclide contamination in some SDA surface soils with subsequent wind transport of some of the contamination (Markham, 1978; Markham et al., 1978).

The SDA is located in a cool desert sagebrush community which has diverse vegetation and wildlife populations. Since the possibility exists that populations occurring in or adjacent to the SDA could contact radionuclide contamination, a radioecological research project was initiated in October 1977 to assess the role of various ecosystem pathways in transporting radionuclides through the environment. Objectives of the research were 1) to define potential pathways and to estimate the quantity of radionuclides accumulated and/or transported, and 2) to determine the impact of subsurface disposal of radioactive wastes on animal species occurring in the area.

STUDY AREA

The SDA occurs at an elevation of 1527 m and occupies 36 ha of the 230,000 ha Idaho National Engineering Laboratory in southeastern Idaho. Geologic features at the SDA consist of successive subsurface basalt flows and interbedded sediments overlain by 1.0 to 7.6 m (average 5.0 m) of lacustrine and eolian deposits. The major soils are Polatis coarse, silty, mixed frigid and Tenno loamy, mixed frigid. Average yearly precipitation is 22 cm, with maximum moisture from May to June. During winter, the average minimum and maximum temperatures are -16°C and -3°C , respectively. In summer, these averages are 10°C and 31°C , respectively. Local winds are channeled by the terrain into a prevailing southwest-to-northeast direction.

Most of the SDA has been seeded with crested wheatgrass (Agropyron cristatum). Russian thistle (Salsola kali), an invader species, grows over many recently disturbed sites that were not seeded with wheatgrass. Other common plant species are tansey mustard (Descurania sophia), summer cypress (Kochia scoparia), common dandelion (Taraxacum officinale) and cheatgrass (Bromus tectorum). The vegetation surrounding the SDA is dominated by big sagebrush (Artemisia tridentata), green rabbitbrush (Chrysothamnus viscidiflorus) and bluebunch wheatgrass (Agropyron spicatum) (McBride et al., 1978).

Radioactive waste in the SDA consists of transuranic waste from Rocky Flats, Colorado and activation and fission product waste from INEL and several other government facilities. Since 1952 all low-level fission and activation wastes were disposed in trenches which averaged 275 m long, 2 m wide, and approximately 4 m deep, depending upon soil depth over the basaltic bedrock. These wastes consisted of laboratory equipment, filters, paper, protective clothing and building materials. Larger, irregular shaped material (pipes, empty liquid tanks, and other noncompactable items) were disposed in pits which averaged 30 m wide, 4 m deep and varied in length. Transuranic waste disposed during the 1954-1970 period was enclosed in steel drums. Wooden crates were used for any item too large for the steel drums. A small volume was buried in cardboard cartons. Most transuranic waste has been buried in pits, although some of the earlier shipments were interspersed in trenches with activation and fission waste.

To date approximately 8.8×10^6 Ci of radioactive waste have been placed in the SDA. The current quantity of activity remaining in the disposed waste is reduced due to radioactive decay. The major transuranic nuclides and the quantities placed in the SDA were ^{238}Pu (571 Ci), ^{239}Pu (21050 Ci), ^{240}Pu (4935 Ci), ^{241}Pu (179000 Ci) and ^{241}Am (48010 Ci). No estimate is available on the quantity of fission and activation radionuclides placed in the SDA prior to 1971; however, during the 1971-1978 period, 392800, 4700, and 4104 Ci, respectively of ^{60}Co , ^{137}Cs , and ^{90}Sr had been disposed in the SDA. Other shorter half-lived radionuclides frequently disposed in SDA waste were ^{51}Cr , ^{54}Mn , ^{59}Fe , ^{58}Co , ^{103}Ru , ^{141}Ce , ^{144}Ce , and ^{95}Zr . Since 1970 all transuranic waste containing alpha activity greater than 10 nCi/g has been retrievably stored at the Transuranic Storage Area (TSA) located adjacent to the SDA.

After pits and trenches were filled with waste, at least 0.6 m of soil was applied and compacted over the surface as a final cover. Recently filled pits and trenches have been covered with clay silt soils obtained from an area 1.6 km south of the SDA. Most earlier covers used soils excavated from the SDA.

Excavation of older waste disposal pits indicated that some of the transuranic waste containers were severely rusted, or missing covers and subsurface soil contamination had occurred (Card, 1977). Further, transuranic contamination of SDA surface soils occurred during flooding of open pits in 1962 and 1969 at which time some waste containers were breached. The highest concentrations of plutonium were found in surface soil samples collected in the northeast section of the SDA (area of lowest elevation); however, elevated surface soil plutonium and americium concentrations were also found northeast and southwest of the facility but decreased with distance away from the area (Markham et al., 1978).

METHODS

Methods of study design, sample collection and preparation, and statistical design were previously discussed (Arthur and Markham, 1978). Initial research efforts centered on determining wildlife species which could potentially encounter radionuclide contamination at the SDA. One

hundred-ninety-four wildlife inventories were conducted between October 1977 and August 1979. Approximately 2 days per week, a 5.1 km inventory route was driven in and adjacent to the SDA at 3-5 kph. Occurrence and numbers of each species observed were noted and all data were presented as total number and frequency of occurrence of each species at the SDA. No information on species smaller than Townsend's ground squirrel could be obtained from the driving routes; therefore, this information was obtained by an intensive small mammal study conducted at the SDA between May 1978 and August 1979. Objectives of the small mammal research were to determine density, species composition, local movements and dispersal of rodents at the waste disposal facility (Groves and Keller, in press).

Tissues were sampled from wildlife species frequently occurring at the SDA and analyzed for radionuclide concentrations. Deer mice were collected and lung, gastrointestinal tract (GI), hide and carcass tissues were composited. Lung, GI, hide, and carcass tissues were also sampled from cottontail rabbits. Horned larks were whole-body analyzed, whereas muscle and GI contents were analyzed from sage grouse (Connelly and Markham, 1982) and mourning doves (Markham and Halford, 1982). Coyote fecal samples were collected in and immediately adjacent to the SDA in order to provide an estimate of the nuclide concentrations transported by a predatorial species (Arthur and Markham, 1982).

Wildlife tissues were also collected from control areas where no radioactive waste was disposed. All of these samples were collected at least 60 km from the SDA. The control sample sizes were 5 deer mice tissue composites, 5 cottontail rabbits, 20 sage grouse, 5 horned larks, and 12 coyote fecal samples.

After dissection all tissues were weighed (wet weight) and analyzed for gamma-emitting radionuclides on a 65 cm³ germanium-lithium detector coupled to a computerized multichannel analyzer system. Deer mice, rabbit, and coyote fecal samples were also analyzed for transuranic (²³⁸Pu, ^{239,240}Pu, ²⁴¹Am) radionuclides and ⁹⁰Sr.

For each radionuclide detected in wildlife tissues, mean concentrations were calculated for both the SDA and control areas. Due to their frequent occurrence at the SDA, estimates of the total radionuclide inventories in rodent and cottontail rabbit populations were made by multiplying the total species population estimates by average tissue radionuclide concentrations and respective tissue weights for these species. Estimates of the total radioactivity transported away from the SDA by small mammals were determined by relating these inventory estimates to the estimated number of animals that emigrated from the SDA.

Radiation dose rates received by small mammals inhabiting the SDA were determined by surgical implantation of 677 packets each containing two lithium fluoride thermoluminescent dosimeter (TLD) chips in 362 individual deer mice and Ord's kangaroo rats (Arthur et al., draft manuscript). Packets containing three TLD chips were placed 15 cm above the ground surface at each of 296 points on a systematically established grid system to estimate the potential radiation dose rate received by small mammals on the SDA surface. Data obtained on individual small mammal movements (Groves and Keller, in press) were used to determine

locations the animals had been during the time the TLD packets were implanted. Estimates on the proportion of the small mammal population encountering areas of disposed radioactive waste and/or contaminated soil were obtained by comparing the dose rates from the implanted packets to the dose rates estimated to occur on the SDA surface.

Estimates on the quantity of soil excavated to the SDA surface were obtained to determine the impact of small mammal soil burrowing on upward movement of radionuclides (Arthur and Markham, 1983). Twenty-five belt transects, each 2.4 x 75 m, were randomly selected from the 296 point grid system. Each of the transects were searched for soil excavated to the surface by small mammals and all excavated soil was collected and weighed. The average excavated soil mass per unit area was multiplied by the total area encompassed by the SDA to estimate the total quantity of soil excavated over a 1-year period. Samples of excavated and nearby surface (0-5 cm) soils were collected and analyzed for gamma-emitting radionuclides and ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$ and ^{241}Am . Similar sampling was conducted at a control area to determine radionuclide concentrations in surface and excavated soils at an area where no radioactive waste was disposed.

A study was initiated in June 1978 to determine the concentration of gamma-emitting radionuclides and ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am in vegetation growing at the SDA and to estimate the total radionuclide inventory existing in SDA vegetation (Arthur, 1982). Between mid-July and September 1978, 80 1-m^2 plots were randomly selected and vegetation biomass determined by clipping individual species of vegetation at ground level. Vegetation samples for each plot were collected, dried and analyzed for radionuclides. Mean radionuclide concentrations (pCi/g) were multiplied by the estimated vegetation biomass to obtain a total radionuclide inventory for SDA vegetation. Fifteen crested wheatgrass samples were randomly selected and ultrasonically washed in water to remove surficially attached soil particles. Radionuclide concentrations in the washed samples were statistically compared to the concentrations in unwashed samples to assess the importance of surficially attached radionuclide contamination.

RESULTS AND DISCUSSION

Two reptilian, 31 avian, and 18 mammalian species were observed in and adjacent to the SDA between October 1977 and August 1979. The most frequently occurring species were deer mice, montane vole, Ord's kangaroo rat. Townsend's ground squirrel, horned lark, mountain cottontail rabbit, sage grouse, western meadowlark and coyote.

Radionuclide concentration in soils, vegetation, and animal tissues collected at the SDA are presented in Table 1. Elevated radionuclide concentrations in rodent species (deer mice) tissues from the waste disposal area were attributed to their burrowing activities in areas having radionuclide contamination in soil. Concentrations of ^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am in deer mice tissues collected from the SDA were statistically higher than control area tissues. Based

Table 1. Radionuclide concentrations $\bar{x} \pm SD$ (pCi/g) in soils, vegetation and animal tissues at the Subsurface Disposal Area and control area, southeastern Idaho.

Media	n	Area	^{90}Sr	^{137}Cs	^{238}Pu	$^{239,240}\text{Pu}$	^{241}Am
Deer mice carcass	21	SDA	$721^a \pm 1061$	$57.3^a \pm 122$	0.01 ± 0.03	0.04 ± 0.11	0.01 ± 0.02
	5	Control	0.6 ± 0.6	0.20 ± 0.07	0.002 ± 0.003	0.002 ± 0.007	0.003 ± 0.002
Cottontail rabbit carcass ^b	10	SDA	0.30 ± 0.24	0.14 ± 0.33	0.001 ± 0.0004	0.004 ± 0.003	$0.010^a \pm 0.009$
	4	Control	0.37 ± 0.09	0.16 ± 0.12	0.001 ± 0.001	0.002 ± 0.001	0.001 ± 0.001
Horned lark carcass	9	SDA	---	1.07 ± 2.51	---	---	---
	5	Control	---	0.21 ± 0.16	---	---	---
Sage grouse carcass	14	SDA		0.3 ± 0.09	---	---	---
	20	Control		0.3 ± 0.2	---	---	---
Coyote feces	7	SDA	2.0 ± 1.6	3.4 ± 6.5	0.013 ± 0.027	0.5 ± 1.2	$0.4^a \pm 0.9$
	6	Control	0.9 ± 0.2	0.7 ± 0.5	0.003 ± 0.004	0.006 ± 0.003	0.003 ± 0.002
Soil							
Excavated	46	SDA	0.44 ± 0.81	0.45 ± 0.41	0.07 ± 0.16	2.28 ± 6.16	16.2 ± 60.2
Surface	25	SDA	0.17 ± 0.10	0.26 ± 0.22	$0.11^a \pm 0.29$	$3.14^a \pm 10.6$	$6.10^a \pm 12.4$
Surface	10	Control	0.56 ± 0.23	0.70 ± 0.36	0.003 ± 0.003	0.02 ± 0.01	0.007 ± 0.004
Crested wheatgrass	40	SDA	0.23 ± 0.11	0.27 ± 0.40	$0.002^a \pm 0.007$	$0.097^a \pm 0.327$	$0.212^a \pm 0.815$
	7	Control	0.24 ± 0.11	0.15 ± 0.13	0.0002 ± 0.0002	0.001 ± 0.0002	0.0005 ± 0.0004
Russian thistle	24	SDA	0.51 ± 2.23	2.16 ± 10.4	0.004 ± 0.012	$0.016^a \pm 0.014$	$0.058^a \pm 0.046$
	5	Control	0.42 ± 0.41	0.19 ± 0.18	0.001 ± 0.0004	0.0008 ± 0.0005	0.0004 ± 0.0003

^a Significant difference at $P \leq 0.05$

^b Includes gastrointestinal tract.

on an estimated 6160 deer mice inhabiting the SDA over a 1-year period (Groves and Keller, this volume), a total inventory of 23 μCi (^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am) was estimated to occur in deer mice tissues annually. The estimate of 23 μCi transported by deer mice is only a portion of the total radioactivity in the SDA rodent population since deer mice comprised 59% of the total rodent population (Groves and Keller, this volume). On a biomass basis, the other nine rodent species trapped in the SDA comprised 69% (240 of 346 kg live-weight) of the SDA total rodent biomass. An estimated total of 33 μCi of ^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am would occur in the SDA rodent population over a 1-year period (Table 2), by assuming that the other small mammal species had tissue radionuclide concentrations similar to deer mice.

Americium-241 concentrations detected in carcass tissues of cottontail rabbits inhabiting the SDA were statistically greater than control sample; however, the total inventory of 0.01 μCi (^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am) estimated in the SDA rabbit population for 1-year period was similar to that estimated for the control rabbit population. Rabbit feces deposited over a 1-year period in and adjacent to the SDA were estimated to contain 0.11 μCi ^{137}Cs . No estimate was available on the quantities of ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am in rabbit feces.

Radionuclide concentrations detected in horned lark, sage grouse (Connelly and Markham, 1982) and mourning dove (Markham and Halford, 1982) tissues collected at SDA were not statistically different from control area samples. This was likely because of these species limited use of the area. Elevated ^{241}Am concentrations in coyote fecal samples collected around the SDA were attributed to ingestion of contaminated small mammals. Assumptions relative to the coyote use of the SDA permitted an estimate of the maximum quantity of radioactivity exported and eliminated around the facility (Arthur and Markham, 1982). The annual total of 7.2 μCi (^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am) eliminated by coyotes within a 6.3 km radius of the SDA (Table 2) was only four times greater than the quantity eliminated at a control area (Arthur and Markham, 1982).

Fifty-three percent of the 677 TLD packets implanted in SDA rodents were recovered and analyzed. The mean radiation dose rate (Table 2) received by deer mice (364 mrad/day) was statistically greater than that for kangaroo rats (9.9 mrad/day). A mean radiation dose rate of 0.4 mrad/day was received by rodents in a control area. Radiation dose rate differences between the two species of small mammals are likely due to differences in species vertical movements and also differences in exposure rates from disposed radioactive waste. Excluding open pits and trenches being filled with radioactive wastes, which were not likely to be used extensively by rodents, most radiation dose rates on the ground surface of the SDA ranged from 0.4 to 3.0 mrad/day (Fig. 1). Comparisons of the radiation dose rates received by individual rodents to the ambient dose rates on the SDA surface indicated that 49% and 20% of the deer mice and kangaroo rat populations, respectively, encountered areas of disposed radioactive waste and/or contaminated soil (Fig. 2).

Table 2. Radionuclide inventories (μCi) occurring in ecosystem pathways at the Subsurface Disposal Area.

Pathway	Mass (kg)	^{137}Cs , ^{90}Sr	$^{238,239,240}\text{Pu}$, ^{241}Am	Total
Small mammal soil excavations	11700	14.6	30.5	45.1
Vegetation (above ground)	36300	68.2	8.7	76.9
Coyote feces ^a	1134	6.2	1.0	7.2
Small mammals ^b	346	32.8	0.02	32.8
Cottontail rabbits ^b	23	0.01	4.3×10^{-4}	0.01

^aFeces deposited within a 6.3 km radius of SDA.

^bTissue radionuclide inventory only.

Table 3. Radiation dose rates (mrad/day) received by deer mice and Ord's kangaroo rats at the Subsurface Disposal Area.

Species	Spring-Summer	Fall-Winter	Total ^a
<u>Deer Mice</u>			
$\bar{x} \pm \text{SD}$	278 ± 1063	21.6 ± 108	364 ± 2662
Range	$0.4 - 9422$	$0.4 - 929$	$0.4 - 41790$
n	178	61	276
<u>Kangaroo Rat</u>			
$\bar{x} \pm \text{SD}$	2.3 ± 6.2	2.0 ± 2.0	9.9 ± 67.2
Range	$0.4 - 29.2$	$0.4 - 9.0$	$0.4 - 563$
n	38	16	71

^aIncludes radiation dose rates obtained for overlapping seasonal periods.

Figure 1. Isopleth of radiation dose rates (mrad/day) that would be received by small mammals on the surface of the Subsurface Disposal Area facility and surrounding area.

Figure 2. Percentage of deer mice (P) and Ord's kangaroo rat (D) contacting areas of disposed radioactive waste and/or contaminated soil at Subsurface Disposal Area.

Estimates from transects within the SDA indicated that a total of 11700 kg soil was excavated to the SDA surface by small mammals over a 1-year period. Statistically greater concentrations of ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am were detected in excavated and surface soils in the waste disposal area. The inventory of 45 μCi (^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, and ^{241}Am) transported to the surface of the waste disposal area by small mammal soil burrowing was significantly greater than the 19 μCi occurring in excavated soils at a control area where no radioactive waste was disposed. Even though small mammal soil burrowing was a mode of upward radionuclide transport to the SDA surface, the total amount of plutonium in excavated soils was only 0.05% of the 13.7 mCi plutonium estimated to occur in SDA surface soils in 1974 (Harness and Passmore, 1976). Since surface soils in several SDA areas were previously contaminated due to flooding of waste disposal pits and subsequent wind transport, additional contamination due to small mammal burrowing will probably result only in minimal additions of contamination to existing levels in surface soils.

Plutonium-238, $^{239,240}\text{Pu}$, and ^{241}Am concentrations in crested wheatgrass and Russian thistle samples collected at the SDA were statistically greater than concentrations in control area vegetation; however, no statistical differences were observed for ^{90}Sr and ^{137}Cs concentrations between SDA and control area vegetation. Russian thistle samples had greater radionuclide concentrations than crested wheatgrass presumably due to the greater rooting depth of this species and the spreading growth which places the plant close to the ground surface for potential attachment of contaminated soil particles. Based on a total of 36,300 kg of vegetation growing over a 1-year period, 77 μCi ^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$ and ^{241}Am occurred in SDA vegetation (Arthur, 1982). This was not statistically greater than the 17 μCi occurring in the control area vegetative biomass.

Radioecological studies conducted at the INEL Subsurface Disposal Area in southeastern Idaho since 1977 have identified various ecosystem components as potential pathways (Fig. 3) for radionuclide transport as well as providing estimates of quantity of radionuclides transported. Soils, vegetation and tissues of small mammal species sampled in and adjacent to the SDA had elevated radionuclide concentrations; however, when the quantities of ^{90}Sr , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$ and ^{241}Am in ecosystem components were estimated for a 1-year period, the total activity inventory in small mammal soil excavations, vegetation and small mammal tissue biomass were estimated to be less than 0.2 mCi (Table 3). It is unlikely that these ecosystem components currently contribute appreciable quantities of radioactive contamination to the environment surrounding the SDA, since the total plutonium radioactivity transported by the several ecosystem components examined in our studies is only 0.08% of the 13.7 mCi plutonium estimated to occur in SDA surface soils in 1974 (Harness and Passmore, 1976).

More important than the transport of radioactive contamination by ecosystem components may be the intrusion of small mammals and vegetative roots into areas of disposed radioactive waste and affects of these

Figure 3. Ecological vectors as radionuclide transport pathways at the Idaho National Engineering Laboratory Subsurface Disposal Area.

intrusions on the integrity of soil covers over the waste. Additionally, processes such as small mammal burrowing at radioactive waste disposal areas may increase water infiltration rates which could result in increased deterioration of waste containers. Research currently being conducted at the Idaho National Engineering Laboratory will evaluate the effects of small mammal and vegetative intrusion on soils covering disposed waste and will relate results of these studies to management considerations associated with stabilizing shallow land radioactive waste disposal areas (Reynolds and Arthur, this volume). Emphasis will be placed on selecting native soil covers that minimize vegetation and small mammal intrusion into disposed radioactive waste. Additional studies are also currently being conducted on small mammal movements in and out of the SDA and on jack rabbit movements, radionuclide transport and forage consumption at the SDA by jackrabbits.

LITERATURE CITED

- Arthur, W. J. 1982. Radionuclide concentrations in vegetation at a solid radioactive waste disposal area in southeastern Idaho. J. Environ. Qual. 11:394-399.
- Arthur, W. J., D. K. Halford, O. D. Markham, C. R. Groves and B. L. Keller. Radiation dosimetry of small mammals inhabiting a solid radioactive waste disposal area. (draft manuscript).
- Arthur, W. J. and O. D. Markham. 1978. Ecology studies at the Idaho National Engineering Laboratory Radioactive Waste Management Complex. In Ecological Studies on the Idaho National Engineering Laboratory Site-1978 Progress Report. U. S. Department of Energy Technical Report IDO-12087. Nat. Tech. Inf. Ser., Springfield, VA.
- Arthur, W. J. and O. D. Markham. 1982. Radionuclide export and elimination by coyotes at two radioactive waste disposal areas in southeastern Idaho. Health Phys. 4:493-500.
- Arthur, W. J. and O. D. Markham. 1983. Small mammal soil burrowing on a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. J. Environ. Qual. 12:117-122.
- Card, D. H. 1977. Early Waste Retrieval Interim Report. EG&G Idaho, Inc. Technical Report. TREE-1047. Nat. Tech. Inf. Ser., Springfield, VA.
- Connelly, J. W. and O. D. Markham. 1982. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. J. Wildl. Manage. 47:169-177.
- Groves, C. R. and B. L. Keller. In press. Ecological characteristics of small mammals at a radioactive waste disposal area. Amer. Midl. Nat.
- Harness, J. L. and R. W. Passmore. 1976. 1974 Onsite environmental surveillance report for the INEL Radioactive Waste Management Complex. EG&G Idaho, Inc. Technical Report TREE-1014. Nat. Tech. Inf. Ser., Springfield, VA.
- Markham, O. D. 1978. Activation and fission products in the environment near the Idaho National Engineering Laboratory Radioactive Waste Management Complex. U. S. Department of Energy Technical Report. IDO-12085. Nat. Tech. Inf. Ser., Springfield, VA.
- Markham, O. D. and D. K. Halford. 1982. Radionuclides in mourning doves near a nuclear facility complex in southeastern Idaho. Wilson Bull. 94:185-197.

Markham, O. D., K. W. Puphal and T. D. Filer. 1978. Plutonium and americium contamination near a transuranic storage area in southeastern Idaho. J. Environ. Qual. 7:422-428.

McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. U. S. Department of Energy Technical Report. IDO-12084. Nat. Tech. Inf. Ser., Springfield, VA.

PRELIMINARY REPORT OF BIOLOGICAL INTRUSION STUDIES AT THE
IDAHO NATIONAL ENGINEERING LABORATORY SUBSURFACE DISPOSAL AREA

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ABSTRACT

As part of a larger study on the effects of biological intrusion of plants and animals into the soil cover placed over low-level radioactive wastes stored at the Idaho National Engineering Laboratory Subsurface Disposal Area (SDA), research was initiated in the summer of 1982 to determine the burrow characteristics and movement patterns of several small mammal species, and the rooting depths of various plants. The depth, length, and volume of burrows were determined for four small mammal species: deer mouse (Peromyscus maniculatus), Ord's kangaroo rat (Dipodomys ordii), montane vole (Microtus montanus), and Townsend's ground squirrel (Spermophilus townsendii). The latter species excavated the greatest mean burrow depth (39 cm), length (404 cm), and volume (14.8 l). Movement patterns of three species were determined by radiotelemetry. The mean area of use for P. maniculatus, D. ordii, and M. montanus was 2.3, 1.5, and 1.2 ha respectively. Limited data on rooting depths of various native and introduced plant species at the SDA were obtained by literature review and excavation. During FY-83, experiments will be conducted, using the information obtained from the first year of this study, to evaluate the impact of burrowing mammals and root intrusion on the integrity of the soil cover currently existing at the SDA. Details of these experimental studies are presented.

INTRODUCTION

The proper storage of long-lived radioactive waste materials resulting from nuclear power generation is a primary concern. In the case of shallow land burial, in which low-level radioactive wastes are interred in a trench or pit under 1-2 m of back-fill material, the cover material isolates the waste from the environment and reduces the transport of contaminants. Due to the long half-lives of several low-level radionuclides in the waste products, the cover material placed over subsurface disposal areas must retain its functional integrity for long periods of time. Failure of the cover material to perform its function may be the result of abiotic or biotic factors, or a combination of both (Hakonson et al., 1982a).

Water appears to be a major factor in the failure of cover materials at both arid and humid site subsurface disposal areas (Jacobs et al., 1980). Water action can physically erode the cover material, penetrate and reduce the integrity of containment devices, and/or translocate subsurface waste

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substances by underground pathways (Lane and Nyhan, 1981). Hakonson et al. (1982a) presented a water balance equation to express the hydrologic interaction with waste cover materials:

$$\frac{dS}{dt} = P - Q - ET - L$$

where,

S = soil moisture

P = precipitation

Q = runoff

ET = evapotranspiration

L = percolation or seepage beyond soil cover

t = time.

All components on the right of the equation, with the exception of P, can be altered by planting vegetation on the cover material. Dense rooted stands of vegetation can stabilize soils and reduce soil erosion due to water and/or wind. Plants can reduce the amount of water available for seepage or percolation into lower soil profiles. Plant species that transpire and take up water whenever it is present, regardless of the season or phenologic development, are of particular interest as species for vegetal cover over shallow land disposal areas. Some experiments on water and plant relations are planned at the Los Alamos Scientific Laboratory to determine plant species that maximize desirable hydrologic factors (i.e. ET) and minimize undesirable ones (i.e. Q, S, and L; Hakonson, pers. comm.). Studies on these factors will also begin on the INEL during FY 1983.

Although vegetation planted over subsurface waste disposal areas may be beneficial from a hydrologic standpoint, there are several potentially negative factors. The root systems may penetrate contaminated areas and mobilize waste substances (Grzybowka, 1974; Cline, 1981). Plants could accumulate radionuclides into their tissues and thus make wastes available to a variety of herbivores (O'Farrell and Gilbert, 1975; Hakonson and Bostick 1976; Arthur 1982). Moreover, hazardous materials accumulated in leaf tissues could migrate from disposal areas as a result of annual leaf fall and subsequent wind dispersal. In addition, vegetation over buried wastes provides habitat for many small mammal species, especially small burrowing rodents.

Burrowing animals may affect the quality of the cover material in a variety of direct and indirect means. A burrowing rodent may come into direct contact with contaminated materials. As a result, it may spread contaminants in its daily movements (Landein and Mitchell, 1982; Arthur and Markham, in press). Moreover, contaminated rodents make previously contained wastes immediately available to wide ranging predatory species higher up the ecological food chain (Arthur and Markham, in press (b)). Burrowing activities of rodents may bring contaminated soils and waste materials to the surface (Arthur and Markham, 1982) where they are susceptible to wind erosion (Hakonson et al., 1982b). The burrow itself may indirectly increase the potential for the migration of hazardous substances. It may act as a

funnel, redirecting the movement of water from rainfall or melting snow through the soil and increase the potential for waste containment failure, soil subsidence, penetration of plant roots into waste materials, and the translocation of wastes by underground aquatic pathways.

There seems to be a complex ecological interaction between plants, animals, water, and the cover material isolating hazardous waste materials. These interactions must be evaluated to assess the effectiveness of cover types currently placed over radioactive dispersal areas. The overall objective of this study was to determine the effectiveness of soil barriers over waste at the Idaho National Engineering Laboratory (INEL) Subsurface Disposal Area (SDA) in precluding plant and animal intrusion into, and concomitant translocation of, low-level waste materials.

MATERIALS AND METHODS

Phase I of the study, conducted during the 1982 summer field season, concentrated on the burrows and movement patterns of small mammals resident on the SDA. Small mammal burrow systems exterior to the SDA were injected with polyurethane foam following the methods of Felthouser and McInroy (in press). Hand tools and a back-hoe were used to expose the resultant foam castings of the burrow systems in situ. Horizontal and vertical measurements were made by placing a 1 x 2 m aluminum frame at the surface level above each casting. The frame was divided into 100 cm² grids by wire placed at 10 cm intervals across the length and breadth of the frame. A quantitative graphic representation of each burrow system was generated simply by recording the distance from the surface to the casting by suspending a rod (ruled in 5 cm increments) through the center of each grid above the casting. These data were recorded on graph paper, with each grid on the paper corresponding to a grid on the frame. The result was a top-view schematic of each burrow system, with data within each cell representing depth. The volume of soil removed by the animals in digging each burrow was estimated by placing each polyurethane burrow casting in a large graduated cylinder and recording water displacement.

Radioelemetry techniques were used to determine the movement patterns of small mammals at the SDA. Small mammals were live trapped from the SDA, removed to a field laboratory, and anesthetized with a mixture of ketaset and rompum. Microtransmitters, coated with Elvax (an inert surgical wax), were implanted in each animal's body cavity. After a 48 hour recovery period, the animals were released at the point of capture. Locations were determined for each animal at 15 minute intervals 3 nights each week until either the transmitter no longer functioned or until the animal could no longer be located. Location data were analyzed following the grid methodology described by Laundre' (1979) using grids 5 x 5 m in size to estimate each animal's area of use.

RESULTS

A total of 97 burrow systems were injected with polyurethane foam. Snap trapping, and fecal and hair analysis indicated the burrows had been

used, and presumably constructed, by four small mammal species: Peromyscus maniculatus, Spermophilis townsendii, Microtus montanus, and Dipodomys ordii. The depth, length, and volume of the burrows of M. montanus and P. maniculatus were quite similar (Table 1). Burrows of these two species had a smaller depth, length, and volume than burrows of D. ordii and S. townsendii.

Ten small mammals, representing three species, were successfully implanted with transmitters and monitored a total of 28 nights (Table 2). P. maniculatus had the largest recorded area of use. Although the majority of the activity of each of the study animals occurred within the SDA boundaries, animals were frequently recorded outside of the SDA fence. The movements of one peromyscus (#700) were of particular interest. Each evening at dusk, this animal would move from its burrow to the SDA where it would forage both inside and outside of the SDA throughout the night. At dawn, the animal would return to its burrow, traversing a linear distance of about 250 m. Movement data from this portion of the study will be related to data on radionuclide concentrations in small mammal tissues (Arthur et al. in prep) to calculate the potential for small mammals to vector radionuclides from the SDA.

Table 1. Mean + SD and (range) of burrow parameters of four species of burrowing rodents at the Idaho National Engineering Laboratory.

Species	N	Depth (cm)	Length ^a (cm)	Volume (l)
<u>Peromyscus maniculatus</u>	26	24 + 11 (13 - 55)	132 + 107 (30 - 470)	1.7 + 1.8 (0.3 - 7.7)
<u>Microtus montanus</u>	14	23 + 6 (15 - 55)	113 + 82 (20 - 220)	1.1 + 1.2 (0.1 - 4.0)
<u>Dipodomys ordii</u>	19	34 + 12 (20 - 69)	253 + 233 (50 - 930)	7.2 + 7.7 (1.0 - 26.3)
<u>Spermophilis townsendii</u>	20	39 + 30 (14 - 138)	404 + 349 (30 - 890)	14.8 + 11.1 (1.2 - 29.9)

^aRepresents the sum of the linear run of all main and side tunnels for each burrow system.

Table 2. Area of use of small mammals on the Idaho National Engineering Laboratory determined by telemetry and subsequent 5 x 5 m grid use analysis.

Species	Animal #	# nights monitored	$\bar{x} \pm SD$ Area of Use (ha)
<u>Microtus montanus</u>	005	3	1.5 ± 1.5
	782	2	1.6 ± 0.8
<u>Microtus Total</u>		5	1.5 ± 1.1
<u>Dipodomys ordii</u>	491	3	3.4 ± 2.6
	929	6	1.0 ± 0.5
	259	5	0.8 ± 0.4
<u>Dipodomys Total</u>		14	1.2 ± 0.8
<u>Peromyscus maniculatus</u>	955	2	1.3 ± 0.9
	729	1	1.3
	943	1	0.9
	753	1	0.8
	700	4	4.0 ± 1.7
<u>Peromyscus Total</u>		9	2.3 ± 2.0

DISCUSSION AND CONCLUSIONS

Phase II of the study will be conducted during FY-83. First, data from the FY-82 burrow system analysis will be used to determine the effects of burrows in altering the movement of water through the soil profile. A trench, 2 m deep, 3 m wide, and 10 m long will be excavated. This will be backfilled and compacted similar to current SDA operations, using similar soils. The trench will be subdivided into 1 x 3 m plots. Artificial burrow systems, having dimensions and configurations similar to those determined for small mammals during FY-82, will be placed into five of these plots. Moisture probes will be placed above, lateral to, and below each burrow to assess water infiltration. The remaining five plots will serve as controls and will have no burrows. Moisture probes will be placed in these plots at the same levels as in the experimental plots. All plots will be irrigated at similar rates, and probes will be read on a daily basis.

Second, results of the radiotelemetry movement study indicate that more movement data is needed for all species occurring on the SDA, especially S. townsendii. The goal for FY-83 will be to monitor a minimum of five individuals of each of the four dominant species over at least five 24-hour periods.

Third, during the winter of 1982-83, a literature search will be completed to determine the ecological requirements and rooting depths of plant species that are likely candidates for stabilizing soils over subsurface wastes. Because rooting depths are site specific, dependent on local soil and moisture conditions, root depths of selected species on the INEL will be verified by excavation and radioactive tracer root uptake studies following the methods of Currie and Hammer (1979).

Last, a lysimeter study will be initiated to test the effectiveness of the cover material currently used at the SDA in preventing root intrusion into contaminated wastes. This material will be compared with two different biobarrier materials: 1) a combination of gravel and cobble, shown to be an effective barrier at LASL (Hakonsen, pers. comm), and 2) volcanic cinders, a readily available and inexpensive material at the INEL. Three plant species (crested wheatgrass (A. cristatum), alfalfa (Medicago sativa), and the cultivar Sodar (A. riparium ssp.) will each be planted in one-third of the lysimeters. Thus, there will be nine possible combinations of biobarrier and plant cover. Control lysimeters will be those with the current backfill material planted with crested wheatgrass. A radioactive tracer material will be placed below the biobarrier level in each lysimeter. Any plant roots that penetrate the biobarrier will transport the tracer to the leaves of the plant. Weekly monitoring of leaf tissues will indicate when and which biobarriers have been violated. Additionally, a moisture probe will be placed below the level of each biobarrier. Data gathered biweekly from these will indirectly indicate which cover plant species is most efficient in capturing available water, and thus most effective in reducing water infiltration into wastes. These data may then be entered into the water balance equation previously given, and corroborate or extend the usefulness of the findings of the LASL studies.

Data from FY-83 will determine the direction this study will take in subsequent years.

LITERATURE CITED

- Arthur, W. J. III. 1982. Radionuclide concentrations in vegetation at a solid radioactive waste disposal area in southeastern Idaho. J. Environ. Qual. 11:394-399.
- Arthur, W. J. III. and O. D. Markham. In press. Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. J. Environ. Qual.
- Arthur, W. J. III and O. D. Markham. 1982. Radionuclide export and elimination by coyotes at two radioactive waste disposal areas in southeastern Idaho. Health Physics 43:493-500.

- Cline, J. F. 1981. Aging effects of the availability of strontium and cesium to plants. *Health Phys.* 41:293-296.
- Currie, P. O. and F. L. Hammer. 1979. Detecting depth and lateral spread of roots of native range plants using radioactive phosphorus. *J. Range Manage.* 32:101-103.
- Felthausen, M. and D. McInroy. In press. Mapping pocket gopher burrow systems with expanding polyurethane foam. *J. Wildl. Manage.*
- Grzybowka, D. 1974. Uptake of ^{226}Ra by plants from contaminated soils. *Nukleonika* 19:62-68.
- Hakonson, T. E. and K. V. Bostick. 1976. The availability of environmental radioactivity to honey bee colonies at Los Alamos. *J. Environ. Qual.* 5:307-310.
- Hakonson, T. E., L. J. Lane, J. G. Steger, and G. L. DePoorter. 1982a. Some interactive factors affecting trench cover integrity on low-level waste sites. *Symp. Low-level Waste Disposal: Site Characterization and Monitoring.* Arlington, VA.
- Hakonson, T. E., J. L. Martinez, and G. C. White. 1982b. Disturbance of a low-level waste burial site cover by pocket gophers. *Health Phys.* 42:869-871.
- Jacobs, D. G., J. S. Epler, and R. R. Rose. 1980. Identification of technical problems encountered in the shallow land burial of low-level radioactive wastes. ORNL/SUB-80/136/1.
- Landeen, D. S. and R. M. Mitchell. 1982. Intrusion of radioactive waste burial sites by the Great Basin pocket mouse (Perognathus parvus). IAEA-SM-257/58. p. 501-509.
- Lane, L. J. and J. W. Nyhan. 1981. Cover integrity in shallow-land burial of low-level wastes: Hydrology & Erosion. 3rd Annual Information Meeting, DOE low-level waste management program ORNL/NFW-81-34.
- Laundre', J. W. 1979. A behavioral study of home range utilization by coyotes on the INEL Site in southeastern Idaho. Ph.D. Thesis. Idaho State Univ., Pocatello. 70 p.
- O'Farrell, T. P. and R. O. Gilbert. 1975. Transport of radioactive materials by jackrabbits on the Hanford Reservation. *Health Phys.* 29:9-15.

POPULATION ECOLOGY OF SMALL MAMMALS ON THE RADIOACTIVE
WASTE MANAGEMENT COMPLEX, IDAHO NATIONAL
ENGINEERING LABORATORY

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ABSTRACT

Species composition, diversity, biomass, population dynamics, absolute density, and movements of small mammal populations were examined on and adjacent to a solid radioactive waste disposal area in southeastern Idaho. The 15-month live-trapping study resulted in marking 2,384 individuals representing 10 species of small mammals. Three vegetation types were sampled: crested wheatgrass (Agropyron cristatum) and Russian thistle (Salsola kali) habitats on the disposal area and native sagebrush (Artemisia tridentata) habitat surrounding the disposal area. The deer mouse (Peromyscus maniculatus) was the most common rodent in both disposal area habitats as well as the adjacent sagebrush habitat; Ord's kangaroo rat (Dipodomys ordii) was also an abundant rodent in all vegetation types. The montane vole (Microtus montanus) was common only in crested wheatgrass stands on the disposal area. Although the adjacent native sagebrush habitat had the highest species diversity and the Russian thistle habitat on the disposal area had the lowest, the total rodent density was not significantly different among the three vegetation types. Crested wheatgrass within the disposal area contained the largest rodent biomass throughout the study, partly due to an increasing population of montane voles. The peak small mammal biomass of 5000 g/ha in crested wheatgrass and sagebrush habitats was much higher than previously reported for similar habitats. The assessment line technique was utilized to estimate the absolute density of small mammals. Problems associated with use of the technique in a live-trapping study were outlined. Three measures of movement were used to estimate average linear movements on a seasonal basis for deer mice, Ord's kangaroo rats, and montane voles residing within the confines of the disposal area. Deer mice moved significantly greater distances in spring and summer compared to fall and winter. Kangaroo rats showed a trend of decreasing movements from spring to fall, whereas montane voles moved greater distances in winter and summer compared to spring and fall. The annual total small mammal biomass of 346 kg for the entire disposal area represents a potentially large vector for movement of radionuclides off the disposal area. However, the number of animals known to contact waste areas and traverse at least 50 m beyond the perimeter of the SDA appears to be small (8.7%).

INTRODUCTION

Although many field studies of small mammals have focused on population dynamics of rodents exposed to acute radiation doses in the laboratory (Buech, 1977) or exposed to a point source of radiation in the field (Bongiorno and Pearson, 1964; French et al., 1974), only a few studies have been published on small mammals in areas where radioactive wastes have been deposited. Dunaway and Kaye (1963, 1964) investigated body weight, breeding condition, and other population characteristics of small mammals residing on the dry bed of a former settling basin for radioactive effluents. More recently, Hedlund and

Rogers (1980) reported on population parameters of pocket mice (Perognathus parvus) in the vicinity of a solid radioactive waste area. Because small mammals may serve as a vector for transport of radionuclides from contaminated areas, studies of rodent ecology are particularly important in radioactive waste disposal areas.

Since 1952, approximately $9.9 \times 10^4 \text{ m}^3$ of solid wastes contaminated with radionuclides have been interred at the Subsurface Disposal Area (SDA) on the Idaho National Engineering Laboratory (INEL) Radioactive Waste Management Complex. Markham (1976, 1978) reported that deer mice (Peromyscus maniculatus) collected outside the SDA had higher concentrations of activation and fission products than mice from control areas; deer mice collected on the perimeter of the SDA had higher concentrations of ^{241}Am and ^{239}Pu than animals collected from background locations (Markham et al., 1978). On the basis of these observations, we initiated a study to examine several ecological characteristics of small mammals on and adjacent to the SDA. The objectives of our study were to: 1) estimate the species composition and diversity, biomass, and population numbers over time of small mammal populations on and adjacent to the SDA, 2) estimate the absolute density (numbers/unit area) of small mammal populations on and adjacent to the SDA, 3) estimate the average linear movements of small mammal populations on the SDA, and 4) estimate the number of marked individuals that move beyond the confines of the SDA.

METHODS

The Subsurface Disposal Area (SDA) is a 36 ha portion of the INEL Radioactive Waste Management Complex used for interment of solid radioactive wastes into pits or trenches. Details on radionuclide inventories and waste disposal procedures at the SDA are provided by Arthur and Markham (1978). Vegetation on the SDA and its perimeter is dominated by seeded crested wheatgrass (Agropyron cristatum) with Russian thistle (Salsola kali) growing over more recently disturbed and unseeded areas. Additionally, a network of gravel and dirt roads used by heavy machinery exists on the surface of the area. Native flora surrounding the SDA is predominantly a big sagebrush (Artemisia tridentata)/bluebunch wheatgrass (Agropyron spicatum) steppe (McBride et al., 1978). The soil is a shallow silt-loam loess over basalt and varies in depth from 1.5 to 6.0 m. A minimum of 0.9 m of soil cover exists over filled pits and trenches on the SDA.

To determine the species composition and abundance of small mammals residing on the SDA, four 0.6 ha trapping grids (A, B, C, and D) were established between May and July, 1978 (Fig. 1). Each grid was established over a particular series of radioactive pits and trenches (Arthur and Markham, 1978). These grids originally contained 100 Longworth live traps placed at 9 m intervals in a 5 x 20 configuration. Due to waste management projects, Grid D was eliminated in September 1978 and Grid B was later modified to a 5 x 17 configuration with an additional row of 15 traps. A dry drainage channel lies between a dike and fence that surround the perimeter of the disposal area (Fig. 1). To assess rodent populations in this area, Longworth live traps were placed at 9 m intervals around the entire perimeter. The four unequal sides of the perimeter were designated as G (109 traps), H (120), J (12), and

K (56). Vegetation on Grids A, B, and D, and perimeter trap lines consisted largely of crested wheatgrass, whereas Grid C supported a sparse cover of Russian thistle.

RADIOACTIVE WASTE MANAGEMENT COMPLEX

Figure 1. Location of Grids A, B, C, D, and M with assessment lines, perimeter trap lines G, H, J, and K, and Dispersal Capture Systems 1 and 2, on and adjacent to the 36 ha Subsurface Disposal Area (SDA), INEL Site.

In September 1978, two 3-tier trapping transects were established 50 m north of the SDA to evaluate movement of marked individuals beyond the confines of the perimeter and internal trapping areas. Dispersal Capture System 2 paralleled 386 m of perimeter adjacent to trap lines H and J, whereas Dispersal Capture System 1 paralleled 288 m of perimeter along the central portion of trap line H and exterior grid M (Fig. 1). Ketch-all traps, which can collect up to 15 individual rodents, were placed in the initial tier. The second tier contained Longworth live traps shifted 3 m east and 9 m north of the row of Ketch-all traps. Live traps in this row were permanently left locked open to enhance use by individuals exposed to live trapping in other areas. The third tier consisted of pitfall traps developed from two joined number 10 tin cans buried with the opening flush to the surface of the ground. All pitfall traps were located 3 m east and 9 m north of the trapping points established for Longworth live traps.

In October 1978, a fifth grid (M), containing 160 live traps in a 5 x 32 configuration, was established to estimate small mammal abundance in native vegetation 150 m north of the SDA. Additionally, movement toward the SDA was determined by catching individuals marked on grid M that were subsequently caught in Dispersal Capture System 2.

All animals caught on live-trapping grids and perimeter trap lines were eartagged with numbered fingerling fish tags. Rodents with small pinnae were marked by toe clips or numbered Essex bird bands attached to a leg. Trap location, species, sex, weight, and reproductive condition were recorded and animals were released at the point of capture. Perimeter lines and grids were trapped every other week from May through October 1978, and monthly from November to July 1979. Animals obtained in Ketch-all or pitfall traps were collected weekly from September 1978 to May 1979.

Species diversity of the live-trapped small mammal fauna was estimated with the Shannon-Wiener function (Pielou, 1966). Dominance values (D), consisting of the percentage of individuals contained in the two most common species, were estimated for each trapping area (Krebs and Wingate, 1976). Population numbers were estimated by direct enumeration to avoid violation of the statistical assumptions of random sampling. Total small mammal biomass was estimated for each trapping period in the three different vegetation types (crested wheatgrass, Russian thistle, and sagebrush). Additionally, we estimated the total number of small mammals and the total small mammal biomass that were potentially present on the entire SDA surface over a 1-year period. The size of unsampled areas that were similar in habitat to the gridded areas or perimeter lines was estimated by planimetering a map of the SDA, as we trapped only 4.3 ha or 16.2% of the total surface. Then the number of individuals marked in each area over a year and the mean weight of each species over a year were used to extrapolate data on density and biomass on an annual basis for the entire vegetated surface of the SDA. Details on methods for estimating density and biomass are provided in Groves and Keller (1983).

The absolute density of small mammals on and adjacent to the SDA was estimated during July 1979 with the assessment line technique (O'Farrell et al., 1977; O'Farrell and Austin, 1978). Grids A, B, and C with assessment lines were utilized to estimate the density of small mammals on the SDA; Grid M with assessment lines was used to estimate rodent density adjacent to the SDA (Fig. 1). Grid traps were checked once each morning for 2 days followed by two consecutive mornings of trapping on assessment lines. During the trapping period on assessment lines, traps remained on the grids with trap doors closed. Equations for estimation of density by the assessment line technique are given in Groves (1981).

Three measures of linear movement similar to those described by Brant (1962) were used to estimate seasonal movements by small mammals on the SDA:

- (1) $\bar{D}$, average distance between captures from one trapping period to the next,
- (2) $\bar{M}$, maximum distance between captures from one trapping period to the next,
- and (3) $\bar{S}$, average distance between captures within a 2-day trapping session.

Movement from trapping points on the SDA or grid M to the dispersal systems was determined by calculating the straight-line distance moved from the last known point of live capture to the point of collection in a Ketch-all or pitfall trap for each marked animal caught. Additionally, the previous capture history was detailed for each individual to determine if it had been caught over buried wastes.

To minimize differences in the number of times individual animals were recaptured, estimation of movements was restricted to four seasonal periods. As a result, within any season an animal was recaptured in no more than six trapping periods and the majority of animals were recaptured two to four times. To be considered in the movement analysis, only animals that remained on a grid or trap line during their recapture history were tallied, except where animals moved the short distance (9 m) between Grid A and trap line G, Grid B and trap line H, or Grid D and trap line H.

All statistical tests that we used, except as cited, are detailed in Zar (1974). Significant differences were determined at $P \leq 0.05$. Grid D was excluded from statistical analyses because it was trapped for only a short time. Trap line J was also excluded due to the small number of traps. For seasonal analyses, seasons were separated by months as follows: March-May = Spring, June-August = Summer, September-November = Fall, and December-February = Winter. Skewness and kurtosis values indicated that the movement data were not normally distributed. Additionally, the assumption of homoscedasticity among seasonal measures within each species was violated. Thus, non-parametric procedures, available as SPSS programs (Nie et al., 1975; Hull and Nie, 1979) were employed.

RESULTS

Diversity, Biomass, and Population Numbers. A total of 20,689 trap nights resulted in marking 2,384 individual animals during the 15-month study. The deer mouse (Peromyscus maniculatus) accounted for 59% of the total species composition and was the most common rodent on all live-trapping sites (Table 1). The montane vole (Microtus montanus) was generally the second most abundant rodent in crested wheatgrass and fenceline habitats. In Russian thistle habitat (Grid C), Ord's kangaroo rat (Dipodomys ordii) was the most common species besides the deer mouse, whereas Townsend's ground squirrel (Spermophilus townsendii), the least chipmunk (Eutamias minimus), and Ord's kangaroo rat were all common in sagebrush habitat (Grid M). The Great Basin pocket mouse (Perognathus parvus) was live trapped in both crested wheatgrass and sagebrush habitats, but was not an abundant species.

The largest number of species and the highest species diversity were recorded for sagebrush habitat (Table 2). Further, our capture of one sagebrush vole (Lagurus curtatus) by live trap probably under represents the abundance of this species on Grid M because we caught a significant number of individuals in both dispersal capture systems (see ahead). Russian thistle habitat (Grid C) had the smallest number of species and lowest species diversity. In fact, deer mice and Ord's kangaroo rats dominated the species composition on Grid C ($D = 0.99$), whereas dominance values in other habitats ranged from 0.75 to 0.79. The small mammal fauna in crested wheatgrass was only slightly less diverse than that of sagebrush habitat (Grid M), whereas species diversity on perimeter trap lines fell between the highest and lowest values recorded for the entire study area.

Table 1. Number of animals marked and percent species composition for small mammals in different habitats on and adjacent to the Subsurface Disposal Area, May 1978 through July 1979.

Species	Crested wheatgrass habitat (Grids A, B)	Russian thistle habitat (Grid C)	Sagebrush habitat (Grid M)	Fenceline habitat (trap lines G, H, J, K)	Total (%)
<u>Peromyscus maniculatus</u>	256	185	101	852	1,394 (58.5)
<u>Microtus montanus</u>	177	2	7	263	449 (18.8)
<u>Dipodomys ordii</u>	58	23	9	193	293 (12.3)
<u>Spermophilus townsendii</u>	32	2	33	59	126 (5.3)
<u>Perognathus parvus</u>	34	--	12	23	69 (2.9)
<u>Eutamias minimus</u>	--	--	23	6	29 (1.2)
<u>Reithrodontomys megalotis</u>	6	--	2	3	11 (0.5)
<u>Onychomys leucogaster</u>	3	--	1	5	9 (0.4)
<u>Lagurus curtatus</u>	--	--	1	2	3 (0.1)
<u>Thomomys sp.</u>	1	--	--	--	1 (0.0)
Total	567	212	159	1,406	2,384
Trap nights	5,993	2,965	2,240	9,491	20,689

Table 2. Species diversity (H') and dominance values (D) for small mammals in different habitats on and adjacent to the Subsurface Disposal Area, May 1978 through July 1979. Formulae for H' and D are provided in Groves (1981).

Species	Crested wheatgrass habitat (Grids A, B)	Russian thistle habitat (Grid C)	Sagebrush habitat (Grid M)	Fenceline habitat (trap lines G, H, J, K)
Number of Species (S)	8	4	9	8
Species diversity (H')	1.48	0.45	1.55	1.16
Community dominance (D)	0.76	0.99	0.75	0.79

Crested wheatgrass habitat (Grids A and B) supported a greater biomass of small mammals than Russian thistle (Grid C) or sagebrush (Grid M) habitats throughout the study (Fig. 2). Small mammal biomass peaked in crested wheatgrass and Russian thistle habitats in fall 1978, declined in winter, and reached its apex in summer 1979. Rodent biomass in sagebrush was similar to estimates in Russian thistle until summer 1979. At this time, total small mammal biomass peaked in sagebrush at approximately 5000 g/ha, an estimate similar to the peak rodent biomass observed in crested wheatgrass.

Figure 2. Changes in total small mammal biomass for Grids A, B, C, and M on and adjacent to the Subsurface Disposal Area, 1978-1979.

Crested wheatgrass grew over nearly 75% of the surface of the SDA not occupied by roads or open pits (Table 3). Although the potential number of small mammals inhabiting crested wheatgrass and Russian thistle habitat on an annual basis did not differ greatly on a per unit basis, the total small mammal biomass per unit area of crested wheatgrass (13.5 kg/ha) was nearly twice that of Russian thistle (7.7 kg/ha). Fenceline habitat, consisting of a drainage channel that lies between the dike and fence surrounding the SDA, supported nearly twice as many rodents as crested wheatgrass or Russian thistle stands on the SDA. Additionally, on an areal basis, this habitat contained a greater annual biomass of small mammals than either vegetation type on the surface of the SDA. However, because crested wheatgrass covered nearly 75% of the SDA, this habitat accounted for the greatest number and biomass of small mammals on the study area.

Table 3. The total number of small mammals and total small mammal biomass potentially present in different habitats on the entire Subsurface Disposal Area over a 1-year period.

	Crested wheatgrass habitat (Grids A, B, D)	Russian thistle habitat (Grid C)	Fenceline habitat (Lines G, H, J, K)	Total
Area (ha)	20.18 (76%)	4.57 (17%)	1.82 (7%)	26.57
Potential number of small mammals present during a 1 yr. period.	8,968	1,615	1,408	11,991
Potential number of small mammals per unit area (#/ha).	444	353	774	--
Potential biomass of small mammals present during a 1 yr. period (kg).	272	35	39	346
Potential annual biomass of small mammals per unit area (kg/ha).	13.5	7.7	21.4	--

Friedman's analysis of variance by ranks followed by non-parametric multiple range tests was used to test for differences in population density among the three vegetation types (i.e. grids) for deer mice, Ord's kangaroo rats, montane voles, and the total number of small mammals. Monthly time intervals served as blocks and data were standardized to the number of individuals captured per 100 trap nights to account for the different number of traps on grids.

The density of deer mice was not significantly different among the three different vegetation types--crested wheatgrass habitat (Grids A, B, and perimeter trap lines), Russian thistle habitat (Grid C), and sagebrush habitat (Grid M) (Fig. 3). From May through October 1978, numbers of deer mice on all sites were stable with approximately 25 to 35 animals present on Grids A, B, and C, and 40 to 60 individuals on trap lines G, H, and K. During winter months of snow cover, densities decreased on grids and trap lines. Although in spring 1979, the number of deer mice increased on Grid C and line K, similar increases were not observed on other trapping sites.

The density of Ord's kangaroo rats was lower than deer mice on all sites (Fig. 4). No significant difference was found in the density of this species among live-trapping grids. Thus, like deer mice, the density of kangaroo rats was not significantly different among vegetation types. Except for line K, all sites showed considerable decreases in density with the onset of snow cover and subsequent increases during spring.

Montane voles were captured commonly only on Grids A and B (crested wheatgrass) and trap lines G and H (Fig. 5). There was no significant difference in the density of montane voles between Grids A and B. This species was caught in all seasons and showed a pattern of increasing numbers throughout the study, particularly during winter. Unlike deer mice and Ord's kangaroo rats, the density of montane voles did not decrease during the snow cover period.

Three other species were caught in sufficient numbers during some portion of the study to merit mention of their population dynamics. Great Basin pocket mice were captured on Grids A, B, and M, during fall 1978 and spring and summer 1979. The least chipmunk was generally captured only in sagebrush habitat (Grid M); it first appeared in the trappable population during April. Its numbers increased in spring 1979 and peaked at approximately 20 individuals in summer. Townsend's ground squirrel was captured on all sites during spring and summer 1979 although it was only abundant on Grid M and line K. When all species were considered, the total density of small mammals was not significantly different among the three vegetation types.

Absolute Density. Estimates of absolute density (#/ha) for small mammals on Grids A, B, C, and M are summarized in Table 4. The greatest density of small mammals on the study area was recorded in crested wheatgrass for Grids A and B. Grid C, a more recently disturbed site with a sparse cover of Russian thistle, had less than half the total rodent density of either Grid A or B. The lowest total small mammal density was recorded for Grid M which occupied the native big sagebrush habitat adjacent to the SDA. Montane voles were the most abundant rodent in crested wheatgrass, whereas deer mice were the most common species in Russian thistle vegetation and least chipmunks the most abundant rodent in sagebrush habitat.

Figure 3. Changes in population density for *P. maniculatus* on Grids B, C, and M (a) and trap lines H and K (b), 1978-1979. Population trends were similar for Grids A and B and for trap lines G and H. Therefore, only Grid B and trap line H are shown in the figure. The shaded area represents the winter period of intermittent snowfall.

Figure 4. Changes in population density for *D. ordii* on Grids B, C, and M (a) and trap lines G and K (b), 1978-1979. Population trends were similar for Grids A and B and for trap lines G and H. Therefore, Grid A and line H are excluded from the figure.

Figure 5. Changes in population density for *M. montanus* on Grids A and B (a) and trap lines G and H (b), 1978-1979.

Table 4. Estimates of rodent density by the assessment line technique for Grids A, B, C, and M on the INEL Radioactive Waste Management Complex, Summer 1979. N_g = number of animals marked on grid, R_p = ratio of marked to total animals on assessment lines, N_a = adjusted number of animals within area of effect (N_g/R_p), W_a = width of area of effect, A = area of effect, D = density (N_a/A). Blanks indicate no marked individuals of a species were captured on assessment lines. Values of zero for W indicate no marked individuals were captured in assessment line traps that laid outside the grid.

Grid and Species	N g	R p	Statistics			
			N a	W (m) a	A (ha)	D (#/ha)
<u>Grid A</u>						
<u>Dipodomys ordii</u>	7	2/2	7.0	4.3	0.8	8.8
<u>Microtus montanus</u>	18	1/2	36.0	10.6	0.9	40.0
<u>Peromyscus maniculatus</u> (F) ^a	22	11/19	37.9	55.2	3.9	9.7
<u>Peromyscus maniculatus</u> (M) ^a	17	11/15	23.3	48.8	3.4	6.9
<u>Perognathus parvus</u>	6	--	--	0.0	0.6	10.0
<u>Spermophilus townsendii</u>	4	4/5	5.0	31.5	2.2	2.3
Total						77.7
<u>Grid B</u>						
<u>Dipodomys ordii</u>	4	2/2	4.0	0.0	0.6	6.7
<u>Microtus montanus</u>	14	4/6	20.9	0.0	0.6	34.8
<u>Peromyscus maniculatus</u>	10	4/10	25.0	43.0	2.8	8.9
<u>Perognathus parvus</u>	6	2/3	9.0	46.2	3.0	3.0
<u>Spermophilus townsendii</u>	7	4/5	8.8	14.4	1.1	8.0
Total						61.4
<u>Grid C</u>						
<u>Dipodomys ordii</u>	6	4/4	6.0	55.2	3.9	1.5
<u>Peromyscus maniculatus</u> (F)	21	10/19	39.9	55.2	3.9	10.2
<u>Peromyscus maniculatus</u> (M)	14	7/15	30.0	29.7	2.1	14.3
Total						26.0
<u>Grid M</u>						
<u>Dipodomys ordii</u>	6	4/4	6.0	42.5	4.3	1.4
<u>Eutamias minimus</u>	15	6/12	30.0	67.9	6.7	4.5
<u>Microtus montanus</u>	1	--	--	0.0	1.0	1.0
<u>Peromyscus maniculatus</u> (F)	13	11/16	18.9	93.4	9.6	2.0
<u>Peromyscus maniculatus</u> (M)	14	11/16	20.4	87.0	8.9	2.3
<u>Perognathus parvus</u>	8	3/5	13.3	93.4	9.6	1.4
<u>Spermophilus townsendii</u>	14	4/9	31.8	80.6	8.1	3.9
Total						16.5

^a M = males, F = females

Small Mammal Movements on the SDA. A Kruskal-Wallis analysis of variance and non-parametric multiple range tests indicated that deer mice moved significantly longer distances ($P < 0.05$) in spring and summer than other seasons as estimated by $\bar{D}$ or $\bar{M}$ (Fig. 6a). Average distance between successive captures within a trapping session ($\bar{S}$) was not significantly different among seasons for deer mice. Ord's kangaroo rat was rarely active in winter, a factor precluding any estimate of movement during this season. Average distance between successive captures ($\bar{D}$) was significantly different ($P < 0.05$) among spring, summer, and fall periods for this species; $\bar{M}$ was also significantly different ($P < 0.05$) among these seasons (Fig. 6b). There was a trend of decreasing length of movement from spring to fall, although short-term movement ($\bar{S}$) was less than $\bar{D}$ or $\bar{M}$ in spring and fall and nearly equal to $\bar{M}$ in summer. Again, $\bar{S}$ was not significantly different among seasons. Both $\bar{D}$ and $\bar{M}$ were significantly greater ($P < 0.01$) in winter and summer compared to spring and fall for montane voles (Fig. 6c). Average distance between successive capture within a trapping session ($\bar{S}$) was always less than $\bar{D}$ or $\bar{M}$, particularly in winter and spring. As with deer mice and Ord's kangaroo rats, $\bar{S}$ was not significantly different among seasons.

Ord's kangaroo rats and montane voles showed similar lengths of movement, although Ord's kangaroo rats demonstrated greater distances of movement in the spring. In all seasons, both species moved greater distances than deer mice as indicated by all three measures of movement. In addition to seasonal measures of movement for species, the movement data were also analyzed for differences between sexes and age classes. Results of these analyses can be found in Groves (1982).

Movements Between SDA and Sagebrush. A total of 356 individual rodents and 8 shrews (*Sorex* sp.) was captured in Ketch-all or pitfall traps on both dispersal capture systems (Tables 5 and 6). Twenty-seven percent ($n = 97$) of the rodents had been previously marked on the perimeter of the SDA, on the grids inside the perimeter (A, B, C, D), or on Grid M. The marked sample consisted largely of deer mice (86%, $n = 83$) caught during fall and spring. Only four marked individuals were collected in pitfall traps. Alternatively, 51 unmarked sagebrush voles (*Lagurus curtatus*), 9 pocket gophers (*Thomomys* sp.), and 8 shrews were collected in pitfall traps, but because we could not use pitfall traps on the SDA, we do not know whether these species traversed waste areas and were not represented in live-trap enumerations on the SDA grids and perimeter.

Thirty-two marked individuals trapped at least once on grids inside the SDA, were collected at dispersal capture systems (1 western harvest mouse (*Reithrodontomys megalotis*), 29 deer mice, 2 Ord's kangaroo rats (Table 7)). Given that the two combined dispersal transects effectively caught all individuals traversing to 50 m beyond the confines of the SDA and that the combined 674 m edge trapped represents a typical catch pattern for September to May (fall, winter, spring), the 2,362.3 m of edge around the entire SDA would be traversed by 111 individuals known to have been trapped on wastes at least once. On an annual basis, 169 individuals from our marked populations

Figure 6.

Seasonal estimates of $\bar{D}$ (average distance between successive captures from one trapping period to the next) and $\bar{S}$ (average distance between successive capture within a trapping period) for *P. maniculatus*, *D. ordii* and *M. montanus* on and adjacent to the Subsurface Disposal Area. Closed circles = $\bar{D}$; open circles = $\bar{S}$; bars = 1 standard error; sample sizes are in parentheses. Because estimates of $\bar{D}$ and $\bar{M}$ were very similar, data for $\bar{M}$ were not reported.

Table 5. Species composition, number of marked (M) and unmarked (U), and total marked animals removed (MR)^a during 34 consecutive weeks of removal trapping along a 386 m two tier collection system containing Ketch-all or pit-fall traps. Dispersal Capture System 1 was 50 m and 68 m beyond the perimeter traps on the SDA (Fig. 1), and contained a central row of Longworth traps not employed for removal (see text).

	Ketch-all traps							Pit-fall traps						
	Fall		Winter		Spring		Total	Fall		Winter		Spring		Total
	M	U	M	U	M	U	MR	M	U	M	U	M	U	MR
<u>Dipodomys ordii</u>	3	4					3	0	2					0
<u>Lagurus curtatus</u>							0	0	22	0	7	0	6	0
<u>Microtus montanus</u>			0	1	0	2	0	0	6	0	2	0	4	0
<u>Onychomys leucogaster</u>					1	1	1	0	1					0
<u>Peromyscus maniculatus</u>	18	28	4	2	10	10	32	1	12			0	1	1
<u>Perognathus parvus</u>							0	0	12					0
<u>Reithrodontomys megalotis</u>							0	0	14					0
<u>Spermophilus townsendii</u>					1	12	1							0
<u>Thomomys sp.</u>	—	—	—	—	—	—	0	0	1	—	—	0	5	0
Totals all species	21	32	4	3	12	25	37	1	70	0	9	0	16	1

^aTotal number marked removed = 38 of 193 = (20% marked)

Table 6. Species composition, number of marked (M) and unmarked (U), and total marked animals removed (MR)^a during 34 consecutive weeks of removal trapping along a 288m two tier collection system containing Ketch-all or pit-fall traps. Dispersal Capture System 2 was 50 m and 68 m beyond the perimeter traps on the SDA (Fig. 1), and contained a central row of Longworth traps not employed for removal (see text).

	Ketch-all traps						Pit-fall traps							
	Fall		Winter		Spring		Total	Fall		Winter		Spring		Total
	M	U	M	U	M	U	MR	M	U	M	U	M	U	MR
<u>Dipodomys ordii</u>	1	0			3	0	4							0
<u>Lagurus curtatus</u>					0	1	0	0	15			0	1	0
<u>Microtus montanus</u>			0	2	0	2	0	0	3			0	2	0
<u>Onychomys leucogaster</u>	0	1	0	1				0						0
<u>Peromyscus maniculatus</u>	12	16	4	1	36	22	52	0	14	0	1	1	0	1
<u>Perognathus parvus</u>					0	1	0	0	4			1	0	1
<u>Reithrodontomys megalotis</u>							0	1	4	0	1			1
<u>Spermophilus townsendii</u>					0	8	0							0
<u>Thomomys sp.</u>	—	—	—	—	—	—	0	—	—	—	—	0	4	0
Totals all species	13	17	4	4	39	34	56	1	40	0	2	2	7	3

Table 7. Mean Euclidean distance moved (m) $\pm$ standard error from point of last capture to Dispersal Capture Systems 1 and 2 for 86 tagged Peromyscus maniculatus and 7 tagged Dipodomys ordii captured on and adjacent to the SDA, INEL Site. Thirty-two individuals were known to have traversed waste sites but this table excludes one Reithrodontomys megalotis included in this total.

Species, position of last live capture and dispersal capture system where caught	Mean distance moved (m)	Standard error	Total sample	Movement Maximum (m)	extremes Minimum (m)	Area known traversed by individuals (see Fig. 1)
<u>Peromyscus maniculatus</u> to Dispersal Capture System 1						
Last capture was on perimeter (H)	99.53	$\pm$ 13.76	23	307.1	50.1	6-D and H; 17-H only
Last capture was on grid D	105.08	$\pm$ 22.93	6	216.2	71.4	1-C; 5-D only
Last capture was on grids A, B, or C	716.35	$\pm$ 84.77	4	831.2	465.4	2-A; 1-B; 1-C
<u>Peromyscus maniculatus</u> to Dispersal Capture System 2						
Last capture was on perimeter (H)	122.20	$\pm$ 24.81	28	722.1	50.0	23-H only; 1-D and H; 1-B, D and H; 1-B and H; 1-C and H; 1-K, B and H
Last capture outside SDA (control) grid M	126.95	$\pm$ 3.91	17	173.8	101.5	15-M only; 2-M and H
Last capture was on grid B	142.82	$\pm$ 23.38	6	204.2	59.7	2-B only; 1-G and C
Last capture was on grid C	365.35		2	490.2	240.5	3-H and B 2-C only
<u>Dipodomys ordii</u> to both dispersal capture systems (3 to system 1, 4 to system 2)						
	98.37	$\pm$ 10.46	7	128.6	50.8	1-D and J; 1-D; 1-H and J; 2-H and M; 2-H only

would be predicted to traverse from waste areas to 50 m beyond the SDA, given that summer patterns of movement are typical to the 34-week pattern we documented from September to May. Because we trapped only 16.2% of the surface of the SDA, the potential number of dispersers for the entire SDA small mammal community per year would equal 1,043 individuals.

The above computations are conservative as a large number of individuals, caught only on the perimeter and subsequently in Dispersal Capture System 1 or 2 may have actually resided inside the SDA. Table 7 indicates that some deer mice and kangaroo rats live trapped on the perimeter moved significantly ($P < 0.01$) greater distances to Dispersal Capture Systems 1 or 2 than their congeners caught among trapping points along the perimeter, on grids within the SDA, or on grid M.

DISCUSSION

The SDA is a unique island of habitat, parts of which have been disturbed continually for a period of 20 years. The soil profile has been disrupted by both burial of solid radioactive wastes and addition of soil from areas adjacent to the SDA. Thus, fauna invading the SDA do not encounter soil compaction and vegetative conditions similar to adjacent areas. Additionally, some small mammals on the SDA are receiving radiation doses greater than background rates and have become contaminated with radionuclides (W. J. Arthur, pers. comm.). The effect of these factors, either singly or collectively is difficult to assess.

The deer mouse was the most common small mammal species both on the Subsurface Disposal Area and in adjacent sagebrush habitat, a finding in agreement with rodent studies conducted elsewhere on the INEL Site (Allred, 1973; Johnson, 1977; Reynolds, 1980). Halford and Markham (1978) also reported deer mice to be the most common small mammal at a liquid radioactive waste disposal pond on the INEL Site. The montane vole was the second most abundant species on the SDA, although it was generally restricted to crested wheatgrass habitat. Because the montane vole is a cyclic species (Hoffmann, 1958), it is probable that we detailed a period of colonization and expansion on the SDA. The occurrence of winter breeding of montane voles on the SDA (Groves, 1981), a phenomenon that appears to be common in mid-latitude microtine populations prior to periods of "peak" density (Keller and Krebs, 1970), adds further support to this hypothesis.

Ord's kangaroo rat was captured commonly in all vegetation types on and adjacent to the SDA, including the sparsely covered Russian thistle habitat (Grid C). Allred (1973) captured Ord's kangaroo rats in several different plant communities including sagebrush on the INEL Site, and Halford and Markham (1978) also trapped several individuals on a liquid radioactive waste disposal area. Disturbed soils may have facilitated burrowing and colonization of the SDA by this species.

The greatest diversity of small mammals was observed in sagebrush habitat adjacent to the SDA and the least in Russian thistle within the SDA. This result was primarily due to the larger number of species and the greater number of least chipmunks captured in native sagebrush compared to Russian thistle and crested wheatgrass habitats on the SDA. The restriction of least

chipmunks to sagebrush habitat has been demonstrated in other studies (Allred, 1973; Reynolds, 1980) and is probably related to differences in the abundance and distribution of food in sagebrush compared to crested wheatgrass and Russian thistle habitats on the SDA. Although crested wheatgrass stands have been proposed to contain impoverished small mammal faunas when compared to native vegetation (Reynolds and Trost, 1980), montane voles were able to colonize and expand their numbers in crested wheatgrass on the SDA during our study. This expansion may have been related to an early spring growth and late fall resurgence of vegetation on the SDA in 1978, conditions suspected to affect the reproductive capacity of montane vole populations (Berger et al., 1981).

The low diversity of small mammals in the sparsely covered Russian thistle habitat on the SDA may be due to two factors. First, the lack of cover and/or food may have made this habitat largely unsuitable for most species of small mammals. Secondly, in fall 1976, 1.2 m of additional soil cover were placed over the area as part of a moisture exclusion project. This addition of highly compacted soil may have had an adverse effect on the availability and distribution of burrows for rodents. Only deer mice successfully colonized this habitat. Reduced diversity of small mammals and successful colonization of sparsely vegetated mine waste by deer mice has been reported in the Adirondack Mountains of New York (Kirkland, 1976). Our study lends further support to Kirkland's contention that the deer mouse is a species with broad ecological tolerance and sufficient adaptability to colonize and reproduce in disturbed environments.

Total biomass of small mammals peaked on all three vegetation types in summer 1979. Prior to this time, crested wheatgrass stands supported a greater biomass of rodents than either sagebrush or Russian thistle habitats. However, with the appearance of ground squirrels in late spring, the sagebrush habitat was nearly equivalent to crested wheatgrass stands in terms of total small mammal biomass. Both crested wheatgrass stands on the SDA and adjacent sagebrush vegetation supported a considerably greater biomass of rodents than reported for similar vegetation in other areas. French et al. (1976) reported total small mammal biomass of 650 g/ha during summer in bunchgrass stands of south-central Washington. In contrast, we found a rodent biomass of over 5000 g/ha in crested wheatgrass stands on the SDA in summer. Nichols et al. (1975) noted rodent biomass ranging from 130 to 440 g/ha during summer in sagebrush communities of Utah, whereas rodent biomass in sagebrush adjacent to the SDA ranged from 1,500 to 5,000 g/ha in summer.

Population numbers (minimum number alive) of deer mice and Ord's kangaroo rats were highest on the study area during fall 1978 and late spring 1979. Several species of Peromyscus commonly attain peak population densities in fall (Terman, 1968), although many studies on natural populations of deer mice have not involved repeated live trapping over several months. Only one study has been reported on the population dynamics of Ord's kangaroo rat. In western Texas, Garner (1974) observed trends in population dynamics that were nearly opposite those on the SDA, with peaks in numbers occurring in winter months. However, winter conditions in western Texas are more moderate than those in southeastern Idaho. The decrease in numbers of Ord's kangaroo rats during winter on the SDA is probably the result of reduced activity or torpor (O'Farrell, 1974).

Although data on population numbers through time (i.e. relative density) are important in assessing population dynamics, we also wanted to estimate the absolute density (numbers/area) of small mammals on the study area. Such data would be useful in the construction of a model of radioactive export by small mammals (Arthur et al., unpublished manuscript) and would permit later evaluation of rodent population changes related to radioactive waste management procedures. Additionally, we wanted to determine the usefulness of the assessment line technique in an unusual habitat like the SDA. We noted several problems associated with the use of the assessment line technique, some of which were not confined to an unusual habitat like the SDA. These problems included: 1) questionable reliability of density estimates when species numbers are low, 2) assumption of equivalent movements among animals in heterogeneous habitat, 3) an inappropriate equation for calculation of area in the original technique, and 4) an unknown effect of removal or retention of grid traps during assessment line trapping. A more detailed discussion of the difficulties that we encountered with this technique has been prepared (Groves and Keller, unpublished manuscript).

On the SDA, deer mice moved approximately 20 m between trapping periods in fall and winter and 30 m in spring and summer. In comparison, Brant (1962) reported D values for this species in a shrub-grassland of northern California to be 70.2 m, 47.7 m, 47.4 m, and 54.9 m for spring, summer, fall, and winter, respectively. A reduction in linear movement during fall and winter by deer mice may be the result of reduced activity by this species during these times. Stebbins (1971) has documented periods of torpor for deer mice in Canada during periods of cold and snow. A similar trend of reduced movement in fall was noted for Ord's kangaroo rat, but no estimates of movement were made for this species in winter due to low densities.

Data from the SDA showed that Ord's kangaroo rats move approximately 70 m between trapping periods in spring and exhibit reduced linear movement through summer to around 30 m in fall. Ramsey (1969) used techniques similar to those of the present study and reported D values ranging from 30 m in winter to 18 m in summer for Ord's kangaroo rats in Texas. Whereas average linear movements of individuals within the confines of the SDA appeared to be small, some individual deer mice and kangaroo rats were found to move great distances between the point of capture on the SDA and the point of removal in dispersal capture systems (Table 7). Additionally, some individuals residing along the perimeter of the SDA were caught traveling toward sagebrush habitat. We have defined individuals showing either type of long-range movement as dispersers. French et al. (1968) have suggested that dispersal distances among several Mojave Desert rodents follow a non-random distribution with too many individuals moving short and great distances and too few moving intermediate distances. The data we presented also suggest this trend for individuals trapped on the SDA. However, individuals trapped in perimeter transition areas between crested wheatgrass plantings and sagebrush steppe may traverse more habitat than individuals residing in the central portion of the planting, thereby increasing their chance of assessment as short-range dispersers. Filipovich and Keller (this volume) are presently investigating movement patterns in transition areas with radiotelemetry procedures on a smaller waste disposal area having a vegetative edge similar to that on the SDA. Reynolds (pers. comm.) is presently investigating movements of small mammals on the SDA with radiotelemetry techniques.

Because we suspect that individuals using edge transition areas may traverse greater distances than individuals residing in non-edge areas, all individuals caught on the SDA perimeter and subsequently in Dispersal Capture Systems 1 or 2, may have actually contacted waste areas, but were not tallied in these areas as a result of the interval between trapping efforts. Elimination of these individuals from our estimation of animals known to have traversed waste areas significantly decreased our estimate of movement of animals from waste areas to sagebrush from 22.3% (2,674/11,991) to 8.7% (1,043/11,991) of the projected total animals on the SDA.

Our study indicates that the Subsurface Disposal Area on the INEL Site does not constitute a dispersal sink (Lidicker, 1975) as we proposed earlier (Keller and Groves, 1978). Rather, the area contains a large reproducing community of small mammals with a diversity less than but a biomass per unit area greater than that in native vegetation. These differences are most likely attributable to differences in soil compaction, cover, and food availability between the two areas.

LITERATURE CITED

- Allred, D. M. 1973. Small mammals of the National Reactor Testing Station, Idaho. *Great Basin Nat.* 33:246-250.
- Arthur, W. J. and O. D. Markham. 1978. Ecology studies at the Idaho National Engineering Laboratory Radioactive Waste Management Complex, p. 74-92 *In* O. D. Markham (ed.) *Ecological Studies on the Idaho National Engineering Laboratory Site 1978 Progress Report*. IDO-12087. National Tech. Inf. Ser., Springfield, VA. 371 p.
- Berger, P. J., N. C. Negus, E. H. Saunders and P. D. Gardner. 1981. Chemical triggering of reproduction in Microtus montanus. *Science* 214:69-70.
- Bongiorno, S. F. and P. G. Pearson. 1964. Orientation of Peromyscus in relation to chronic gamma radiation and vegetation. *Amer. Midl. Nat.* 72:82-92.
- Brant, D. H. 1962. Measures of the movements and population densities of small rodents. *Univ. Calif. Publ. Zool.* 62:105-184.
- Buech, R. R. 1977. Small mammals in a gamma-irradiated northern forest community, p. 167-180 *In* J. Zavitzovski (ed.), *The Enterprise, Wisconsin, Radiation Forest: Radioecological Studies*. ERDA Report TID-26113-P2. 211 p.

- Dunaway, P. B. and S. V. Kaye. 1963. Effects of ionizing radiation on mammal populations on the Whiteoak Lake Bed. p. 33-338 In V. Schultz and A. W. Klement, Jr. (eds.) Proc. First Natl. Symp. Radioecology. Sept. 10-15, 1961. Rheinhold, New York, and AIBS, Washington. 746 p.
- _____, 1964. Weights of cotton rats in relation to season, breeding, and environmental contamination. Amer. Midl. Nat. 71:141-155.
- French, N. R., T. Y. Tagami, and P. Hayden. 1968. Dispersal in a population of desert rodents. J. Mammal. 49:272-280.
- _____, B. G. Maza, H. O. Hill, A. P. Aschwanden, and H. W. Kaaz. 1974. A population study of irradiated desert rodents. Ecol. Monogr. 44:45-72.
- _____, W. E. Grant, W. Grodzinski, and D. M. Swift. 1976. Small mammal energetics in grassland ecosystems. Ecol. Monogr. 46: 201-220.
- Garner, H. W. 1974. Population dynamics, reproduction and activities of the kangaroo rat, Dipodomys ordii in western Texas. Graduate Studies No. 7, Texas Tech Press, Lubbock. 28 p.
- Groves, C. R. 1981. The ecology of small mammals on the Subsurface Disposal Area, Idaho National Engineering Laboratory Site. M.S. Thesis, Idaho State Univ., Pocatello. 87 p.
- _____, and B. L. Keller. 1983. Ecological characteristics of small mammals on a radioactive waste disposal area in southeastern Idaho. Amer. Midl. Nat. 09: 253-265.
- Halford, D. K., and O. D. Markham. 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. Ecology 59:1047-1054.
- Hedlund, J. D. and L. E. Rogers. 1980. Great Basin pocket mice (Perognathus parvus) in the vicinity of radioactive waste management areas. Northwest Sci. 54:153-159.
- Hoffmann, R. S. 1958. The role of reproduction and mortality in population fluctuations of voles (Microtus). Ecol. Monogr. 28:79-109.
- Hull, C. H. and N. H. Nie. 1979. Statistical packages for the social science update - new procedures and facilities for releases 7 and 8. McGraw Hill, New York. 238 p.
- Johnson, W. C. 1977. Examination of censusing techniques for small mammals in a high desert ecosystem. M.S. Thesis, Idaho State Univ., Pocatello. 95 p.
- Keller, B. L. and C. J. Krebs. 1970. Microtus population biology III: reproductive changes in fluctuating populations of M. ochrogaster and M. pennsylvanicus in southern Indiana. Ecol. Monogr. 40: 263-294.

- _____, and C. R. Groves. 1978. Theoretical problems in defining dispersal in small mammals occupying the Subsurface Disposal Area, Idaho National Engineering Laboratory Site. p. 32-33 In Proceedings of the symposium on the Idaho National Engineering Laboratory Ecological Programs. O. Doyle Markham and W. John Arthur (eds.). IDO-12088. Nat. Tech. Inf. Ser., Springfield, VA. 72 p.
- Kirkland, G. L., Jr. 1976. Small mammals of a minewaste situation in the central Adirondacks, New York: a case of opportunism by Peromyscus maniculatus. Amer. Midl. Nat. 95:103-110.
- Krebs, C. J. and I. Wingate. 1976. Small mammal communities of the Kluane Region, Yukon Territory. Can. Field Nat. 90:379-389.
- Lidicker, W. Z., Jr. 1975. The role of dispersal in the demography of small mammals. p. 103-128 In Small mammals: their productivity and population dynamics. F. B. Golly, K. Petruszewicz, and L. Ryszkowski (eds.). Cambridge Univ. Press. 451 p.
- Markham, O. D. 1976. Polonium-210 in deer mice near the INEL Radioactive Waste Management Complex. p. 47-48 In 1975 Progress Report Idaho National Engineering Laboratory Site Radioecology-Ecology Programs. IDO-12080. Nat. Tech. Inf. Ser., Springfield, VA. 205 p.
- _____. 1978. Activation and fission radionuclides in the environment near the Idaho National Engineering Laboratory Radioactive Waste Management Complex. IDO-12085. National Technical Information Service, Springfield, VA. 19 p.
- _____, K. W. Puphal, and T. D. Filer. 1978. Plutonium and americium contamination near a transuranic storage area in southeastern Idaho. J. Environ. Qual. 7:422-428.
- McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. National Technical Information Service, Springfield, Va. 28 p.
- Nichols, D. W., H. D. Smith, and M. F. Baker. 1975. Rodent populations, biomass and community relationships in Artemisia tridentata, Rush Valley, Utah. Great Basin Nat. 35:191-202.
- Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical packages for the social sciences - 2nd edition. McGraw Hill, New York. 675 p.
- O'Farrell, M. J. 1974. Seasonal activity patterns of rodents in a sagebrush community. J. Mammal. 55:809-823.

- _____, and G. T. Austin. 1978. A comparison of different trapping configurations with the assessment line technique for density estimations. J. Mammal. 59:866-868.
- _____, D. W. Kaufman, and D. W. Lundahl. 1977. Use of live-trapping with the assessment line method for density estimation. J. Mammal. 58:575-582.
- Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13:131-144.
- Ramsey, P. R. 1969. Analysis of movement patterns in a population of Dipodomys ordii. M.S. Thesis, Texas Tech College, Lubbock. 25 p.
- Reynolds, T. D. 1980. Effects of some different land management practices on small mammal populations. J. Mammal. 61:558-561.
- _____, and C. H. Trost. 1980. The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. J. Range Manage. 33:122-125.
- Stebbins, L. L. 1971. Seasonal variations in circadian rhythms of deer mice in northwestern Canada. Arctic 24:124-131.
- Terman, C. R. 1968. Population dynamics, p. 412-445 In J. A. King (ed.) Biology of Peromyscus (Rodentia). Special Publication No. 2, American Society of Mammalogists, Lawrence, Kansas 593 p.
- Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey. 620 p.

SMALL MAMMAL DENSITY AND MOVEMENT ON THE SL-1 DISPOSAL AREA,
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ABSTRACT

This study was initiated to examine the population composition, density and food habits of small mammals on a radioactive waste disposal area. Population parameters of small mammals were studied at 3-month intervals on and adjacent to the SL-1 radioactive waste disposal area (1.4 ha) and a 0.3 ha control area between August 1981 and February 1982 with mark-release methods. Both areas have crested wheatgrass (Agropyron cristatum) stands surrounded by sagebrush steppe. Species composition on the SL-1 and control area was similar to that found on the Subsurface Disposal Area at the Idaho National Engineering Laboratory. Considerable use by small mammals of the perimeter of the crested wheatgrass stands was found on both the SL-1 and control area. Additionally, deer mice (Peromyscus maniculatus) and Ord's kangaroo rats (Dipodomys ordii) that frequent the crested wheatgrass stands of the SL-1 and control area were often captured over 100 m from the crested wheatgrass stands. Thus, future research efforts will focus on examining the intensity of perimeter use and food habits of rodents residing on and adjacent to the SL-1. Results of this study will be used to evaluate ecological conditions that affect small mammal use of radioactive waste disposal areas.

INTRODUCTION

Research, conducted at the Subsurface Disposal Area (SDA) of the Idaho National Engineering Laboratory (INEL), has established that populations of rodents residing on and especially near the fenceline perimeter of this facility are significantly greater than populations in the surrounding sagebrush steppe (Groves, 1981). To better understand the factors that enhance the number of rodents on the SDA, a study was initiated on a smaller waste disposal facility containing similar vegetation. The SL-1 area, which has remained undisturbed for 20 years, was uniquely suited to such a study due to its small size (1.4 ha). Additionally, since some small mammals captured near the outside perimeter of the SDA contained higher concentrations of ^{210}Po , activation, and fission products than mice from control locations (Markham, 1976, 1978; Markham et al., 1978), it seemed prudent to determine whether small mammals residing on other sites of the INEL containing interred radioactive wastes become contaminated (Arthur et al., this volume).

The present study was initiated to evaluate ecological conditions that affect small mammal use of radioactive waste disposal areas. The objectives of this research were to determine: 1) if species composition and density of small mammal populations are similar among the SL-1, control area, and SDA, 2) whether seasonal trends for Euclidean distances of movement documented by

Groves (1981) are similar to seasonal trends on the SL-1 and control area, 3) determine the extent that small mammals use the perimeters of the crested wheatgrass stands on the control area and SL-1, and 4) examine food habits of rodents residing on and adjacent to the SL-1. The results of this research should be of benefit in planning close-out and stabilization of waste disposal facilities in order to minimize small mammal penetration of interred wastes.

METHODS

Study Area

The SL-1 area is located over disposed radioactive materials generated largely from decontamination procedures following an excursion and explosion of the Stationary Low-Power Reactor in 1961 on the INEL. Approximately 1 m of compacted earth was placed over these materials and the entire area was seeded with crested wheatgrass (Agropyron cristatum). The disposal area has remained undisturbed for 20 years, excepting filling operations over areas of subsidence. Vegetation surrounding the crested wheatgrass stand is dominated by big sagebrush (Artemisia tridentata).

A 0.3 ha control area was selected approximately 2 km northwest of the SL-1 which consisted of a stand of crested wheatgrass bordered by a continuous stand of sagebrush on three sides. One side of the area is bordered by a mixed stand of crested wheatgrass and big sagebrush.

Initial Density Estimation

The initial collection of representative species and an estimate of relative density of the total species composition on the SL-1 and control area were obtained during a 4-day trapping effort. Longworth live traps, containing non-absorbent cotton nesting material and baited with whole oats, were placed at 10 m intervals in a 9 by 19 station matrix on the SL-1. Each trap was covered by a board to reduce heat buildup. All traps on the SL-1 grid were positioned with doors closed for 10 days before trapping was initiated. Doors were closed to prevent contamination of materials inside traps. The control grid contained only background levels of radioactive particles, so trapping was initiated with the door left open immediately following placement of the traps on a 5 by 8 matrix grid area.

Trapping was initiated on the SL-1 and control area in June and July 1981 respectively. Traps were set each evening and checked early the next morning. Since rodents residing on the SL-1 area might be contaminated, all traps containing animals were removed and replaced with a clean trap to prevent cross-contamination of future catches at the same location. Following captures on the control area, the contents of the capturing trap were replaced or a clean trap was substituted. Daily catches were immediately submitted to the Radiological and Environmental Sciences Laboratory of the INEL for radionuclide analyses. Periods of 53 and 33 days were then allowed for reinvasion of the SL-1 and control area before subsequent mark-release studies began.

Mark-Release Studies

The two grid matrices used for initial trapping will be referred to as the MAIN grids of the SL-1 (Fig. 1) and control area. A SHIFT grid was employed on each area to evaluate the number of animals that had home ranges that overlapped both the crested wheatgrass stand and the sagebrush area adjacent to the long axis of the MAIN grid. The SHIFT grid of the SL-1 had 76 trap stations that were coincident with the MAIN grid in crested wheatgrass and 95 trap stations located in the sagebrush habitat adjacent to the SL-1. Two HEXAGON grids were established 190 m from the MAIN grid of the SL-1 and 50 m from a smaller 8 by 5 matrix INTERMEDIATE grid. The two HEXAGON grids and the INTERMEDIATE grid will be referred to collectively as the SAGE grids. The MAIN and SHIFT grids of the control area were each 8 by 5 matrices that had two lines of overlap along the long axis. The dimensions of the SAGE grids adjacent to the control area were the same as the dimensions of those adjacent to the SL-1. Also, the locations of the SAGE grids relative to the MAIN grid on the control area were consistent with the grid design at the SL-1.

Figure 1. Grid configuration on the SL-1 waste storage area and adjacent area. The shaded portion of the diagram is crested wheatgrass and the surrounding vegetation is big sagebrush. All measurements are in meters, and all traps were located at 10 m intervals within matrices.

A mark-release program was conducted in August and November 1981, and February 1982 to obtain data on species composition, densities, and movement patterns for comparison between our study areas that could be related with previous studies done on the SDA. A prebaiting period of 3 to 5 days preceded trapping on each grid. Sessions of live-trapping were conducted for three consecutive nights and the two intervening days. In all cases, excepting August when traps were locked open during the day, traps were checked in the mornings and evenings. Live-trap sessions on the MAIN grids were followed by sessions on the SAGE and SHIFT grids respectively.

Snow cover was present from late November 1981 to mid-February 1982 on the study areas. Containers that allowed access to the traps by rodents using the subnivean space (Keller et al., 1982) were placed at each trap station of the MAIN and SAGE grids following the last trapping session in November to protect and enhance accessibility of live traps during February.

Individuals were ear tagged with a serially numbered and lettered fingerling fish tag or a numbered Essex leg band. Trap station, species, weight, sex, and reproductive condition were recorded for each animal prior to release. To eliminate the possibility of enhanced survival or induced establishment of home range by individuals frequenting the study areas, traps were removed from the MAIN and SHIFT grids between trap sessions.

Radiotelemetry

Three adult Ord's kangaroo rats (*Dipodomys ordii*), captured on the SL-1 MAIN grid, were fitted with 3.7 to 4.0 g radio packages to examine the feasibility of using telemetry procedures the following year. The presence or absence of each animal in the SL-1 area was noted over a period of 21 nights in August with a hand held Yagi antenna.

Radiotelemetry procedures will resume in June 1982. If possible, two null-peak Yagi antenna systems will be monitored simultaneously to obtain point location data through triangulation. Adult deer mice and kangaroo rats will be radiocollared and allowed 2 days to adjust to the transmitter package before tracking begins. When base estimates of movement patterns have been established, a sample of individuals will be removed with snap-traps. Radiotelemetry will be continued to assess relative changes in movement patterns of remaining animals that may occur following removal of individual animals from a local area. Food habit analyses will be performed by the Colorado State University Composition Analysis Laboratory on the contents of gastro-intestinal tracts taken from removed individuals.

RESULTS

Estimates, derived by the regression line technique (Hayne, 1950) after the initial trapping effort, suggest population sizes of 45 and 51 animals for the MAIN grid on the SL-1 and control area respectively. These data would indicate population densities of 32 animals per ha and 170 animals per ha on the two areas; however, data from our mark-release program indicate that a number of deer mice and kangaroo rats, captured on the MAIN grids, regularly frequent the SAGE grids which are 100 m distant (Table 1). Further, deer mice are most often captured within 20 m of the sagebrush when present on the MAIN

Table 1. Number of individual rodents with all captures restricted to the MAIN grid, SAGE grids, or captured on both the MAIN and SAGE grids on the SL-1 and control study areas, INEL. Values in (.) indicate the total recaptures tallied during August and November 1981 and February 1982.

Species	SL-1 Study Area			Control Study Area		
	Main Only	Sage Only	Both Main & Sage	Main Only	Sage Only	Both Main & Sage
<u>Dipodomys ordii</u>	8 (59)	--	4 (21, 8)	5 (22)	3 (11)	3 (12, 10)
<u>Eutamias minimus</u>	2 (4)	4 (22)	--	3 (5)	7 (23)	5 (16, 17)
<u>Lagurus curtatus</u>	--	--	--	--	5 (10)	--
<u>Microtus montanus</u>	25 (89)	--	--	6 (12)	1 (1)	--
<u>Onychomys leucogaster</u>	--	2 (9)	1 (1, 4)	1 (1)	2 (6)	1 (4, 8)
<u>Perognathus parvus</u>	14 (35)	6 (12)	1 (1, 1)	8 (30)	19 (54)	2 (3, 6)
<u>Peromyscus maniculatus</u>	33 (123)	28 (71)	28 (74, 97)	26 (78)	43 (149)	18 (65, 66)
<u>Reithrodontomys megalotis</u>	2 (8)	--	--	4 (9)	1 (1)	1 (1, 2)
TOTALS	84 (318)	40 (114)	34 (97, 110)	53 (157)	81 (255)	30 (101, 109)

grid of the SL-1 (Table 2). These data then suggest 32 animals per ha and 170 animals per ha as an index of utilization intensity rather than a density estimate of resident animals on the two study areas.

Average movement distances between successive captures were calculated for deer mice (Table 3). There were no significant differences (Paired and Group t-tests, $P > 0.05$) between the average distances moved during August and November as tested among repetitive captures for individuals or among individuals not recaptured in both periods. The minimum number known alive decreased among seasons for both areas (Table 4), although the February estimate for the control area may be low due to unusually cold weather during sampling.

Radiotelemetry data were limited since triangulation was not possible with a single antenna. Although specific locations were not plotted, the radiocollared kangaroo rats usually stayed within 100 m of their burrow systems. Burrow systems were readily located for the three radiocollared kangaroo rats since the soil did not greatly attenuate the signal.

DISCUSSION

Species composition of the SL-1 and control area is similar to that reported for the SDA (Groves, 1981). The density of small mammals in the area surrounding the dike channel of the SDA was twice that on grids in the SDA and greater than that observed in sagebrush steppe (Groves and Keller, this volume). These findings are consistent with the intensity of perimeter use found on the SL-1 and control area of our study. Further, movement patterns between August and November were not significantly different on both our study areas, a condition also noted for the SDA. However, our data suggest that the movements of deer mice and kangaroo rats regularly reach distances greater than 100 m outside of the crested wheatgrass stands. We derived these estimates from a sampling design that maximizes information on movement by animals from the SL-1 into the surrounding sagebrush steppe. We have assumed that this pattern, as established on one long axis of the study areas, is representative of the entire perimeter. If this is the case, then an area greater than four times the SL-1 surface area may be traversed on a regular basis by small mammals that use the disposal area frequently.

Since movement patterns, species composition, and perimeter use were consistent between the SL-1 and control area, the factors that substantially influence the small mammal populations on these areas are most probably related to the vegetative condition. However, the three radiocollared kangaroo rats had burrow systems located where filling operations had taken place. Kangaroo rats were present in similar numbers on both the SL-1 and control area, so soil condition might affect burrow location but not population levels. Future study with radiotelemetry will provide more information on burrow sites.

The effects of vegetative condition on our study areas might include differences in seed reserve, invertebrates that serve as a food source, or cover. The results of food habit analyses will help determine the type of food reserve being exploited by rodents. Radiotelemetry data will help establish the type of vegetation where foraging occurs most often. In

Table 2. Number of captures per 100 live-trap nights on the SL-1 MAIN grid during August and November 1981, and February 1982. Catch rates are shown for traps within 20 m of sagebrush (OUTSIDE) and traps greater than 20 m from sagebrush (INSIDE). Numbers in parentheses are actual numbers of captures.

Species	Number of captures per 100 live-trap nights	
	Outside	Inside
<u>Dipodomys ordii</u>	4.6 (39)	2.0 (12)
<u>Eutamias minimus</u>	0.5 (4)	--
<u>Lagurus curtatus</u>	--	--
<u>Microtus montanus</u>	2.3 (20)	5.2 (32)
<u>Onychomys leucogaster</u>	--	--
<u>Perognathus parvus</u>	2.4 (21)	1.1 (7)
<u>Peromyscus maniculatus</u>	15.2 (130)	1.0 (6)
<u>Reithrodontomys megalotis</u>	0.2 (2)	0.3 (2)
TOTALS	25.2 (216)	9.6 (59)

Table 3. Estimates of mean distance moved in meters between successive captures ($\bar{x}$) + S.E. (n) for Peromyscus maniculatus on and adjacent to the SL-1 and control areas, 1981. Paired comparisons involve separate movement patterns contrasted seasonally for the same individuals.

Area	Type of Comparison	August	November
SL-1	Paired	40.3 + 7.7 (11)	46.8 + 6.2 (11)
	Group	43.3 + 5.0 (58)	49.3 + 16.5 (16)
Control	Paired	44.2 + 8.6 (7)	53.2 + 14.3 (7)
	Group	29.2 + 3.1 (62)	38.1 + 6.5 (18)

Table 4. Minimum number of rodents known alive in crested wheatgrass stands and adjacent sagebrush habitat of the experimental (2.8 ha) and control (1.0 ha) plots Idaho National Engineering Site, as determined during three live-trapping periods for 1981-1982.

Species	SL-1			Control		
	August	November	February	August	November	February
<u>Dipodomys ordii</u>	8	6	4	9	--	--
<u>Eutamias minimus</u>	2	3	3	8	2	--
<u>Lagurus curtatus</u>	--	--	--	1	--	--
<u>Microtus montanus</u>	7	9	7	2	2	--
<u>Onychomys leucogaster</u>	--	3	2	1	4	1
<u>Perognathus parvus</u>	11	--	--	13	--	--
<u>Peromyscus maniculatus</u>	55	22	10	60	24	--
<u>Reithrodontomys megalotis</u>	2	--	--	3	--	--
TOTALS	85	43	26	102	32	1

addition, telemetry data, collected following removal of animals for food habit analyses, will allow evaluation of interactions between individuals that may limit densities. Such perturbations could not be employed up to this point as we lacked information on the similarity of undisturbed movements on the SL-1 and surrounding sagebrush steppe.

LITERATURE CITED

- Groves, C. R. 1980. The ecology of small mammals on the subsurface disposal area, Idaho National Engineering Laboratory Site. M.S. thesis, Idaho State University, Pocatello. 87 p.
- Hayne, D. W. 1950. Two methods for estimating population from trapping records. *J. Mammal.* 30:399-411.
- Keller, B. L., C. R. Groves, E. J. Pitcher, and M. J. Smolen. 1982. A method to trap rodents in snow, sleet, or rain. *Can. J. Zool.* 60:1104-1106.
- Markham, O. D. 1976. Polonium-210 in deer mice near the INEL Radioactive Waste Management Complex, p. 47-48. In: 1975 Progress Report Idaho National Engineering Laboratory Site Radioecology-Ecology Programs. IDO-12080. Nat. Tech. Inf. Serv., Springfield, VA. 205 p.
- _____. 1978. Activation and fission radionuclides in the environment near the Idaho National Engineering Laboratory Radioactive Waste Management Complex. IDO-12085. Nat. Tech. Inf. Serv., Springfield, VA. 19 p.
- _____, K. W. Puphal, and T. D. Filer. 1978. Plutonium and americium contamination near a transuranic storage area in southeastern Idaho. *J. Environ. Qual.* 7:422-428.

IMPORTANCE OF BIOTA IN RADIONUCLIDE TRANSPORT AT THE SL-1 RADIOACTIVE WASTE DISPOSAL AREA

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ABSTRACT

During summer 1981 and 1982, radioecological research was conducted at the Stationary Low Power Reactor-1 radioactive waste disposal area to 1) identify vegetation, wildlife, and invertebrate species occurring at or using the area, 2) determine radionuclide concentrations in these various ecosystem components and 3) to evaluate their respective roles in radionuclide uptake and transport through the surrounding environment. Cesium-137 concentrations detected in surface soils, small mammal excavated soils and small mammal tissues collected at the waste disposal site were significantly ($P \leq 0.05$) greater than control area samples. Strontium-90 and ^{235}U analyses of SL-1 and control area samples and projections of total mass of ecosystem components in SL-1 area will be completed in summer of 1983 at which time estimates will be made on the total quantity of fission and activation radionuclides occurring in ecological media at the SL-1 waste disposal area.

INTRODUCTION

Solid radioactive contaminated wastes from the Idaho National Engineering Laboratory (INEL) Stationary Low Power Reactor (SL-1) accident were disposed in an area 1.6 km northeast of the former reactor site. As part of a project to evaluate the importance of various ecosystem components in radionuclide uptake and transport at INEL radioactive waste disposal areas, a radioecology study was initiated at the SL-1 waste disposal area in June 1981. Objectives of the research were to: 1) determine radionuclide concentrations in surface soils, vegetation, small mammal tissues, insects, and coyote (Canis latrans) feces near the waste disposal area, 2) determine the quantity of radionuclides excavated to the surface by small mammal burrowing and 3) evaluate the role of these ecosystem components in radionuclide uptake and transport in the surrounding environment. ✓

STUDY AREA

The SL-1 reactor began critical operations in August 1958 and was located at the present site of the Auxiliary Reactor Area III on the INEL in Southeastern Idaho. This boiling water reactor contained 40 fuel elements of 91% enriched uranium with aluminum-nickel alloy cladding (Gammill, 1961).

On 3 January 1961, an explosion occurred at the SL-1 reactor which resulted in release of radioactive contamination in a southeasterly direction (downwind) from the area. Less than 10 Ci of ^{131}I were released

during the first 16 hours of the accident and less than 70 Ci of this nuclide were released over the following 30 days (Gammill, 1961). Approximately 0.1 Ci ^{90}Sr , 0.5 Ci ^{137}Cs and lesser quantities of ^{95}Zr , ^{95}Nb , ^{144}Ce , ^{140}Ba , and ^{140}La were released, the majority of which was deposited within a 1.2 ha area around the facility (Gammill, 1961).

Most of the radioactive wastes from the initial cleanup of the SL-1 area were disposed at the Subsurface Disposal Area on the INEL Radioactive Waste Management Complex. However, between May 1961 and July 1962 approximately 2300 m³ of activation and fission product contaminated soil and reactor hardware were disposed in two pits and one trench located 1.6 km northeast of the former reactor site. These wastes contained approximately 600 Ci of mixed activation and fission products. Wastes were covered with 1 m soil and the 1.4 ha area was seeded with crested wheatgrass (Agropyron cristatum). The area is relatively flat, and vegetation in the surrounding area is dominated by big sagebrush (Artemisia tridentata), green rabbitbrush (Chrysothammus viscidiflorous), and squirreltail grass (Sitanion hystrix) (McBride et al., 1978).

METHODS AND MATERIALS

Sampling was initiated at the SL-1 area on 1 June 1981. A 9 x 19 grid system was placed within the SL-1 waste disposal area (Filipovich and Keller, this volume). Each of the grid points were spaced at 10 m distances. An 8 x 5 grid system was placed at a 0.3 ha control area located 2 km northwest of the SL-1 area. The vegetation in the control area was similar to that in the SL-1.

To determine radionuclide concentrations in surface soils, 30 soil samples were collected from randomly selected grid points at the SL-1, and five samples were collected at the control area. A coring tool was used to collect surface (0-5 cm) soil samples. One soil sample was collected from the center and one from each corner of each selected 10 x 10 m transect. All stones and debris were removed from the samples, and the coring tool was rinsed with demineralized water and wiped clean to avoid cross-contamination. The five samples from each transect were composited and homogenized. A 400 cc sub-sample was selected, dried at 60°C for 72 hours, weighed and analyzed for gamma-emitting radionuclides on a lithium-drifted germanium crystal attached to a computerized multichannel analyzer. Strontium-90 and ^{235}U analyses were conducted at a commercial laboratory.

In conjunction with surface soil sampling, the soil density (g per cm³) was determined. This data will be used to obtain an estimate of the overall inventory of radionuclides in surface soils.

The role of small mammal soil burrowing in radionuclide transport was estimated by determining the quantity of soil excavated to the surface of each area and analyzing soil samples for radionuclide concentrations. During June 1981, 42 transects (each 10 x 10 m) within the SL-1 area

and 15 at the control area were searched for small mammal soil excavations. Fifteen transects were also measured in undisturbed sagebrush habitat adjacent to the SL-1, to determine whether soil excavation rates varied between vegetation types. All excavated soil was collected and weighed to provide data on the mass of soil excavated per m^2 . Ten of the burrowed soils collected from the SL-1 area and five from the crested wheatgrass control area were randomly selected and analyzed for radionuclides. A 400 ml sample of undisturbed surface soil was collected within 2 m of each burrow sample and was analyzed for radionuclides. Paired t-test procedures were used to test for differences in radionuclide concentrations between surface and excavated soil samples. A significance level of $P = 0.05$ was used for rejection of null hypothesis.

Information on vegetative species composition within the SL-1 area was obtained in conjunction with other ecological research activities. To determine vegetative biomass and vegetative radionuclide concentrations, a $1 m^2$ metal frame was placed in the east corner of 25 randomly selected grid points at the SL-1 area and in the northwest corner of 10 randomly selected grid points at the control area. All plant species occurring in the $1 m^2$ frame were identified and clipped at ground level. All samples were oven-dried for 72 hours at $60^\circ C$, weighed, and analyzed for gamma-emitting radionuclides. Five of the crested wheatgrass samples from the SL-1 area were washed in an ultrasonic bath for 30 minutes to remove surfically attached soil particles. Student's t-test procedures were used to compare radionuclide concentrations between washed and unwashed samples and also between SL-1 and control area vegetation.

Small mammals were obtained from Longworth live traps placed at the SL-1 and control areas. Hide, gastrointestinal tract, and carcass tissues were collected from each animal, dried for 72 hours at $60^\circ C$, and weighed. When five animals of the same species were caught within 20 m of each other, like tissues were pooled. Twenty-two and nine small mammal tissue composites from the SL-1 and control areas, respectively, were analyzed for gamma-emitting radionuclides, ^{90}Sr and ^{235}U .

In conjunction with an insect species composition study conducted at the SL-1 (Veith and Keller, this volume), 12 insect composite samples (Silphadae family) from the SL-1 and two from the control area were obtained, ultrasound washed, oven-dried and analyzed for radionuclides.

Areas near the SL-1 and control sites were searched for coyote (Canis latrans) feces to assess radionuclide transfer through the predator-prey food chain. Fifteen fresh coyote fecal samples were collected from the SL-1 area and 10 from the control area. Samples were washed to remove external soil contamination, oven-dried, and analyzed for radionuclides. All samples were collected within a 200 m radius of the respective areas.

RESULTS AND DISCUSSION

Forty-two transects encompassing 3450 m² were measured at the SL-1 for small mammal soil excavations in July 1981. A mean soil excavation rate ($\bar{X} \pm \text{SD}$) of 6.2 ± 21.0 g soil/m² (range 0.0 - 110.3 g/m²) was estimated for the SL-1 area. Multiplying this rate by the total area encompassed by the SL-1 (14000 m²) resulted in an estimated 86.8 kg soil excavated to the SL-1 surface. Fifteen transects encompassing a total of 1500 m² were measured for soil excavations at each the crested wheatgrass control area and also in a undisturbed sagebrush habitat type adjacent to the SL-1. Mean excavation rates of 5.4 ± 12.4 g/m² (range 0.0 - 46.5 g/m²) and 2.3 ± 2.6 g/m² (range 0.0 - 9.0 g/m²) were obtained for the crested wheatgrass and sagebrush areas, respectively. Mean soil excavation rates among the SL-1, crested wheatgrass and sagebrush areas were not significantly different ($P > 0.05$); therefore, vegetation type did not appear to have an effect on the mean mass of soil excavated to the surface by small mammals. Since the small mammal soil excavation data collected in summer 1981 could have resulted from burrowing over several years, the quadrats were remeasured in July 1982 to obtain the quantity of soil excavated over a 1-year period.

Vegetation species composition within the SL-1 area was dominated by crested wheatgrass which had at a mean biomass ($\bar{X} \pm \text{SD}$) of 195.5 ± 133.2 g/m² (range 1.5 - 524.3 g/m²). Including crested wheatgrass, Russian thistle, cheatgrass (Bromus tectorum), lambsquarter (Chenopodium album), western stickseed (Lappula redowski), halogeton (Halogeton glomeratus), giant wildrye (Elymus cinereus), goatsbeard (Tragapogon dubius), and tansey mustard (Descurainia sophia) a mean biomass of 203.2 ± 124.2 g/m² was obtained for all vegetative species in the SL-1. Other vegetation occurring in the SL-1 area but not observed on the vegetation plots were big sagebrush, green rabbitbrush, and Jim Hill mustard (Sisymbrium altissimum).

A mean vegetation biomass estimate of 210.1 ± 134.7 g/m² was obtained in the control area. Tansey mustard, western stickseed, cheatgrass, big sagebrush and crested wheatgrass were the dominant vegetation in the control area. No significant difference ($P > 0.05$) was observed for biomass estimates between the SL-1 and control area. Due to the similarity in biomass estimates and the vegetative species composition between the SL-1 and control area, these areas should provide "normalized" conditions whereby data from the small mammal studies (Filipovitch and Keller, this volume) can be interpreted to evaluate various ecological conditions at radioactive waste disposal areas which may enhance or inhibit rodent use.

Surface and small mammal excavated soil samples from the SL-1 area had significantly ($P \leq 0.05$) greater ¹³⁷Cs concentrations than control area samples (Table I). No significant difference was observed for ¹³⁷Cs concentrations between excavated and surface soils at the SL-1 area. Small mammal burrowing does not appear to be the primary reason for elevated radionuclide concentrations in surface soils at the SL-1 waste disposal

Table 1. Cesium-137 concentrations (pCi/g dry weight) in ecological media at the SL-1 radioactive waste disposal area and a control area in southeastern Idaho.

Media	SL-1			CONTROL		
	$\bar{x} \pm \text{SD}$	Range	n	$\bar{x} \pm \text{SD}$	Range	n
Surface soil ^a	56.5 $\pm$ 104	0.3 - 340	10	0.6 $\pm$ 0.3	0.3 - 1.1	5
Excavated soil ^a	19.5 $\pm$ 34.3	0.9 - 111	10	0.8 $\pm$ 0.6	0.4 - 1.8	5
Crested wheatgrass						
Washed	0.8 $\pm$ 0.4	0.4 - 1.2	5	----	---	---
Unwashed	0.6 $\pm$ 0.4	0.1 - 1.4	12	0.2 $\pm$ 0.1	0.05 - 0.3	5
Coyote feces	2.4 $\pm$ 2.7	0.4 - 11.2	15	0.8 $\pm$ 0.5	0.1 - 1.5	10
Insect composites	13.1 $\pm$ 25.9	0.3 - 86.0	12	6.8 $\pm$ 7.5	1.5 - 12.1	2
<u>Deer Mice</u>						
GI tract ^a	223 $\pm$ 342	4.1 - 1270	15	7.4 $\pm$ 5.8	1.7 - 14.8	4
Hide ^a	330 $\pm$ 247	9.3 - 692	15	0.6 $\pm$ 1.0	0.1 - 2.2	4
Carcass ^a	194 $\pm$ 268	4.8 - 1010	15	2.2 $\pm$ 0.5	1.5 - 2.6	4
<u>Pocket Mice</u>						
GI tract	14.9 $\pm$ 8.5	5.8 - 25.0	4	1.5 $\pm$ 1.1	2.8 - 25.0	3
Hide	7.2 $\pm$ 2.6	4.5 - 10.7	4	2.5 $\pm$ 2.0	0.3 - 4.0	3
Carcass	5.1 $\pm$ 5.4	0.04 - 12.7	4	3.6 $\pm$ 2.9	0.9 - 6.6	3

^aSignificant ($P \leq 0.05$) difference between SL-1 and control area radionuclide concentrations in this media.

area. Instead, the elevated ^{137}Cs concentrations in SL-1 soils may be because much of the soil cover applied over the disposed waste was obtained from areas adjacent to the former SL-1 reactor area site (Mortenson, B. M., personal communication). Additionally, the soil cover existing over the SL-1 disposal site can be affected by deposition of wind blown contamination from the surrounding area. A 1977 soil sampling program conducted around the SL-1 area detected ^{137}Cs concentrations of 2.2 to 121 pCi/g soil within 250 m of the disposal area (U.S. Department of Energy, unpublished data).

The occurrence of other activation and fission radionuclides in SL-1 and control area soils was minimal (Table 2). Manganese-54 was detected in one of 10 SL-1 surface soils whereas ^{95}Nb was detected in one of five control surface area soils. Niobium-95 was also detected in four of 10 SL-1 and three of five control area excavated soil samples and was likely due to fallout from worldwide nuclear weapon detonations.

No significant ($P>0.05$) difference was observed between ^{137}Cs concentrations in washed and unwashed crested wheatgrass samples from the SL-1 area, indicating that surficial attachment of contaminated soil was probably minimal. Also no significant difference was observed for ^{137}Cs concentrations between SL-1 and control area crested wheatgrass samples (Table 1). A greater number of activation and fission radionuclides were detected in vegetation samples than in soil samples from both areas (Table 2). Cerium -144, ^{141}Ce , and ^{103}Ru were detected in 12, 2, and 2 of 17 SL-1 vegetation samples respectively as compared to ^{144}Ce and ^{140}La which were detected in five of five and one of five control area vegetation samples, respectively.

Even though some coyote fecal and insect samples collected from the SL-1 area had elevated levels of ^{137}Cs , the mean ^{137}Cs concentrations in these media were not significantly ($P>0.05$) different between the SL-1 and control areas. Eight of the 14 insect samples analyzed for ^{137}Cs were carrion beetles (Nicrophorus sp.) composites which due to their feeding habits could be expected to consume small mammals, some of which would be contaminated.

A majority of the small mammals sampled in the SL-1 and control areas were deer mice (Peromyscus maniculatus). Gastrointestinal tract, hide and carcass tissues collected from SL-1 deer mice had significantly ($P\leq 0.01$) greater ^{137}Cs concentrations than control area samples. The elevated ^{137}Cs concentrations in hide tissues are likely due to attachment of soil particles while burrowing through contaminated soil, whereas the increased concentration in gastrointestinal tract and carcass tissues probably occurred due to ingestion of contaminated soil and/or insects. Food habits analyses of gastrointestinal tract contents were conducted in fall 1982 (Filipovich and Keller, this volume).

No significant ($P>0.05$) difference was observed for ^{137}Cs concentrations in pocket mice (Perognathus parvus) tissues between the SL-1

Table 2. Occurrence of activation and fission produced radionuclides (excluding ^{137}Cs and ^{90}Sr) in ecological media from the SL-1 radioactive waste disposal area and a control area in southeastern Idaho.

Media	Area	Sample Size	^{54}Mn	^{95}Nb	^{95}Zr	^{103}Ru	^{106}Ru	^{140}Ba	^{141}Ce	^{144}Ce
Surface soil	SL-1	10	1 (0.1) ^a	-- ^b	--	--	--	--	--	--
	Control	5	--	1 (0.1)	--	--	--	--	--	--
Excavated soil	SL-1	10	--	4 (0.2)	1 (0.3)	--	--	1 (4.0)	--	--
	Control	5	--	3 (0.2)	--	--	--	--	--	--
Crested wheatgrass	SL-1	17	--	16 (1.6)	9 (1.7)	2 (0.9)	--	--	2 (1.5)	12 (3.8)
	Control	5	--	5 (1.4)	3 (1.1)	--	--	--	--	5 (3.5)
Coyote feces	SL-1	15	--	--	1 (6.8)	--	1 (18.1)	--	--	--
	Control	10	--	--	--	--	1 (9.4)	--	--	--
Insect	SL-1	12	--	--	--	--	--	--	--	--
	Control		--	--	--	--	--	--	--	--
Deer mice tissues	SL-1	60	1 (2.7)	1 (70.2)	--	--	--	--	1 (13.6)	1 (2.7)
	Control	16	--	--	--	--	--	--	--	--

^aFirst number is number of samples in which radionuclide detected; maximum radionuclide concentration (pCi/g) in parenthesis.

^bRadionuclide not detected.

and control area. Also based on a limited sample size of kangaroo rat (Dipodomys ordii) (n=3) and montane vole (Microtus montanus) (n=2) tissue composites, only one gastrointestinal tract sample from a montane vole appeared to have elevated levels of ^{137}Cs . A minimal occurrence of other activation and fission products were detected in small mammal tissues (Table 2).

Results of radionuclide concentrations in SL-1 ecosystem components will be related to the respective biomass estimates to determine the total radionuclide inventories in these media. A final report on the role of ecosystem components in radionuclide transport near the SL-1 waste disposal area will be published in summer 1983. Information obtained from this study will be combined with results of radioecological studies conducted at the Subsurface Disposal Area (Arthur and Markham, this volume) and used to assess the importance of various environmental pathways in transporting radionuclides from INEL radioactive waste disposal areas.

LITERATURE CITED

- Gammill, W. P., 1961. Environmental aspects of the SL-1 accident.
Paper presented at the 7th Annual Meeting of the Pacific Northwest
Section of the American Industrial Hygiene Associates. September 22,
1961. 14 p.
- McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer, 1978. Vegetation
types and surface soils of the Idaho National Engineering Laboratory
Site. IDO-12084. Nat. Tech. Inf. Serv. Springfield, VA. 29 p.

ECOLOGY OF CARRION BEETLES (Nicrophorus spp.)
AT A SOLID RADIOACTIVE WASTE DISPOSAL AREA

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ABSTRACT

A study of the population ecology of three species of carrion beetles (Nicrophorus hecate, N. hybridus, N. marginatus) was initiated on a solid radioactive waste disposal area on the Idaho National Engineering Laboratory in June, 1981. Successive mark and recapture procedures were used to document redistribution of individually numbered adults. During the first summer of research, 1410 individuals were captured in baited pitfall traps, marked, and released during three 12-day sampling periods. Eighty marked individuals were subsequently caught at sampling stations located at varied distances from the site of release, but half of the recaptures occurred within 66.2 m of this point, and a decline in number of recaptures was observed with increasing distance. Capture of beetles at trapping points was related to the prevailing wind direction. Based upon the observed densities, local populations of these species could have an important role in the organic breakdown of small mammals that die on or adjacent to the disposal area. Thus, they may also be an important vector in the redistribution of radionuclides present in small mammals that became contaminated prior to death.

INTRODUCTION

The SL-1 is a 1.4 ha waste disposal area on the INEL where radioactively contaminated materials from a nuclear excursion and explosion were disposed approximately 20 years ago. The uncontained waste was covered with 1 m of compacted earth, and the area was seeded with crested wheatgrass (Agropyron cristatum). The area surrounding the SL-1 is dominated by a big sagebrush vegetation type described by McBride et al. (1978).

The general life histories of some carrion beetles have been documented (Balduf, 1935; Milne and Milne, 1944; Ratcliffe, 1972), but the population ecology and life history of the species found on the INEL (Nicrophorus hecate, N. hybridus, and N. marginatus) have never been investigated. Recently conducted research on the INEL concluded that soils, and deer mouse (Peromyscus maniculatus) tissues at the SL-1 area had elevated ¹³⁷Cs concentrations (Arthur, this volume). Because carrion beetles bury small mammal carcasses that are utilized as a food supply in rearing of young (Balduf, 1935; Milne and Milne, 1944), these insects could serve as a vector for the redistribution of radionuclides. Additionally, small mammals could ingest insects that had become contaminated through burrowing or foraging. Consequently, it is important to document the life history and insect species that may serve as either food input or as organic breakdown vectors for mammals located on waste disposal areas. The objectives of our research

will be to: 1) study the population ecology of Nicrophorus spp. on and adjacent to the SL-1 and 2) sample the relative densities of common insects found in crested wheatgrass stands on the SL-1 and a control area. These data will be used to detail the relationship of insects to small mammal communities residing over disposed radioactive wastes.

METHODS

Successive mark and recapture procedures were undertaken during June through August, 1981, on individual carrion beetles collected in pitfall traps. Traps were baited with carcasses of small mammals collected from the INEL and frozen prior to use. Shubeck's collection method (1968a) was modified in conjunction with suggestions by Newton and Peck (1975) and Luff (1975). Number 10 metal cans (15.5 cm in diameter and 17.5 cm deep) were covered with a 1.25 cm mesh metal screen wired to the top of each can to prevent removal of bait by vertebrate scavengers. Traps were buried such that the tops were flush with the soil surface to retard bait desiccation and minimize mortality of trapped beetles.

A sampling plot was established in the center of the SL-1 and four recapture plots were located in the sagebrush community at 65.8, 105.8, 131.5, and 182.3 m from the center of the SL-1 (Fig. 1). A fifth plot, located in the center of a 0.3 ha crested wheatgrass planting approximately 2 km northwest of the SL-1, served as a control for collection of insects for radionuclide analysis (Table 1) and to document long-distance dispersal of carrion beetles released from the SL-1. Each sample plot consisted of a hexagon configuration with six pitfall traps spaced at 10 m intervals around the perimeter.

Upon capture inside the SL-1, beetles were individually numbered with a three dot, two color coding system painted on the elytra with Testors brand enamel paint. Individuals were collected over 5-day sampling periods, and released on the sixth day from the center of the SL-1. Just prior to release, the four adjacent trapping plots and the 2-km distant crested wheatgrass area were baited. The purpose of the release was to study dispersal and relative density of carrion beetles on the SL-1.

Following each release, a 7-day capture-mark-release procedure was undertaken. All individuals captured outside the SL-1 were marked and released inside the SL-1 the same day. During the 12-day sampling periods, traps were checked daily and the number of beetles caught per day for each trap was recorded. In the subsequent 7-day capture-mark-release procedure, the number of each recaptured individual, date of recapture, trap number, and area were recorded. Wind speed and direction, temperature, and humidity were monitored as factors that could affect the dispersal behavior of carrion beetles.

During the August recapture effort, different baits were tested for effectiveness in attracting carrion beetles. Traps were baited with carcasses of black-tailed jack rabbit (Lepus townsendii) cut into thirds,

Figure 1. Pitfall trap locations on and adjacent to the SL-1. The sampling plots are composed of hexagons with six trapping stations.

Table 1. Methods used for collection of insects for radionuclide analysis from the SL-1 and control, summer 1981.

System	Size	Duration	Location
Malaise trap	10 x 15 x 7 feet	3 days	main control + SL-1
Window trap	3 x 5 foot pane	5 days	main control + SL-1
Black-light trap	18 inches long	1 night	main control + SL-1

Townsend's ground squirrel (Spermophilus townsendii), deer mice (Peromyscus maniculatus), and least chipmunk (Eutamias minimus). A random numbers table was used to select traps within the hexagon matrix that received a given bait to eliminate position bias relative to prevailing wind patterns. Subsequent studies will be conducted to further test the effectiveness of bait size and the speed of location of fresh versus frozen carcasses.

Since position of capture in circular distributions cannot be analyzed by statistical methods for linear data (Zar, 1974), mean angles of the sampled population were calculated with the formulae:

$$X = \frac{\sum_{i=1}^n \cos a_i}{n} \quad \text{and} \quad Y = \frac{\sum_{i=1}^n \sin a_i}{n}$$

Thus: $r = \sqrt{X^2 + Y^2}$, $\cos \bar{a} = \frac{X}{r}$, and $\sin \bar{a} = \frac{Y}{r}$.

The sample direction consists of n angles, denoted as a_1 through a_n , and $\bar{a}$ is an estimate of the mean angle of the sampled population when the value of a is determined from a table of Sines and Cosines of angles.

The standard deviation for the distribution is calculated with the formula:

$$S = \sqrt{-2 \log r \text{ (in radians)}}$$

The significance of the mean angle was tested with Rayleigh's test (Zar, 1974), to determine how large a sample (r) must be obtained to estimate a non-random population distribution. Rayleigh's R was obtained by:

$$R = nr$$

In all cases, a null hypothesis of no significant direction in R was rejected ($P < 0.05$), and we concluded that there was a mean direction of flight to the point of capture. However, mean angles were only calculated for the July trapping period when the number of individuals captured was greatest. Additionally, the most distant sampling plot in sagebrush could not be analyzed due to loss of data from trap disturbance by a badger.

Samples of insects from the SL-1 and a control area were collected for radionuclide analysis during the summer 1981. Duration of sampling effort and sampling methodologies are detailed in Table 1. During the summer 1982, these areas will be resampled during fixed intervals to document relative densities of common insects that may serve as food items for small mammals residing on the SL-1 and control area. Additionally, unbaited pitfall traps will be used to document species that may not be collected by the other methods.

RESULTS AND DISCUSSION

Beetles of the family Silphidae are commonly associated with carrion and are considered ecologically important due to their role in the breakdown and recycling of nutrients (Shubeck, 1969; Putman, 1978). Three genera in the family are saprozoic, but Necrodes was not collected on the SL-1 site, and individuals of the genus Silpha were only captured infrequently. Thus, the genus Nicrophorus seemed to be the most common carrion beetle on the study sites and was represented by four species, three of which were abundant.

Carrion beetles locate dead animals by chemoreceptors, located on the antenna, that detect decaying flesh (Abbott, 1927b; Dethier, 1947; Waldow, 1973; Shubeck, 1975). Once a carcass is found, the burial process begins. Burial is accomplished on soft substrates by one to several beetles. The head and mouthparts are used to plow under the carcass and the earth is shoved up on the opposite side (Milne and Milne, 1944). The process is repeated such that the carcass falls below the soil surface allowing the piles of plowed earth to cave in over the top of the dead animal. When burial is completed, mating and egg-laying occur (Milne and Milne, 1944). Development from egg to adult takes approximately 2 weeks (Balduf, 1935). Parental care is invested in the young, with the interred carcass used as the food source. The species found on the SL-1 site may over winter in the pupal stage, emerging as adults the following spring, or they may complete development and over winter as adults. In either case, the adults live for approximately 1 year, but the exact pattern in desert areas remains to be established.

The major emphasis of this study was to document movement distances and dispersal patterns of carrion beetles for the SL-1 site. Capture-recapture studies were conducted for this purpose. Dilution of the percent of recaptures by new captures was an indication of the population density in a given area. Table 2 details the mean distances moved by recaptured beetles, and the percent of total recaptures for each trapping area. An overall recapture rate of 6% was documented, with no marked individuals captured at the 2 km distant trapping plot. This may be because this plot was not located upwind of the point of release. Other investigators have found that Nicrophorus spp. are attracted to carrion from great distances. Petruska (1964) documented movement toward carrion sources of greater than 4 km in 24 h for two species native to Russia (N. germanicus and N. vespillo), and rapid long-distance movements have been reported by other investigators (Fabre, 1899; Abbott, 1927a, 1937; Dethier, 1947) in other species.

Shubeck (1968b) found that carrion beetle movements in a deciduous forest, with a negligible amount of wind were random until they were within 1 m of a baited trap. The results of our study indicated that carrion beetle movements were non-random and correlated with wind direction. Table 3 shows that mean angles of beetle captures calculated for the center of the SL-1 and 2 km crested wheatgrass area pointed to the downwind (NE) side of the hexagonal trapping grids, indicating that beetles were moving upwind in the process of carrion location when only one grid was baited. Mean angles for three of the simultaneously baited trapping grids in sagebrush adjacent to the SL-1 did not correspond to the wind direction in all cases (Table 3). This was probably due to the presence of several baited trapping grids in the area.

Table 2. Mean Euclidian distances moved by Nicrophorus spp. (with 95% confidence limits) to sagebrush plots when released from the center of the SL-1, and the percent of total recaptures caught adjacent to the SL-1 on the four trapping plots.

Area Location in Increasing Distance from the Center of the SL-1	Straight-line Distances (m) Moved by <u>Nicrophorus</u> spp. $\bar{x} \pm SE$	95% Confidence Limits Around Mean Euclidean Distance Moved by Beetles	Number of Recaptures	Percent Recaptured
1	63.4 $\pm$ 0.74	61.93-64.91	39	49
3	103.0 $\pm$ 1.67	99.57-106.55	21	26
2	131.3 $\pm$ 1.99	126.86-135.72	11	14
4 ^a	183.0 $\pm$ 2.72	176.70-189.23	9	11

^aDuring the July sampling period an unknown quantity of carrion beetles were lost because of trap disturbance by a badger.

Table 3. The mean angle of the circular distribution of Nicrophorus spp. captures among the sample data. The general compass directions are also tabulated. All mean angle calculations were significant ($p < 0.05$) as determined by Rayleigh's test.

Area	Mean Angle (Degrees)	General Direction	Angular Deviation (Radians)	Sample Size
Control	98	NE	1.52	231
SL-1	61	NE	1.40	386
1	348	NW	3.48	188
2	71	NE	3.00	263
3	246	S	2.01	206

The number of individuals of the genus Nicrophorus trapped during this study was found to be much greater than numbers documented by investigators of different species in habitats other than crested wheatgrass or sagebrush steppe (Table 4). Further, larger carcasses attracted more beetles over time than smaller ones (Table 5). During the three 12-day sampling periods completed for the summer 1981, 1875 carrion beetles were captured and 1410 were marked and released. Heat induced mortality accounted for the 465 beetles that were not released. Daily captures, excluding recaptures, ranged from 0 to 332.

The mean number of beetles caught per day for the summer of 1981 on the SL-1 trapping grid was significantly greater than the means that were calculated for any of the other trapping grids in this study (Table 6). The second largest mean was documented for the trapping grid that was located upwind of the SL-1, in sagebrush habitat. This mean was less than half the mean calculated for the SL-1 grid. The explanation for the higher density of carrion beetles is not known, but the effect is important relative to pathways for carrion breakdown by animals associated with the SL-1 food chain.

Carrion location efficiency by Nicrophorus is dependent upon their population density (Conley, 1982), and based upon the high density of carrion beetles observed on the SL-1, speed of location may be greater for beetles than vertebrate scavengers. Consequently, burial of a carcass could occur before the arrival of other scavengers. As a result, radionuclides from contaminated mammal carcasses could enter the food chain at a lower trophic level. Additionally, different organisms could be involved in the carrion food chain on the SL-1 than were previously assumed. For example, burrowing owls in eastern Oregon were found to feed on N. hecate extensively during the winter (T. Rich, pers. comm.) and thus would be involved in the carrion food chain, even though they do not feed directly on carrion.

In summary, until initiation of this research, it was assumed that dead animals would usually be moved through the food chain by carnivores and raptors frequenting waste disposal areas. This definitely seems to be the case in open habitat such as sand dunes and cinder cones (McKinnerney, 1978), but conflicting evidence on the time of arrival of Nicrophorus spp.--35 min., (Milne and Milne, 1944); 2-3 days (Payne, 1965; McKinnerney, 1978; Conley, 1982)--occurs in the literature. Since previous studies of location efficiency were conducted with different species of Nicrophorus in dissimilar habitats, with lower population densities than those found on the SL-1 area, speed of location in crested wheatgrass plantings and sagebrush steppe will be determined and compared during the summer of 1982. Speed of burial in different soil densities will also be documented in both habitat types. Additionally, reproductive studies will be conducted to establish general life history patterns for the three species of Nicrophorus which occur on the study site.

Table 4. Comparison of the numbers of carrion beetles captured in a single trap and over an entire trapping period for the data collected from the SL-1, Idaho National Engineering Laboratory Site, and several other studies.

Greatest No. of Individuals Captured in one trap	Total No. of Beetles Caught per study period cited	Author and Time Period
162	1875	This study, June-August
14	61	Conley, 1982, June & July
16	175	Shubeck et al., 1981, Apr.-Nov.
37	492	Shubeck, 1976, Apr.-Oct.
27	205	Shubeck, 1968a, June & July
Nd ^a	144	Shubeck, 1969, June-August
13	Nd	Ratcliffe and Luedke, 1969
14	Nd	Putman, 1978

^aNo documentation

Table 5. Comparison of numbers of carrion beetles captured for three types of bait placed randomly in traps on the SL-1, Idaho National Engineering Laboratory. Two of each of the three types were put in each hexagon sampled. Four grids were sampled and 99 beetles were captured.

Type of Bait	Percent of Total Captures
Jack rabbit (cut into thirds)	48
Deer mice/chipmunks	5
Ground squirrels	46

Table 6. The number of carrion beetles trapped per area, and the mean number caught per day for each area over the three 12-day sampling periods during the summer of 1981. The SL-1 was trapped for a duration of 15 days and the other areas for 21 days.

Sampling Location and Vegetation	Number of Beetles Captured	Mean Number of Beetles Caught per Day
Crested Wheatgrass Hexagon Plots		
SL-1	477	32
Control	249	12
Sagebrush steppe Hexagon Plots		
Location 1	269	13
Location 2	294	14
Location 3	244	12
Location 4 ^a	324	15
Total	1,875 ^b	

^aDuring the July sampling period an unknown quantity of carrion beetles were lost because of bait depredation by a badger.

^b1410 individuals from this sample were individually marked and released.

During the summer of 1981, other insects frequenting the SL-1 were sampled. These insects may be directly involved in the food chain on the SL-1, because small mammals are known to feed on insects. Thus, the relationship of insect abundance to small mammal ecology on the SL-1 will be studied by detailing insect species present for contrast against food habit analysis to be undertaken on the more common rodents frequenting the SL-1 and control area (Filipovich and Keller, this volume).

LITERATURE CITED

- _____. 1927a. Further observations on the olfactory powers of the Necrophori. *Ann. Entomol. Soc. Amer.* 20:207-216.
- _____. 1937. The necrophilous habit of Coleoptera. *Bull. Brooklyn Entomol. Soc.* 32:202-204.
- Abbott, C. E. 1927b. Experimental data on olfactory sense of Coleoptera, with special reference to the Necrophori. *Ann. Entomol. Soc. Amer.* 20:550-553.
- Balduf, W. V. 1935. The Bionomics of Entomophagous Coleoptera. J. S. Swift Co., Inc. New York (Reprinted by E. W. Classey, Ltd., Hampton, Middlesex, England, 1969). 220 p.
- Conley, M. R. 1982. Carrion locating efficiency in burying beetles, Nicrophorus carolinus (L.) (Silphidae). *Southwestern Nat.* 27:11-15.
- Dethier, V. G. 1947. The role of the antennae in the orientation of carrion beetles to odors. *J. New York Entomol. Soc.* 55:285-293.
- Fabre, J. H. 1899. *Souvenirs Entomologiques*. VI:113-153.
- Luff, M. L. 1975. Some features influencing the efficiency of pitfall traps. *Oecologia*. 19:345-357.
- McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. *Nat. Tech. Inf. Ser.*, Springfield, VA. 28 p.
- McKinnerney, M. 1978. Carrion communities in the northern Chihuahuan desert. *Southwestern Nat.* 23:563-576.
- Milne, L. L. and M. J. Milne. 1944. Notes on the behavior of burying beetles (Nicrophorus spp.). *Behavior* 52:311-327.
- Newton, A. L. and S. B. Peck. 1975. Baited pitfall traps for beetles. *Coleop. Bull.* 29:45-46.
- Payne, J. A. 1965. A summer carrion study of the baby pig Sus scrofa L. *Ecology* 46:592-602.

- Petruska, F. 1964. Concerning the mobility of some beetle species concentrating on decaying animal matter (Col. Silphidae and Histeridae). Acta. Univ. Polack, Olomuc. Fac. Natur. Biol. 6:159-189.
- Putman, R. J. 1978. The role of carrion frequenting arthropods in the decay process. Ecol. Entomol. 3:133-139.
- _____. 1972. The natural history of Necrodes surinamensis Fabr. (Coleoptera:Silphidae). Trans. Amer. Entomol. Soc. 98:359-410.
- Ratcliffe, B. C. and R. J. Luedke. 1969. A comparison of Silphids taken from covered and uncovered carrion (Coleoptera:Silphidae). Coleop. Bull. 23:103-105.
- Shubeck, P. P. 1968a. Trapping Fabre's "sexton" beetles. Amer. Bio. Teach. 30:564-565.
- _____. 1968b. Orientation of carrion beetles to carrion: Random or non-random? J. New York Entomol. Soc. 76:253-265.
- _____. 1969. Ecological studies of carrion beetles in Hutcheson Memorial Forest. J. New York Entomol. Soc. 77:138-151.
- _____. 1975. Do diurnal carrion beetles use sight as an aid to olfaction in locating carrion? William L. Hutcheson Memor. For. Bull. 3:36-39.
- _____. 1976. Carrion beetle response to poikilotherm and homoiotherm carrion (Coleoptera:Silphidae). Entomol. News 87:265-269.
- _____. N. M. Downie, R. L. Wenzel and S. B. Peck. 1981. Species composition and seasonal abundance of carrion beetles in an oak-beech forest in the Great Swamp Wildlife Refuge (N.J.). Entomol. News 92:7-16.
- Waldow, U. 1973. The electrophysiology of a new carrion receptor and its relation to the behavior of the carrion beetle (Necrophorus) (sic). J. Comp. Physiol. 83:415-424.
- Zar, J. H. 1974. Biostatistical Analysis. Prentice-Hall Inc., New Jersey. 620 p.

RODENT MOVEMENTS, DENSITIES AND RADIONUCLIDE CONCENTRATIONS AT A LIQUID RADIOACTIVE WASTE DISPOSAL AREA

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ABSTRACT

Movements and densities of rodents at a liquid radioactive waste disposal area were studied from June to September 1981 using trap line and assessment line techniques. The average distance between points of successive capture was 42 ± 25 (SD) m for deer mice (Peromyscus maniculatus) and 37 ± 21 m for kangaroo rats (Dipodomys ordii). Densities of deer mice averaged 10.2/ha with a population estimate of 57 within the area of rodent captures. The population estimate of 4 species of small mammals at the waste pond complex was 93. Radionuclide concentrations averaged 133 ± 97 pCi/g for rodents captured inside the disposal area boundary, 18 ± 22 pCi/g for those captured outside of the disposal area fence and 0.50 ± 0.6 pCi/g for control animals. Species captured outside of the waste area boundary had significantly lower ($P < 0.05$) radionuclide concentrations than those captured inside the waste area. The gamma emitting radioactivity inventory (^{137}Cs , ^{134}Cs , ^{60}Co and ^{65}Zn) in rodents at the liquid waste disposal area was estimated to be about 162 nCi.

INTRODUCTION

Small mammals inhabiting radioactive waste disposal areas may become contaminated with radioactive materials and transport this material from contaminated sites. Contamination in or on small mammals at radioactive waste areas may be transferred to predators (Halford and Markham, 1978; Craig et al., 1979; Arthur and Markham, 1982). Halford and Markham (1978) found that rodents collected inside of a waste disposal area had higher radionuclide concentrations than control animals. Therefore, we initiated a study around a liquid radioactive waste disposal area on the Idaho National Engineering Laboratory (INEL) Site to determine: 1) small mammal densities in the waste area; 2) small mammal movements out of the waste area, and; 3) the amount of radioactive contamination transported out of the area by small mammals.

STUDY AREA

The study was conducted at the Test Reactor Area (TRA) radioactive leaching ponds on the INEL in southeastern Idaho. TRA is located in the cool sagebrush desert biome of the upper Snake River Plain at an elevation of 1500 m. The TRA ponds have been used for disposal of low-level liquid radioactive wastes from three light-water-moderated and cooled reactors. The first of three liquid radioactive waste ponds was dug in 1952 and a second pond was dug in 1957; the two ponds presently constitute one continuous body of water 0.82 ha in area with a mean depth of 3 m. Due to a decrease in permeability and consequently the percolation

of liquid radioactive waste into the soil, a third pond was excavated in 1964. The radioactive waste water is pumped into the 1952-1957 ponds where it mixes with previously deposited water and eventually flows through an overflow parshall flume to the 1964 pond where it soaks into the soil. The 1964 pond was partially covered with shallow water in 1976 which formed a marshy area of about 0.13 ha. The 1964 pond has a total area of 0.93 ha and was the primary capture location of small mammals. A continuous 1.1 m high, 10 cm square mesh wire and barbed-wire fence encloses all three ponds, forming a total area of 3.02 ha.

As liquid in the ponds percolates into the soil, radioactivity is deposited onto the sediments. Approximately 48,000 Ci of activation and fission products were released from the TRA facilities into the ponds from 1952 through 1980 (Batchelder, 1981). Radionuclides with half-lives less than 1 yr compromised 80% of this radioactivity.

The pond bottoms and banks consist of gravelly alluvium. Sedge (*Cyperus* sp), thistle (*Cirsium arvense* and *C. vulgare*) and wild lettuce (*Lactuca serriola*) are common near water. The 1964 pond basin and adjacent banks are sparsely vegetated by cheatgrass (*Bromus tectorum*), wild barley (*Hordeum jubatum*) and rabbitbrush (*Chrysothamnus nauseosus* and *C. vicidiflorus*). Vegetation outside of the pond fence consists primarily of big sagebrush (*Artemisia tridentata*), rabbitbrush, cheatgrass, and wild barley. The soil outside the pond fence is sandy. The southwest side of the pond is bordered by a road and the TRA facility. Radionuclide concentration data obtained from animals captured 5 km south of the TRA ponds in a previous study (Halford and Markham, 1978) were used as a control group for radionuclide concentration comparisons.

MATERIALS AND METHODS

Movement data were obtained by ear-tagging rodents with numbered fingerling fish tags and recording locations on the trap grid and line system (Fig. 1). To determine rodent movements, 96 sampling stations were placed at 10 m intervals in a 12 x 8 configuration on a rectangular grid on the 1964 pond (Fig. 1). Eighty stations were placed at 10 m intervals in 4 lines of 20 traps each outside of the pond fence parallel to the north, east and south fence lines. The north and south lines contained one transect placed 50 m from the pond fence while the eastern line contained 2 transects at 50 and 125 m from the fence. The western side of the 1964 pond was bordered by the TRA ponds. Any westerly movements would be inside the confines of the waste area and was therefore not trapped. One Longworth live-trap containing cotton nesting material was placed at each station. Traps were baited with rolled oats, set at 1600 hr and checked between 0800 and 1000 hr the following morning. The grid system was trapped for 8 nights (4 weeks x 2 consecutive nights) from 30 June 1981 to 3 August 1981 for a total of 768 trap nights. The line system was trapped for 6 nights (3 weeks x 2 consecutive nights) during the same dates for a total of 480 trap nights.

Rodent densities in the TRA pond area were estimated from 4 August to 4 September 1981 using the assessment line (O'Farrell et al., 1977) adjusted for a 12 x 8 trap grid. The same grid used for movement studies was intersected by 8 assessment lines which radiated at 45° angle from the grid center (Fig. 2). The maximum assessment line length was 200 m (20 traps at 10 m intervals). Some lines had less than 20 traps because of water, roads and excavation areas. The total numbers of traps on the assessment lines was 130. The grid was trapped for 4 consecutive days (twice) (768 trap nights), then traps were removed for 3 days to eliminate rodent attraction to the traps. Assessment lines were then trapped for 3 consecutive days (twice) plus one day to obtain samples (910 trap nights).

When trapping began on the assessment lines, capture locations of all animals previously captured on the grid were recorded. These animals were recorded as "marked" and the ratio of marked animals to total captures on assessment lines was used to estimate population size. Density was calculated by dividing the population size by the area of effect of marked animals on the assessment lines. Thus:

$$A = L_w L_l + 2 L_l W_a + \pi r^2$$

Where: A = area of rodent captures,
 L_w = width of grid,
 L_l = length of grid,
 W_a = width of area of effect (distance from edge of grid to farthest capture point of rodents on assessment lines), and
 r = W_a plus one half of L_w .

The estimate of the number of animals captured within the area of effect (N_a) was calculated by:

$$N_a = N_g / R_p$$

where: N_g = the total number of animals marked on the grid and
 R_p = the ratio of marked rodents (M) to the total number of rodents (T), marked and unmarked, caught on the assessment lines ($R_p = M/T$) (O'Farrell et al., 1977).

Only the first capture was used to determine W_a for rodents caught more than once on the assessment lines. Rodent density was estimated by N_a/A .

Rodents were collected at the last trapping session and, with those that died during previous trapping, were analyzed for radionuclide contamination. Small mammals were placed in plastic vials and analyzed for gamma emitting radioisotopes on a 65 cm³ germanium lithium crystal coupled to a computerized multichannel analyzer. Carcass and gut-hide samples from these rodents will be oven dried and submitted to a commercial laboratory for transuranic element (Pu, Am, Cm) determinations.

Student's t-test was used to statistically compare species home range sizes and radionuclide concentrations in rodents trapped inside and outside of the waste area boundary. Significance was set at $P < 0.05$.

Figure 1. Trap grid and line configuration at the Test Reactor Area radioactive leaching ponds.

Figure 2. Assessment line configuration at the Test Reactor Area radioactive leaching ponds.

RESULTS

Deer mice (*Peromyscus maniculatus*), Ord's kangaroo rat (*Dipodomys ordii*), western harvest mouse (*Reithrodontomys megalotis*), Great Basin pocket mouse (*Perognathus parvus*), northern grasshopper mouse (*Onychomys leucogaster*), montane vole (*Microtus montanus*) and least chipmunk (*Eutamias minimus*) occurred on the study and control areas.

Although 92 different rodents of four species were trapped and marked during this study, we calculated only movement data for individual rodents captured five or more times (21 animals). The maximum distance traveled between consecutive captures for kangaroo rats and deer mice was 201 m by a female deer mouse. Female deer mice traveled significantly further ($P < 0.05$) than male deer mice or kangaroo rats (no females were captured) (Table 1). Movements into and out of the TRA pond boundaries were documented for 14 of the 21 rodents captured multiple times. Eight rodents traveled 100 m or more between consecutive captures.

Table 1. Ranges and mean distance traveled between consecutive captures of rodents at the TRA pond area during summer 1981.

Measurement	Deer Mouse			Kangaroo Rat
	Male (n = 13)	Female (n = 5)	Both Sexes (n = 18)	Male ^a (n = 3)
<hr/>				
Distance Between Capture				
Range (m)	7 - 143	40 - 201	7 - 201	20 - 112
$\bar{X} \pm SD$ (m)	35 $\pm$ 23	62 $\pm$ 20	42 $\pm$ 25	37 $\pm$ 21

^aNo females captured.

Densities and population numbers were estimated for four species of TRA pond rodents (Table 2). Deer mice had the highest population estimates followed by Great Basin pocket mice, western harvest mice, and kangaroo rats. Sex ratios (number of males/female) were 2.3 for deer mice, 4.0 for pocket mice, 0.6 for harvest mice, and unknown for kangaroo rats. Density and population estimates from two grid and assessment line trapping sessions were averaged. A population of 93 small mammals, representing four species, was estimated to occur within the 5.6 ha area of rodent captures at the TRA pond which included a radius of about 60 m outside of the TRA pond fence.

Table 2. Population and density estimates of small mammals^a at the TRA pond during summer 1981.

Species	Population	Density (#/ha)
Deer mouse	57	10.2
Great Basin pocket mouse	17	3.0
Western harvest mouse	15	2.7
Kangaroo rat	4	0.7
Total	93	16.6

^aLeast chipmunks and montane voles were also captured but not in sufficient numbers to estimate population or density.

Radionuclides detected in rodents captured inside the pond area were ¹³⁷Cs, ¹³⁴Cs, ⁶⁰Co, and ⁶⁵Zn, with ¹³⁷Cs and ⁶⁰Co contributing 60 and 25%, respectively, of the total gamma-emitting radionuclide concentrations. Rodents captured outside of the fence had ¹³⁷Cs, ¹³⁴Cs, ⁶⁰Co, and ²¹⁴Pb in tissues. Cesium 137 and ⁶⁰Co made up 33 and 19% of the total concentration in animals outside the fence. Cesium 137 was the only nuclide detected in control rodents. Gamma-emitting radionuclide concentrations for deer mice, harvest mice, pocket mice and kangaroo rats captured inside the TRA pond fence averaged 133 ± 97 (SD) pCi/g (N = 25) with a range of 4-430 pCi/g. These species had significantly lower ($P < 0.05$) radionuclide concentrations when captured outside of the TRA pond fence (18 ± 22 (N = 21) pCi/g, range 1-97 pCi/g). Control rodents (N = 37) had average radionuclide concentration of 0.5 ± 0.6 pCi/g and ranged from nondetectable to 2 pCi/g.

Transport of radionuclides from the TRA pond site was determined by multiplying the average radionuclide concentration by the average weight and the estimated population size for four small mammal species inside the TRA fence during the summer of 1981 (Table 3). A total of 162 nCi of radioactivity could be transported out of the TRA ponds by small mammals residing inside the pond area. This estimate does not include least chipmunks (n = 5) and montane voles (n = 1). It appears that these two species did not occur in high enough numbers within the TRA pond area (all but 1 chipmunk were trapped outside of the waste area fence) to remove a significant amount of radioactivity.

Table 3. Inventory of gamma emitting radioactivity^a for small mammals at the TRA ponds.

Species	Average Inventory (nCi)
Deer mouse	123
Western harvest mouse	25
Great Basin pocket mouse	13
Kangaroo rat	1
Total	162

^aAverage radionuclide concentration (nCi/g) x average weight (g) x population estimate from Table 2.

DISCUSSION

Movement by small mammals at the TRA ponds and other radioactive waste management areas is important because of the potential removal of contamination from waste areas. Extensive linear movement would increase the likelihood of removal of radioactivity from a waste management area by small mammals. Deer mice exhibited similar linear movement at the TRA ponds and the Subsurface Disposal Area (SDA), another waste management complex on the INEL (Groves, 1981). Linear movement data (Table 1) suggests that although some small mammals may travel nearly 200 m away from the pond area, about 70% of the linear movement is less than 50 m.

Female deer mice had linear movements significantly greater ($P < 0.05$) than male deer mice. These results are contradictory to those reported by Groves (1981) and Brant (1962). The amount of usable habitat in our study area may have made it necessary for females to disperse to surrounding sagebrush areas to find a suitable area to have young. However, the difference is likely a sampling artifact since there was no difference ($P > 0.05$) in home range between male and female deer mice (Table 1).

Deer mouse densities at the TRA ponds were similar to those determined at the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) (Groves, 1981). The density of all rodent species at TRA was lower than at SDA (Table 2) partly because we did not census all species. Also habitat differences between the two areas is a factor influencing the rodent populations and densities. However deer mice populations may vary by factors of two or three from year-to-year, and by as much as a factor of 10 (Sadler, 1965).

Radionuclides at the TRA ponds can potentially be removed by small mammals. Radionuclide concentrations in small mammals known to inhabit the TRA ponds were about 7 times greater than radionuclide concentrations in small mammals captured consistently outside of the fenced waste area (Table 3) and 1.6×10^4 times greater than control rodents ($\bar{X} = 0.01$ nCi). Based on the assumption that the entire small mammal population leaves the TRA pond area, small mammals may remove approximately 160 nCi of gamma emitting radionuclides from the TRA ponds (Table 3) per year. This compares to migratory waterfowl which were estimated to remove 1×10^6 nCi of radionuclides from the TRA ponds per year (Halford et al., 1981). Thus, the potential removal of radioactive material from TRA is much less for the small mammal population. Rodents inside the TRA waste boundary were limited in their movement away from TRA vicinity by man-made barriers such as roads, excavation and water (Fig. 2).

Gamma contamination of higher trophic levels that consume rodents at the TRA has been shown to be insignificant (< 100 pCi/g whole body for raptors and < 30 pCi/g feces for coyotes (*Canis latrans*)) (Craig et al., 1979; Arthur and Markham, 1982). Rodent density and movement do not appear to be important factors in the removal of gamma emitting isotopes

from the TRA pond waste management area. Additional data will be available to determine concentration and to estimate the transport rate of transuranics by small mammals at TRA. Radiotelemetry, if feasible, is recommended to determine more precise movements of small mammals at the TRA ponds and similar waste disposal areas.

LITERATURE CITED

- Arthur, W. J. and O. D. Markham. 1982. Radionuclide export and elimination by coyotes at two radioactive waste disposal areas in southeastern Idaho. *Health Physics* 43:493-500.
- Batchelder, H. M. 1981. Radioactive waste management information for 1980. IDO Rep.10055(80). 273 p.
- Brant, D. H. 1962. Measures of movements and population densities of small rodents. *Univ. Calif. Publ.* 62: 105-184.
- Craig, T. H., D. K. Halford and O. D. Markham. 1979. Radionuclide concentrations in nestling raptors near nuclear facilities. *Wilson Bull.* 91:72-77.
- Groves, C. R. 1981. The ecology of small mammals on the Subsurface Disposal Area, Idaho National Engineering Laboratory Site. M. S. Thesis, Idaho State Univ. 81 pp.
- Halford, D. K. and O. D. Markham, 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. *Ecology* 59:1047-1054.
- Halford, D. K., O. D. Markham and J. B. Millard. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. *Health Physics* 40:173-181.
- O'Farrell, M. J., D. W. Kaufman and D. W. Lundahl. 1977. Use of live trapping with the assessment line method for density estimation. *J. Mammal.* 58:575-582.
- Sadler, R. M. 1965. The relationship between agonistic behavior and population changes in deer mice, Peromyscus maniculatus (Wagner). *J. Anim. Ecol.* 34:331-352.

IODINE-129 IN MUSCLE OF WATERFOWL USING THE
TEST REACTOR AREA RADIOACTIVE LEACHING
PONDS IN SOUTHEASTERN IDAHO

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ABSTRACT

Waterfowl were collected at the Test Reactor Area (TRA) radioactive leaching pond, and TRA sewage lagoon on the Idaho National Engineering Laboratory Site and nearby control areas to determine $^{129}\text{I}/^{127}\text{I}$ atom ratios in muscle tissue. Iodine-129/127 atom ratios in muscle tissue ranged from 1.5×10^{-7} to 3.8×10^{-6} and averaged about 1.6×10^{-6} for waterfowl from the TRA pond; 2.8×10^{-7} to 4.6×10^{-6} and averaged 1.6×10^{-6} for waterfowl from the TRA sewage pond, and; 4.6×10^{-7} to 3.1×10^{-6} and averaged 1.3×10^{-6} for control samples. Iodine-129/127 atom ratios were statistically higher ($P = 0.05$) for a group of commercially raised ducks placed on the ponds for experimental purposes. Internal wholebody dose to waterfowl from ^{129}I was estimated to be 1.0×10^{-5} mrad for waterfowl from control areas and 3.0×10^{-5} mrad for TRA pond waterfowl. The thyroid dose commitment to man consuming a duck from the TRA ponds was 1.0×10^{-4} mrem. Liquid effluents from the TRA radioactive leaching ponds do not appear to cause an appreciable increase in $^{129}\text{I}/^{127}\text{I}$ atom ratios in tissues of waterfowl using the ponds.

INTRODUCTION

Iodine-129 is a naturally occurring radioisotope, with a radioactive half-life of 1.6×10^7 years; thus, this radioisotope can be considered a permanent component of the environment (Soldat, 1974; Markham et al., in press). The majority of ^{129}I currently in the environment resulted from fission of ^{235}U and ^{239}Pu during atmospheric nuclear weapons testing programs and nuclear fuel reprocessing (Fraley et al., 1982).

The effect of airborne ^{129}I releases on thyroid $^{129}\text{I}/^{127}\text{I}$ atom ratios in a variety of mammalian species has been documented (Boulos et al., 1973; Palms et al., 1975; Ballard et al., 1976; Fraley et al., 1982; Markham et al., in press). Data on ^{129}I uptake are limited to indigenous and relatively unmobile species (Klepper et al., 1976). Birds are highly mobile and could potentially move radionuclides from contaminated sites into surrounding areas (Straney et al., 1975). Waterfowl are of primary concern because of their migratory behavior and use as a recreational and food source by man (Halford et al., 1981). Waterfowl use a liquid radioactive waste disposal area on the Idaho National Engineering Laboratory which contains ^{129}I . Therefore, a study was conducted at a liquid radioactive waste disposal pond on the Idaho National Engineering Laboratory (INEL) to determine the $^{129}\text{I}/^{127}\text{I}$ atom ratios and ^{129}I concentrations in waterfowl muscle and to determine the resultant wholebody dose to waterfowl and thyroid dose to man consuming ^{129}I contaminated waterfowl.

MATERIALS AND METHODS

Muscle tissues were obtained from ducks collected with shotguns from 1975 through 1981. Control waterfowl were collected at Mud Lake and the Little Lost River, Idaho which are 60 km northeast and 40 km northwest, respectively, of the Test Reactor Area (TRA) facilities on the INEL. TRA radioactive leaching ponds have been used for the disposal of low-level liquid radioactive wastes since 1954 and were considered the major source term of ^{129}I in waterfowl on the INEL. The waste consists primarily of activation and fission products of which about $1.1 \times 10^{-8}\text{Ci/yr}$ is ^{129}I (Batchelder, 1981). Seventeen commercially raised mallards (Anas platyrhynchos) were placed on the TRA Ponds for 2 to 156 days as part of a concurrent study, and muscle samples were obtained from these birds. Wild waterfowl were also collected from the TRA pond and from a nonradioactive sewage lagoon 100 m north of the TRA ponds.

Waterfowl were dissected under a hood and dissecting tools were changed between dissections to reduce cross-contamination. Muscle samples were placed in 80 ml plastic vials and dried for 6 days at 28°C . Samples were then sent to Battelle Pacific Northwest Laboratories, Richland, Washington for ^{129}I analyses. Activation analysis of muscle samples was used to determine ^{129}I and ^{127}I concentrations (Brauer and Tenney, 1975). The sample was weighed and placed in a quartz combustion tube with quartz wool plugs at both ends. The sample was spiked with ^{125}I which was used to estimate the procedure yield. Dry oxygen was passed through the sample at 1 l/min and the sample ignited with a hand torch. The off gases were passed through a furnace at 1000°C and then into an activated carbon adsorber. The iodine was transferred from the first carbon adsorber to a small adsorber by combustion. The adsorber was then sealed and evacuated in a vacuum pump. The adsorber was heated to 1000°C to transfer iodine into a sealed quartz ampoule. The quartz ampoules were irradiated with reactor neutrons for 8 to 24 hours. Following irradiation, the ampoules were cleaned, frozen with liquid nitrogen and crushed into a reaction vessel containing H_2SO_4 solution of iodine and bromine carriers and $\text{Na}_2\text{S}_2\text{O}_5$. Excess SO_2 was removed by spraying with nitrogen. The bromide and iodide ions were oxidized with KMnO_4 . Iodine was distilled from the reaction vessel into a $\text{Na}_2\text{S}_2\text{O}_5$ solution and further purified by oxidation with H_2O_2 and extraction into CCl_4 and back extraction with $\text{Na}_2\text{S}_2\text{O}_5$ solution. The iodine was precipitated as AgI and mounted on plastic scintillators for counting by low-level gamma-ray coincidence spectrometry of ^{125}I , ^{126}I , ^{128}I and ^{130}I . Data were computer analyzed to determine the concentrations of ^{127}I and ^{129}I . The detection limit for ^{129}I was about 4×10^{-6} pCi per sample yielding 10^8 atoms of ^{129}I .

Procedures outlined by the International Commission on Radiological Protection (ICRP, 1959) were used to determine whole body radiation doses from ^{129}I to waterfowl after they left the contaminated area. Procedures established by the Nuclear Regulatory Commission were used to determine thyroid dose to man from ^{129}I (Hoenes and Soldat, 1977). Data were analyzed with a one-way analysis of variance and Duncan's

multiple range test. A regression analysis was performed to determine if a relationship existed between atom ratios and the time experimental mallards spent on the ponds. Significance level for statistical tests was set at $P < 0.05$.

RESULTS AND DISCUSSION

Forty-four waterfowl were collected and analyzed for $^{129}\text{I}/^{127}\text{I}$ atom ratios in muscle tissue. Seventeen experimental mallards and 16 wild waterfowl consisting of lesser scaup (*Aythya affinis*), bufflehead (*Bucephala albeola*), mallard, green-winged teal (*Anas crecca*), pintail (*Anas acuta*), common goldeneye (*Bucephala clangula*) and American coot (*Fulica americana*) were collected from the TRA ponds. One mallard and three green-winged teal were collected from the TRA sewage lagoon. The 7 control samples consisted of mallards, widgeon (*Anas americana*), shoveler (*Anas clypeata*) and green-winged teal. Six experimental and one wild waterfowl muscle samples were eliminated from the sample size since stable iodine (^{127}I) could not be adequately determined making the counting errors higher (F. Brauer, PNL, personal communication).

Iodine- $^{129}/^{127}$ atom ratios were significantly ($P < 0.05$) higher in experimental waterfowl muscle than all other groups (Table 1). The mean iodine atom ratios for waterfowl from the sewage pond, leaching pond (wild waterfowl) and control areas were not statistically different ($P > 0.05$). Since some of the experimental mallards spent a considerable time (2-156 days) on the ponds, the high atom ratios were not unexpected. However, there was no correlation ($r_{16, 0.05} = 0.35$, $P > 0.05$) between time ducks spent on the radioactive leaching ponds and the iodine atom ratios. Waterfowl reach equilibrium with iodine in the pond environment in about 2 weeks and additional time does not significantly increase the iodine body burdens (Halford et. al, in press). Our observations indicated that the radioactive leaching ponds were used by waterfowl as a resting area (Halford et. al, 1981; Halford et. al, 1982). Consequently, waterfowl spent a limited period (usually 3 days or less) in contact with the radioactively contaminated environment.

Iodine atom ratios from TRA birds muscle (Table 1) were lower than those found in muscle samples from deer (*Odocoileus* spp), jack rabbit (*Lepus* spp) and goldfish (*Cyprinus* spp) collected at ^{129}I release sites in Washington and New York (Klepper et al., 1976). Iodine ratios for these species were a factor of 10 to 100 greater than Idaho waterfowl atom ratios. Snails (Gastropods) from waste ponds at the Hanford Site, Washington had atom ratios a factor of 100 greater than those in waterfowl from Idaho (Klepper et al., 1976). Rabbit (*Lepus* spp. and *Sylvilagus* spp) thyroids collected on the INEL had maximum $^{129}\text{I}/^{127}\text{I}$ atom ratios of 9.1×10^{-4} , and thyroids from control rabbits were below detection limits for ^{129}I (Fraley et al., 1982).

Table 1. $^{129}\text{I}/^{127}\text{I}$ atom ratios in waterfowl muscle samples from control areas, Test Reactor Area sewage pond and Test Reactor Area radioactive leaching ponds.

Location	N	$^{129}\text{I}/^{127}\text{I}$ Atom Ratio	
		$\bar{X} \pm \text{SD}$	Range
TRA Sewage Pond	4	$1.6 \times 10^{-6} \pm 2.0 \times 10^{-6}$	$2.8 \times 10^{-7} - 4.6 \times 10^{-6}$
Control	7	$1.3 \times 10^{-6} \pm 9.9 \times 10^{-7}$	$4.6 \times 10^{-7} - 3.1 \times 10^{-6}$
TRA Leaching Pond			
wild waterfowl	15	$1.6 \times 10^{-6} \pm 1.4 \times 10^{-6}$	$1.5 \times 10^{-7} - 3.8 \times 10^{-6}$
experimental waterfowl	14	$6.0 \times 10^{-6} \pm 2.1 \times 10^{-6}$	$3.0 \times 10^{-6} - 1.1 \times 10^{-5}$

Total whole body doses from ^{129}I in muscle tissue averaged 3.0×10^{-5} mrad for wild waterfowl from the TRA ponds, 1.4×10^{-5} mrad for waterfowl from the lagoon, and 1.0×10^{-5} mrad for waterfowl from control areas. The wholebody doses for wild and experimental waterfowl were a factor of 20,000 to 80,000 less than the average thyroid dose rates determined for rabbits (Fraley et al., 1982) collected within 10 km of the Idaho Chemical Processing Plant. The average dose rate from background terrestrial and cosmic radiation on the INEL was 117 mrad (USD0E, 1982). Thus, it is unlikely that ^{129}I muscle concentrations in waterfowl using the TRA ponds would result in detectable radiation hazards.

Waterfowl from the TRA ponds move to areas near the INEL where they could be harvested by hunters and consequently provide dose to man. The lifetime thyroid dose commitment to man due to ^{129}I from consuming one contaminated waterfowl would be 1.0×10^{-4} mrem. Dose from consuming a single control duck was 2.6×10^{-5} mrem. The ICRP (ICRP, 1959) recommends that a maximum thyroid dose commitment to an individual in the general population should not exceed 1500 mrad/yr. Thus, recommended thyroid dose commitments are nearly 2×10^7 times the estimated thyroid doses. Therefore, the potential thyroid dose to hunters from consuming TRA pond waterfowl is well below ICRP standards.

This study documents that waterfowl may remove ^{129}I from a radioactive waste disposal pond and provide a radiation dose to man. The amount of ^{129}I removed by waterfowl from TRA is similar to levels in waterfowl from off-site areas and the potential dose to man appears minimal. Thus, removal of ^{129}I from the TRA waste ponds does seem not to be an important source of ^{129}I contamination at this time. However, due to the longevity of ^{129}I , it may be an important environmental contaminant in the future and continued monitoring may be necessary.

LITERATURE CITED

- Ballad, R. V., D. W. Holman, E. W. Hennecke, J. E. Johnson, O. K. Manuel, and L. M. Nicholson. 1976. Iodine-129 in thyroids of grazing animals. Health Physics 30: 345-350.
- Batchelder, H. M. 1981. Radioactive waste management information for 1980. Idaho Oper. Rep. IDO-10055(80): 273 p.
- Boulos, M. S., V. J. Becker, and O. K. Manuel. 1973. Iodine-129 in thyroid glands. Health Physics 24: 375-378.
- Brauer, F. P., and H. Tenney, 1975. ¹²⁹I analysis methodology. Battelle Northwest Laboratories Rep. BNWL-SA-5287. 36 p.
- Fraley, L., G. C. Bowman, and O. D. Markham. 1982. Iodine-129 in rabbit thyroids near a nuclear fuel reprocessing plant in Idaho. Health Physics 43:252-258.
- Halford, D. K., J. B. Millard, and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. Health Physics 40: 173-181.
- Halford D. K., O. D. Markham, and R. L. Dickson. 1982. Radiation doses to waterfowl using a liquid radioactive waste disposal area. J. Wildl. Manage. 46: 905-914.
- Halford, D. K., Markham, O. D. and G. C. White. In press. Biological elimination rates of radioisotopes by mallards contaminated at a liquid radioactive waste disposal area. Health Physics.
- Hoenes, G. R., and J. K. Soldat. 1977. Age - specific radiation dose commitment factors for a one-year chronic intake. NUREG-0172. 103 p.
- International Commission on Radiological Protection. 1959. Permissible doses for internal radiation, publication 2. Pergamon Press, London. 233 p.
- Klepper, B., D. G. Watson and H. A. Sweany. 1976. Iodine-129 concentration in plant and wildlife samples collected on the Hanford Reservation and near the Nuclear Fuels Service Plant. P. 178-182 in Pacific Northwest Laboratory Annual Report for 1975 to the USERDA Division of Biomedical and Environmental Research. BNWL-2000 PT2.
- Markham, O. D., T. E. Hakonson, F. W. Whicker, and J. S. Morton. In press. Iodine-129 in mule deer thyroids in the Rocky Mountain West. Health Physics.

- Palms, J. M., V. R. Veluri, and F. W. Boone. 1975. The environmental impact of ^{129}I released by a nuclear fuel-reprocessing plant. Nuclear Safety 16 :593-602.
- Soldat, J. K. 1974. Environmental behavior and radiation doses from Iodine-129. BNWL-SA-4879, Pacific Northwest Laboratories, Battelle Memorial Institute Richland, WA.
- Straney, D. O., B. Beaman, I. L. Brisbin, Jr., and M. H. Smith. 1975. Radiocesium in birds of the Savannah River Plant. Health Physics 28:341-345.
- U.S. Department of Energy. 1982. 1981 environmental monitoring program report for Idaho National Engineering Laboratory Site IDO-12082 (81). 40 p.

A SURVEY AND ASSESSMENT OF THE RARE VASCULAR
PLANTS OF THE IDAHO NATIONAL ENGINEERING
LABORATORY

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ABSTRACT

In 1973, when the Endangered Species Act was passed, all federal agencies were required to consider in their management plans all species listed by the U.S. Fish and Wildlife Service in their reviews of species considered for endangered and threatened status. In 1981, the Department of Energy contracted with the University of Idaho for a survey of rare plants on the Idaho National Engineering Laboratory site in southeastern Idaho. After one field season two taxa currently under federal review for endangered or threatened status, three taxa on the state watch list, and one taxon previously unknown to occur in Idaho were found. Populations of these taxa were surveyed, whenever possible collections were made, and actual and potential threats were evaluated.

INTRODUCTION

An increasing focus on conservation of natural diversity resulted in passage of the Endangered Species Act of 1973 (Public Law 93-205). As a direct result of this act, the Smithsonian Institution was charged with producing a list of plant species considered endangered or threatened in the U.S. As defined by the Smithsonian (Smithsonian Institution, 1975) endangered species are those in danger of extinction throughout all or a significant portion of their range because of fragile habitats, loss of habitat, exploitation, disease, or predation and also those species which are narrow endemics. Threatened species are those likely to become endangered in the foreseeable future. By law, all federal agencies are required to consider, in their management plans, those plants (or animals) considered endangered or threatened, or proposed for endangered or threatened status. This, however, requires accurate and up-to-date information on plants listed, proposed, or likely to be proposed for endangered or threatened status.

The initial Smithsonian list was refined by the Office of Endangered Species of the U.S. Fish and Wildlife Service and published in the Federal Register on July 1, 1975 and June 16, 1976. In 1977, the Rare Plants Technical Committee of the Idaho Natural Areas Council (INAC) published a summary of known information for 68 of the taxa on the federal list which were of special concern in Idaho (Henderson et al., 1977). Based on intensive field work and searches of regional herbaria, it became clear that more data were required before an accurate recommendation of status could be given for several of the taxa listed, as well as for some taxa which had not been initially considered.

Under the provisions of the Endangered Species Act, all plant species proposed for federal endangered or threatened status were withdrawn in November of 1979, since the law required a 2 year limit on proposed listings. The taxa were then resubmitted or rejected based on new data. In the December 15, 1980 issue of the Federal Register, the U.S. Fish and Wildlife Service published its revised review of plant taxa. This listing is their current evaluation of: 1) taxa considered endangered or threatened, 2) taxa proposed for such status, 3) taxa for which sufficient information exists to support their being repropoed but which are under review pending new information (federal category 1), 4) taxa for which current information indicates probable reproposal but which are under review due to insufficient data (federal category 2), and 5) those taxa no longer considered because of recent data or because of extinction.

The INAC also updated its evaluations of rare plants in Idaho (Rare and Endangered Plants Tech. Comm., 1981). In this revision, taxa of special concern are listed in one of the following categories: 1) federally endangered or threatened--as listed in the Federal Register with recommendations on status consideration, 2) federal watch list--a state-generated list of Idaho's endemic or near-endemic taxa which are not in jeopardy now but which could become jeopardized should land practices change, 3) state endangered or threatened--taxa which are in jeopardy only within the political boundaries of Idaho, and 4) state watch list--taxa which are rare and of special interest but which are not in jeopardy and may be common elsewhere. This last category represents genotypes which may be of importance as populations on the edge of a species' range and which may, therefore, be subject to different selection pressures. Their loss would represent a loss of natural diversity.

Since two of Idaho's "taxa under current federal review" were known to occur either on the Department of Energy's Idaho National Engineering Laboratory (INEL) site, or on lands immediately adjacent, it was important to document their on-site status and to search for other taxa of concern which might be present. In late 1980, therefore, the Department of Energy contracted the University of Idaho to perform a two year survey of rare plants on the INEL.

Although several environmental studies had been initiated on the INEL, few dealt directly with the station's flora. A vegetational transect survey was begun in 1950, continued for several years (Harniss and West, 1973), and was reevaluated in 1975 (Anderson and Holte, 1981). Data from these surveys were used in part towards developing a description of the INEL flora in 1968 and 1969 (Atwood, 1970) and again in 1976 and 1977 (Jeppson and Holte, 1978). However, both of these floristic surveys were superficial, providing only one or two general collection locations without further clues to a species' local abundance or any indication of habitat requirements on the INEL site. It was clear that, at least for plants considered rare, more work was needed.

STUDY AREA

The 231,600 ha (500,000 acres) of the INEL site are located on the eastern end of the basaltic Snake River Plain. On the site, this predominantly level plain rises to an average elevation of 1,525 m. It is interrupted by two volcanic buttes near the southern boundary rising to 1,993 m., and on the northern boundary by the southernmost end of the Lemhi Mountains which here rise to 1924 m. The vegetation is cold-desert typical of the Great Basin region, dominated in varying amounts by big sagebrush, Artemisia tridentata; green rabbitbrush, Chrysothamnus viscidiflorus; bluebunch wheatgrass, Agropyron spicatum; and Indian ricegrass, Oryzopsis hymenoides. A history of fires and past grazing has played a role in the presence of needle-and-thread, Stipa comata; squirreltail, Sitanion hystrix; halogeton, Halogeton glomeratus; and Russian thistle, Salsola kali on certain portions of the site.

Soils on the site are variable and reflect past geologic history. The southwestern portion is covered by fairly recent basalt flows, with or without some clay and/or sand deposition. The central and eastern sector is primarily playa sediments of prehistoric Lake Terreton or aeolian or alluvial sands. The northeastern area is a complex mixture of volcanic deposition, glacial debris, and Lake Terreton playas. For a more nearly complete description of the INEL soils see McBride et al., 1978.

MATERIALS AND METHODS

Before the on-site search for rare plants began, it was necessary to compile a list of those taxa evaluated for endangered or threatened status as listed in the revision of the INAC summary which were known to occur and which might occur on the INEL site. Many of the taxa listed in the INAC list are known or suspected to have rather narrowly defined habitats and; were located and searched, rather than randomly walking transects or setting plots. It was then necessary to gather data on habitat preferences and dates of flowering and fruiting so that the habitats could be searched at the appropriate time. Additionally, previous collections made on the INEL would be relocated and the populations evaluated.

The summary sheets from the 1981 INAC revision of rare plants were examined for this survey. From these, a list was made of taxa which were known from the site or within close proximity. Species were also considered if they were known to occur in the sagebrush zone of nearby counties. Since only the summary sheets were available for this pre-search, data regarding flowering time, details of habitat, and locations of collections nearest the INEL were gathered from herbarium specimens at the University of Idaho and later from the teaching collection in the Radiological and Environmental Sciences Laboratory on the INEL site. Jay Anderson of Idaho State University and Richard Jeppson of Pocatello High School also provided personal observations.

With a list of 22 plant taxa, the most recent vegetation map of the INEL (McBride et al., 1978) was studied to ascertain locations of likely habitats for these plants. During this first year of the rare plants survey, habitats in the northeastern half of the INEL site were intensively searched with occasional forays into the southern portion, which would be searched more intensively during the second field season. Upon encountering species of special concern, the following steps were taken:

1. careful observation of taxonomic characters to confirm tentative field identifications
2. detailed descriptions of the habitat were noted, including estimated coverages of community dominants, associated species, description of soils (texture, approximate depth, color, parent material), elevation, slope, aspect, and as precise a location as possible was indicated
3. estimates of population size and numbers of plants flowering or fruiting were made
4. apparent or potential threats were evaluated
5. photographs of distinguishing characteristics of the species, the plant(s) within its habitat, and an overall view of the habitat were made
6. collections of representative specimens, if population size allowed, were made (whenever possible, enough material was collected for deposition in the University of Idaho Herbarium, the Ray J. Davis Herbarium at Idaho State University, and the teaching collection at the Radiological and Environmental Sciences Laboratory on the INEL site).

Since nearly all of the taxa on our working list had early flowering times, the field study was conducted in late May and June. Towards the end of June, the vegetation was beginning to dry and almost all taxa of concern were beginning to fruit or were already in fruit. During the second field season (1982), these populations will be rechecked.

RESULTS AND DISCUSSION

Table 1 indicates those taxa which comprised the initial working list and their approximate locations (counties). Of these, only five were found on the INEL site during the first field season: two are on the federal list of "currently under review" and three on the state watch list. No taxa listed as endangered or threatened candidates at either the federal or state level were found. A sixth taxon, under federal review, previously was collected at a location just off the site, but could not be found this year. Additionally a seventh taxon, Astragalus kentrophyta var. jessiae, not on the initial list, was discovered and represents a significant range extension. It should be considered in further rare plant studies. Information on these seven species are listed below.

TABLE 1. Tentative species-of-concern list.

Species	Status List	INAC Recommended Status (for taxa of fed- eral concern)	Location (county)
1. <u>Allium anceps</u>	State threatened		Idaho, Twin Falls
2. <u>Antennaria arcuata</u>	Federal review (category 2)	Endangered	Blaine
3. <u>Artemisia papposa</u>	Federal watch		Blaine, Camas, Elmore, Gooding, Lincoln, Owyhee
4. <u>Astragalus aquilonius</u>	Federal watch		Butte, Custer, Lemhi
5. <u>A. atratus insepatus</u>	Federal review (category 1)	Threatened	Blaine, Camas, Lincoln
6. <u>A. ceramicus apus</u>	Federal review	Threatened	Bingham, Bonnevillle, Butte, Clark, Jefferson, Madison
7. <u>A. oniciformis</u>	Federal review (category 1)	Endangered	Blaine
8. <u>A. platytropis</u>	State watch		Butte, Custer, Lemhi
9. <u>A. purshii ophiogenes</u>	Federal review (category 2) and Federal watch	none	Ada, Canyon, Elmore, Gooding, Owyhee, Twin Falls
10. <u>Corypantha missouriensis</u>	State watch		Butte, Clark, Custer, Lemhi
11. <u>C. vivipara</u>	State watch		Ada, Cassia, Lemhi
12. <u>Cuscuta denticulata</u>	State watch		Clark
13. <u>Eatonella nivea</u>	State watch		Custer, Elmore, Owyhee
14. <u>Eriogonum shockleyi shockleyi</u>	State watch		Bannock, Owyhee
15. <u>Gymosteris nudicaulis</u>	State watch		Ada, Bingham, Butte, Canyon, Clark, Elmore, Gem, Gooding, Lincoln, Owyhee, Power, Twin Falls
16. <u>Lepidium davisii</u>	Federal review (category 1)	Threatened	Elmore, Owyhee, Twin Falls

TABLE 1. Continued

Species	Status List	INAC Recommended Status (for taxa of fed- eral concern)	Location (county)
17. <u>Oenothera psammophila</u>	Federal review (category 1)	Endangered	Fremont
18. <u>Oxytheca dendroidea</u>	State watch		Bingham, Butte, Elmore, Fremont
19. <u>Phacelia inconspicua</u>	Federal review (category 1)	Endangered	Butte
20. <u>Primula incana</u>	State threatened		Butte, Clark, Custer, Lemhi, Teton
21. <u>Stipa pinetorum</u>	State watch		Clark, Custer
22. <u>S. viridula</u>	State watch		Clark, Elmore, Owyhee

Taxa Under Current Federal Review

1. Astragalus ceramicus Sheld. var. apus Barneby (Leguminosae) (Fig. 1)

"Painted milkvetch" is a fairly small (1-3 dm), grayish perennial herb which is easily overlooked. Leaflets are often lacking, with the rachis elongate and flexuous. Racemes are 3-10 flowered with small (6-9 mm), pale lavender-yellow flowers which mature May through early June. The most distinguishing feature of this taxon is the red-and-yellow mottled, inflated pod.

Previously known as an inhabitant of dunes and sandy places (Hitchcock et al., 1961), this variety is endemic to the eastern end of the Snake River Plain where previous researchers have indicated little abundance (Andersen and Henderson, 1978; Reese, 1980; Packard, personal communication). In the north-central sector of the INEL site, this taxon generally forms large colonies and may even be a community dominant (Anderson et al., 1978). It is primarily limited to areas of moderate to deep sands in communities dominated by Oryzopsis hymenoides, Chrysothamnus viscidiflorus, Tetradymia canescens, and Stipa comata. Opuntia polyacantha, Agropyron dasystachyum, and Eurotia lanata are often abundant in the communities. Close associates include Lupinus pusillus, Mentzelia albicaulis, Astragalus geyeri, Eriogonum cernuum, E. ovalifolium, Gilia leptomeria, and Streptanthella longirostris. Psoralea lanceolata is a common associate on deep sand hills and Lygodesmia spinosa is common in the vicinity of Circular Butte. One population, in the sand dunes north of the intersection of Lincoln and Franklin, is associated almost exclusively with Salsola kali.

Figure 1. Astragalus ceramicus Sheld. var. apus Barneby (Leguminosae) collection locations on the Idaho National Engineering Laboratory.

Although many of the populations evaluated in this first field season had over 100 individuals, less than 20% were flowering or setting fruit. Several plants appeared to be first year plants and perhaps were a response to a wet spring. The second field season should help to achieve a better understanding of these populations.

A population, composed of only 15 individuals and growing in an atypical habitat, was discovered at the Howe burn site, scheduled for a controlled burn. The second season check of this population should provide some data on the relationship of this taxon to fire.

The major threat to this taxon is grazing by small mammals, most likely jackrabbits. In some places, especially the vicinity of Circular Butte, more than 50% of the plants had been grazed. Approximately 18% were almost completely eaten with only 2.5 to 5 cm of the plant remaining.

In habitats around the southern Lemhi Range livestock grazing does occur but as the cattle tend to congregate mainly in the Big Lost River Sinks, trampling damage caused by these animals is minimal. Should the grazing pressure be increased; however, damage caused by trampling would be a factor to be considered in the future management of this taxon.

The following locations represent populations surveyed by the investigators during this first field season. Exact locations can be obtained from the field notes of the investigators (on file at the University of Idaho Herbarium), herbarium collections, or the site map on file at the Radiological and Environmental Sciences Laboratory.

A. F. Cholewa 591	T6N R30E S25 SW1/4 of NW1/4; 26 May 1981
A. F. Cholewa 602	T6N R30E S35 SE1/4 of NE1/4; 27 May 1981
A. F. Cholewa 608	T6N R32E S26 SW1/4 of NE1/4; 29 May 1981
A. F. Cholewa 615	T5N R31E S15 S1/2 of NW1/4; 30 May 1981
A. F. Cholewa 617	T6N R30E S34 N1/2 of NW1/4; 30 May 1981
A. F. Cholewa 625	T6N R30E S23 SE1/4 of SE1/4; 30 May 1981
A. F. Cholewa 649	T5N R31E S16 NE1/4 of SW1/4; 3 June 1981
A. F. Cholewa 652	T6N R31E S34 SW1/4 of SW1/4; 3 June 1981
A. F. Cholewa 653	T6N R32E S13 SE1/4 of SW1/4; 3 June 1981
A. F. Cholewa 655	T6N R32E S24 W1/2 of NW1/4; 4 June 1981
A. F. Cholewa 660	T6N R32E S35 NW1/4 of NE1/4; 4 June 1981
A. F. Cholewa 663	T6N R32E S36 SW1/4 of NW1/4; 4 June 1981
A. F. Cholewa 665	T6N R33E S31 SW1/4 of SW1/4; 4 June 1981
(no collection made)	
A. F. Cholewa 678	T5N R33E S25 SW1/4 of SW1/4; 5 June 1981
A. F. Cholewa 679	T6N R31E S36 center NW1/4; 6 June 1981
A. F. Cholewa 683	T6N R31E S25 NE1/4 of SE1/4; 6 June 1981
A. F. Cholewa 689	T4N R29E S 9 SW1/4; 6 June 1981
A. F. Cholewa & D. M. Henderson 693	T6N R30E S23 NE1/4 of SW1/4; 7 June 1981
A. F. Cholewa 706	T6N R30E S23 center NE1/4; 9 June 1981
A. F. Cholewa 710	T5N R31E S20 SE1/4 of NW1/4; 10 June 1981
A. F. Cholewa 713	T5N R31E S16 NW1/4 of NW1/4; 10 June 1981
A. F. Cholewa 734	T6N R30E S35 N1/2 of SW1/4; 12 June 1981
A. F. Cholewa 740	T6N R30E S15 SW1/4 of NE1/4; 14 June 1981
A. F. Cholewa 752	T6N R32E S36 NW1/4 of NE1/4; 15 June 1981
A. F. Cholewa 755	T6N R33E S19 SE1/4 of SW1/4; 15 June 1981
A. F. Cholewa 756	T6N R33E S19 NE1/4 of NW1/4; 15 June 1981
A. F. Cholewa 760	T6N R31E S18 NE1/4 of NW1/4; 16 June 1981
A. F. Cholewa 763	T6N R33E S 6 NE1/4 of NE1/4; 16 June 1981
A. F. Cholewa 764	T6N R33E S 6 SW1/4 of SE1/4; 16 June 1981
A. F. Cholewa 766	T6N R33E S 7 W1/2 of NW1/4; 16 June 1981
A. F. Cholewa 771	T5N R30E S12 NW1/4 of SW1/4; 17 June 1981
A. F. Cholewa 774	T5N R31E S 3 center SE1/4; 17 June 1981
A. F. Cholewa 824	T5N R31E S15 SE1/4 of NE1/4; 23 June 1981
A. F. Cholewa 835	T6N R32E S 3 NE1/4 bordering S34; 25 June 1981
A. F. Cholewa 838	T5N R32E S 1 SW1/4 of NW1/4; 25 June 1981

2. Astragalus purshii Dougl. var. ophiogenes Barneby (Leguminosae) (Fig. 2).

"Woolly-pod milkvetch" is a cushion-like, taprooted perennial with a branched root crown. The pinnately compound leaves are crowded and distinctly densely woolly, with elliptic, oblong, or suborbicular leaflets. Racemes have 3-10 large (1-3 cm) flowers which appear April through early June. Pods are densely woolly. Three varieties occur on the INEL site, all in the sagebrush vegetation zone. Var. concinus has broadly suborbicular leaflets and slightly curved pods. Var. purshii has narrow, elliptic leaflets, nearly straight pods and yellow flowers while var. ophiogenes, with reddish-purple flowers, has fruits strongly bent at least 90° and often nearly 180°.

Figure 2. Astragalus purshii Dougl. var. ophiogenes Barneby (Leguminosae) collection location on the Idaho National Engineering Laboratory.

Although an inhabitant of the western half of the Snake River Plain, var. ophiogenes was not thought to occur with any great abundance (Hitchcock et al., 1961; Packard and Grimes, 1981). Only a few locations on the INEL were found this field season and these were mainly in communities of Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus, and either Agropyron dasystachyum or A. spicatum. Poa sandbergii and Sitanion hystrix are often abundant in these communities. Associates generally include Astragalus filipes, Phlox hoodii, Leptodactylon pungens, and Chaenactis douglasii. Astragalus calycosus was almost always present and usually in large numbers. These sites were always in areas of basalt outcrops with either extremely shallow soil or with calcareous playas.

Populations composed of forms intermediate between var. ophiogenes and var. purshii were also found but these occurred on slightly deeper soils with a higher amount of sand.

Nearly all of the populations located this first field season were in areas open to grazing but the rockiness of the terrain would limit trampling. The grazing value of this species is unknown and no grazing was apparent. The only damage which was observed was insect damage in the form of dense webbing.

A few other populations of Astragalus purshii were discovered, but as these contained individuals which were neither flowering nor fruiting, a complete identification could not be made. The following collections represent those populations identified as var. ophiogenes:

A. F. Cholewa 685	T6N R31E S14 SW1/4 of SW1/4; 6 June 1981
A. F. Cholewa 707	T4N R30E S 1 SW1/4 of SE1/4; 10 June 1981

A. F. Cholewa 730	T2N R30E S16 NW1/4 of SW1/4; 12 June 1981
A. F. Cholewa 767	T5N R31E S 6 NE1/4 of NW1/4; 17 June 1981
A. F. Cholewa 785	T2N R32E S20 NW1/4 of SE1/4; 18 June 1981
A. F. Cholewa 799	T4N R28E S35 NE1/4 of NW1/4; 21 June 1981
A. F. Cholewa 818	T4N R29E S19 SE1/4 border with S30; 23 June 1981

3. Phacelia inconspicua Greene (Hydrophyllaceae) (Fig. 3).

This phacelia is a small (0.5-2 dm), freely branching annual which is pubescent but not glandular. The leaves are simple, elliptic and entire margined. Flowers, the most distinguishing feature, are inconspicuous (3-4 mm) and pale blue, appearing in June.

Figure 3. Phacelia inconspicua Greene (Hydrophyllaceae) collection location on the Idaho National Engineering Laboratory.

This taxon is known from only two locations, one in the West Humboldt Mountains of Nevada and the other at Webb Spring on Big Southern Butte, just off the INEL (Cronquist et al., in manuscript). It is reported as occurring on the INEL site (Packard, 1981) but no data regarding this population have been examined. The habitat at Webb Spring is a rocky slope with the dominant plants being Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus, Artemisia arbuscula ssp. nova, and Poa sandbergii. Although this location was searched two times this year during the flowering period, no plants were discovered. It is possible that since this is an annual, not enough precipitation occurred for germination and growth.

A drainage on East Butte was searched as a potential habitat but no plants of this species were found. As this taxon is an annual and is not part of vegetational communities unless the proper growing conditions are

present, it will not necessarily be apparent every year. Because of this feature and because this taxon is a narrow endemic it is important that likely habitats be searched again during the next field season.

State Watch List

4. Coryphantha sp. (Cactaceae) (Fig. 4)

Coryphanthas are small (up to 6 cm), non-branched, pin-cushion cactuses. Several spines are produced from tubercles spirally arranged on the stem. The two species are distinguished primarily on the basis of flower color and fruits. C. missouriensis ("nipple coryphantha") has greenish-white flowers (appearing June to July) and short (under 1 cm) fruits, while C. vivipara ("cushion-coryphantha") has reddish-purple flowers which appear in May through June and fruits 1-2 cm long. As no flowers or fruits were present on those specimens discovered on the INEL site, species identification could not be made.

Figure 4. Coryphantha sp. (Cactaceae).

Both species occur in desert valleys and hillsides and are known from central Idaho, just to the north of the INEL (Hitchcock et al., 1961). Only one location on the site was found at the head of a small side canyon in the

southern Lemhi Range. Here the community was dominated by Juniperus osteosperma, Cercocarpus ledifolius, and Agropyron spicatum. Associates include Haplopappus acaulis, Phlox hoodii, and Poa sandbergii. This particular site was a small (perhaps 7.5 m across), open slope with the substrate composed of loose, limestone pebbles. The location of this population is as follows:

(no collection made)

T6N R30E S10 SW1/4 of SW1/4

No actual threats to this population were apparent but exploitation by cactus hunters may become a consideration in the future. Loss of habitat to erosion may also become a concern should the area be opened to mining, exploration or if livestock grazing were increased.

5. Gymnosteris nudicaulis (H. & A.) Greene (Polemoniaceae) (Fig. 5)

"Large-flowered gymnosteris" is a diminutive (2-10 cm), phlox-like annual, with either white or yellow flowers which mature May through June. It is easily distinguished by the nearly naked stem with a group of bract-like leaves closely subtending the flowers.

Figure 5. Gymnosteris nudicaulis (H. & A.) Greene (Polemoniaceae).

This species was generally known to occur on dry, sandy places throughout the western half of the Snake River Plain (Steele, 1981). Only four populations were found on the INEL site this year. Three were on a gravelly substrate and one on thin sandy-silt on the side of a volcanic cone. The communities were dominated by Artemisia tridentata ssp. wyomingensis and Poa sandbergii. Chrysothamnus viscidiflorus was also a dominant on the volcanic cone site. Bromus tectorum and Leptodactylon pungens were generally abundant. Associates included Oenothera andina, Cryptantha circumscissa, Phlox aculeata, and Mimulus nanus.

All locations were just inside the no-grazing boundary. Three of the populations were above the banks of the Big Lost River and could be subject to trampling damage should the grazing allotment be increased.

The major threat would appear to be loss of habitat due to gravel excavations. Most of the populations found during the 1981 season were on floodplain gravels and one was, in fact, adjacent to an active pit. Although these populations averaged 100 individuals, these are small annual plants which could be destroyed easily through disruption of habitat.

Collection locations:

A. F. Cholewa 634	T3N R29E S33 SW1/4 of NW1/4; 2 June 1981
A. F. Cholewa 644	T2N R29E S 5 center NW1/4; 2 June 1981
A. F. Cholewa 700	T3N R28E S 8 SW1/4 of SE1/4; 9 June 1981
A. F. Cholewa 717	T2N R28E S12 SE1/4 of NW1/4; 11 June 1981

6. Oxytheca dendroidea Nutt. (Polygonaceae) (Fig. 6)

This species is a small (1-3 dm), buckwheat-like annual. The simple leaves are all basal, green above and reddish below. Stems are dichotomously divergent, ending in an inflorescence of white to pink flowers (1 mm long) which begin to appear in late June. A distinguishing feature is the presence of awns on the lobes of the involucre.

This taxon is known to occur in shady areas within the sagebrush zone but its survival within Idaho is "tenuous" (Packard and Ertter, 1981). Nearly all of our collections on the INEL are located in communities dominated by Artemisia tridentata ssp. tridentata, Agropyron dasystachyum, Oryzopsis hymenoides, and Stipa comata. Opuntia polyacantha and Astragalus filipes usually are abundant. Associates vary but generally include Gilia leptomeria, Psoralea lanceolata and Eriogonum ovalifolium.

No apparent threats were observed other than a small amount of grazing by some rodent, perhaps rabbits. A few of the populations, however, were within 1.6 Km of the Special Power Excursion Reactor Test (SPERT) area and any increase in outside activity at this facility could disrupt this species' habitat.

Figure 6. Oxytheca dendroides Nutt. (Polygonaceae).

Collection locations:

A. F. Cholewa 806	T3N R30E S28 SE1/4 of NW1/4; 22 June 1981
A. F. Cholewa 810	T3N R30E S29 SE1/4 of NW1/4; 22 June 1981
A. F. Cholewa 812	T3N R30E S30 center S1/2; 22 June 1981
A. F. Cholewa 822	T4N R31E S 7 NW1/4 of NE1/4; 23 June 1981
A. F. Cholewa 823	T5N R31E S34 center SW1/4; 23 June 1981
A. F. Cholewa 827	T3N R28E S35 SW1/4 border with S36; 23 June 1981

Additional Noteworthy Taxa

7. Astragalus kentrophyta Gray var. jessiae (Peck) Barneby (Leguminosae) (Fig. 7)

"Thistle milkvetch" forms small (to 2 dm tall), greyish-green subshrubs with spiny-tipped leaves which are dissected into 5 to 11 leaflets. The yellowish flowers are small (4 - 8 mm) and inconspicuous in the leaf axils. It is distinguished from other varieties of this species by its yellow flowers and dense covering of two-branched hairs on stems and foliage.

Only two populations were discovered, both of which are on deep sands of dry washes at the southeastern base of the Lemhi Range. The plant communities are open and dominated by Juniperus osteosperma and Agropyron spicatum. Additional associates include Eriogonum ovalifolium, Hymenopappus filifolius var. idahoensis, and Arenaria franklinii.

Locations of this taxon are in areas open to grazing and, as indicated by the abundance of Stipa comata and Bromus tectorum in the vicinity, have received considerable grazing in the past. The habitat is rather vulnerable

Figure 7. *Astragalus kentrophyta* Gray var. jessiae (Peck) Barneby (Leguminosae).

to erosion induced via trampling and could be further degraded if grazing is increased or mining exploration is allowed. The role of disturbance in the life history of this plant, however, is not presently known.

Variety jessiae was known only from the Bruneau Desert vicinity of southwestern Idaho and adjacent Oregon, and from the Green River and Sweetwater River basins of southwestern Wyoming (Barneby, 1964). This taxon's occurrence in southeastern Idaho is significant and will be reported in an appropriate journal (Cholewa and Henderson, 1982). The specimen sent to the New York Botanical Garden was confirmed by Dr. R. C. Barneby.

Population locations:

A. F. Cholewa & D. M. Henderson 777	T6N R30E S23 center N1/2;
17 JUN 1981
A. F. Cholewa 740 (no specimen taken)	T6N R30E S15 sw1/4 of ne1/4;
14 JUN 1981

8. *Lesquerella kingii* S. Wats. var. cobrensis Roll. & Shaw^a

"King's bladderpod" is a spreading, prostrate, perennial herb with basal leaves abruptly tapered to the petiole. The small (5.5 - 10mm), yellow flowers are arranged in a raceme which elongates in fruit. Fruits provide the most distinguishing features in being slightly inflated, obcompressed, and indented at the tip.

^a NOTE: Since the original writing we received word from Barneby at the New York Botanical Garden that our specimens were var. jessiae. This var. was known in Idaho only from the Bruneau area and the rest disjunct in Green River Basin, Wyo.

Figure 8. Lesquerella kingii S.Wats. var. cobrensis Roll. & Shaw (Brassicaceae).

The species is a member of the Great Basin Flora and was not previously known from Idaho. Variety cobrensis, formerly known only from the Pequop Range in Elko Co., Nevada (Rollins & Shaw, 1973), was discovered in the southcentral part of the INEL site. Three small populations are known from open communities dominated primarily by Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus and Poa sandbergii. The Lesquerella is apparently restricted to shallow soils, either playa-like, or volcanic gravel, and has no close associates. The presence of this species on the INEL represents a significant range extension northeastward, constitutes a new record for the state, and will be reported in an appropriate journal (Cholewa and Henderson, 1982). Specimens sent to the Gray Herbarium at Harvard University were confirmed by Dr. Reed Rollins. Although occurring in an area open to grazing, the impact of livestock on this taxon are presently unknown. Cattle may be excluded, however, from some of its habitat simply by the rocky nature of the sites.

Population locations:

A. F. Cholewa 632	T2N R30E S22 SE1/4 of NE1/4; 1 June 1981
A. F. Cholewa 787	T2N R32E S21 SW1/4 of NW1/4; 18 June 1981
A. F. Cholewa 789	T2N R32E S7 SW1/4 of SW1/4; 18 June 1981

LITERATURE CITED

- Andersen, B. P. and D. M. Henderson. 1978. A survey of rare plants: Little Lost-Birch Creek planning units, Idaho Falls District, B.L.M. and University of Idaho, Moscow.
- Anderson, J. E., R. J. Jeppson, R. J. Wilkosz, G. M. Marlette, and K. E. Holte. 1978. Trends in vegetational development on the Idaho National Engineering Laboratory site. p. 144-146 In Ecological studies on the Idaho National Engineering Laboratory site, 1978 progress report. IDO-12087. Nat. Tech. Inf. Ser., Springfield, VA.
- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in Southeastern Idaho. *J. Range. Manage.* 34:25-29.
- Atwood, N. D. 1970. Flora of the National Reactor Testing Station. Brigham Young University Science Bull., Biol. Series 11(4). 46 p.
- Banreby, R. C. 1964. Atlas of North American Astragalus. Mem. New York Bot. Gard. 13 (part 1).
- Cholewa, A. F. and D. M. Henderson. 1982. Noteworthy collections of Idaho. *Madrono* 30:63-64.
- Cronquist, A., A. Holmgren, N. Holmgren, J. Reveal, and P. Holmgren. (in manuscript). Intermountain Flora. Hafner Publishing Co., Inc., New York.
- Harniss, R. O. and N. E. West. 1973. Vegetation patterns of the National Reactor Testing Station, southeastern Idaho. *Northwest Sci.* 47:30-43.
- Henderson, D. M., F. D. Johnson, P. Packard, and R. Steele. 1977. Endangered and threatened plants of Idaho: a summary of current knowledge. University of Idaho, Forest, Wildlife and Range Exp. Sta. Contr. No. 73.
- Hitchcock, C. L., A. Cronquist, M. Ownbey, and J. W. Thompson. 1961. Vascular Plants of the Pacific Northwest. Vol. 3. University of Washington Press, Seattle.
- Jeppson, R. J. and K. E. Holte. 1978. Flora of the Idaho National Environmental Laboratory site. p. 129-143 In Ecological studies on the Idaho National Engineering Laboratory site, 1978 progress report. IDO-12087. Nat. Tech. Inf. Ser., Springfield, VA.
- McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory site. IDO-12084. Nat. Tech. Inf. Ser., Springfield, VA.

- Packard, P. L. 1981. Phacelia inconspicua Greene. p. 33 In Vascular plant species of concern in Idaho (1981). University of Idaho, Forest, Wildlife and Range Exp. Sta. Bull. No. 34.
- Packard, P. L. and B. Ertter. 1981. Oxytheca dendroidea Nutt. p. 123 In Vascular plant species of concern in Idaho (1981). University of Idaho, Forest, Wildlife and Range Exp. Sta. Bull. No. 34.
- Packard, P. L. and J. Grimes. 1981. Astragalus purshii Dougl. var. ophiogenes Barneby. p. 46 In Vascular plant species of concern in Idaho (1981). University of Idaho, Forest, Wildlife and Range Exp. Sta. Bull. No. 34.
- Rare and Endangered Plants Technical Committee. 1981. Vascular plant species of concern in Idaho. University of Idaho, Forest, Wildlife and Range Exp. Sta. Bull. No. 34.
- Reese, R. N. 1980. A survey of rare plants: Big Lost and Mackay planning units, Idaho Falls District, B.L.M. University of Idaho, Moscow.
- Rollins, R. C. and E. A. Shaw. 1973. The genus Lesquerella (Cruciferae) in North America. Harvard Univ. Press, Cambridge.
- Smithsonian Institution. 1975. Report on endangered and threatened plant species of the United States. House Document 94-51. U.S. Government Printing Office, Washington, D.C.
- Steele, R. 1981. Gymnosteris nudicaulis (H. & A.) Greene. p. 114 In Vascular plant species of concern in Idaho (1981). University of Idaho, Forest, Wildlife and Range Exp. Sta. Bull. No. 34.

A NEW POINT INTERCEPTION FRAME FOR ESTIMATING COVER OF VEGETATION

Donald A. Floyd and Jay E. Anderson

ABSTRACT

A new frame for sighting a dot grid onto vegetation is described. It consists of two superimposed string grids mounted one above the other on three adjustable legs. The method was compared to line interception in sagebrush/perennial bunchgrass vegetation in southeastern Idaho. For most species, cover estimates by the two methods were the same. Line interception gave higher cover estimates for shrubs because of the assumption that their foliage completely covered the area within their canopy outlines. The technique was fast, accurate, and objective.

INTRODUCTION

Canopy cover is one of the better indices of importance value of plant species (Rice, 1967; Daubenmire, 1968) because it permits comparisons of species of widely different growth forms (Mueller-Dombois and Ellenberg, 1974). Techniques for measuring cover include line interception, point interception, and the use of quadrats for mapping or cover estimation. The most widely used technique in communities dominated by shrubby or herbaceous vegetation is line interception (Canfield, 1941). A line is stretched across the sample area, and the length of line intercepted by each species is recorded. A species' cover is the sum of its intercepts divided by the total length of line, expressed as a percentage. A plumb bob facilitates objective reading, but does not preclude one from inadvertently pushing the line sideways to hit or miss individual plants. Line interception is tedious when cover of rhizomatous grasses and small forbs is analyzed in detail.

Quadrat techniques range from precise mapping of individual plants to rough estimation by cover classes such as the quadrat estimation method (Daubenmire, 1959) or Braun-Blanquet's (1965) cover-abundance scale. Quadrat estimation is quick but often less precise than desired. Cover estimation by mapping is tedious and time consuming, and it also requires area measurements on the completed maps. This is typically done by counting squares of known size. The problem of fractional squares can be eliminated by using the grid intersections in lieu of the squares themselves (Avery, 1975). Such "dot grids" constitute a point interception technique and are widely used for measuring areas on maps or under curves, cover of colonies in microscopic fields, or areas of leaves.

In applying the dot grid concept to analysis of vegetal cover, the probability of a point landing on a species is directly proportional to the area covered by that species. It follows that the number of points falling on a species divided by the total number of points sampled equals the percent cover for that species.

Mueller-Dombois and Ellenberg (1974) cite over 10 different techniques for applying point interception directly to the measurement of vegetal cover. Most of these have not gained wide use, but their sheer number indicates a strong desire among plant ecologists to use this approach. Many versions of the sliding wire point contact frame (Levy and Madden, 1933; Goodall, 1952; Warren-Wilson, 1960) have been used, even though Goodall (1952) showed that the diameter of the wire should drastically affect cover estimates. Whitman and Siggeirsson (1954) compared point contact to line interception in a field test and found that the point contact technique significantly overestimated nearly all sampled species.

Mueller-Dombois and Cooray (1968) used two 100 cm² superimposed string grids in conjunction with a 1-m² grid to achieve an objective projection of points onto the vegetation or ground. Mueller-Dombois and Ellenberg (1974) note that because this "double-sighting cross method" is used to sight a point it should be more accurate than sliding wire techniques, but that this particular technique was not widely applicable. Mueller-Dombois and Cooray's (1968) technique was limited to use on turf vegetation and other variations have not gained wide usage (Morrison and Yarranton, 1970; Winkworth and Goodall, 1962; Stanton, 1960).

We describe a simple, widely applicable technique that employs the double-sighting cross method to measure vegetal cover. A point sighting frame is used to sight a dot grid on underlying vegetation or ground and "hits" on the vertical projection of each point are recorded. This paper describes construction and use of the frame and presents a comparison of its cover estimation to that of line interception.

METHODS

The point frame consists of two frames, constructed from 2.5-cm x 5-cm lumber, having inside dimensions of 50 x 100 cm. These frames are superimposed 10 cm apart with wooden dowels (Fig. 1). Dark-colored fishing line was strung through holes drilled at 10 cm intervals in each frame to produce a sighting grid of 36 points. These superimposed string grids, mounted on three adjustable camera tripod legs, are leveled using bubble levels to insure vertical projection of the points.

The technique was tested in big sagebrush (*Artemisia tridentata*^a)-perennial bunchgrass communities in southeastern Idaho. Data were collected from a randomly chosen 20-m section of 50-m sample lines that were systematically located. Each 20-m section was read by point interception and line interception. The point frame was centered and leveled over a taut steel tape at 1-m intervals; hits were recorded as shown in Fig. 2. Line interception data were recorded to the nearest cm along the same tape; a plumb bob was used to vertically project the tape (Canfield, 1941).

Wilcoxon's signed-ranks test for paired samples (Zar, 1974) was used to compare cover estimates obtained by the two techniques for 18 sample lines.

^a Nomenclature follows Hitchcock and Cronquist (1978).

Figure 1. Point sighting frame.

RESULTS AND DISCUSSION

This method of collecting point interception data is simple, objective, and accurate. Because of the objectivity of the point frame technique, workers who were experienced in vegetation analysis preferred it over line interception, even though it required greater time at the sampling intensity used in this study.

The sampling intensity of 36 points per metre of line was arbitrarily set to give reasonable coverage for shrubs, grasses, and forbs, and to complement the overall pairing statistical design. At this intensity, the point interception technique took about 30% longer than line interception, but about 50% more species were recorded by point interception. The point frame may be restrung to project any number of points, depending on the composition and fineness of the vegetation and the objectives of sampling. We found that 20 frames provided good estimates of cover for all but the rarest species. However, sample size should be determined according to the needs and objectives of each study.

B	—	B	Agda	B	—	B	DS
•	•	•	•	•	•	•	•
A	B	A	L	L	Tofl	B	—
•	•	•	•	•	•	•	•
B	A	A	B	—	B	DS	—
•	•	•	•	•	•	•	•
B	—	B	A/Sihy	B	—		
•	•	•	•	•	•	•	•

Figure 2. Top: A diagrammatic representation of the projected dot grid on a 50 x 100 cm portion of a plant community. Shrubs and forbs are counted when points are projected onto their stems or foliage; inflorescences are not counted. Grasses are counted only when points are projected onto their basal areas.

Bottom: a data sheet record of the point plot shown above. A one or two letter code is used for more common species and non-living entities; four letter codes consisting of the first two letters of the genus and species are used for other plants. Lines indicate continuation of the same entity. Codes shown are B = bare ground, DS = dead sagebrush, L = litter, A = Artemisia tridentata, Agda = Agropyron dasytachyum, Tofl = Townsendia florifer, and Sihy = Sitanion hystrix. A/Sihy indicates that the point intercepted Artemisia tridentata in the overstory and Sitanion hystrix in the understory.

Across the 18 lines, no significant differences were found between cover estimates of forb species by the two techniques, but 18 forb species were recorded by point interception whereas only 10 were recorded by line interception. Of the remaining 16 pairs of estimates, significant differences were found in only four cases (Table 1). Point interception gave lower estimates for both live and dead sagebrush and higher estimates for bare ground and litter. The same trend is shown for

TABLE 1. Average percent cover as estimated by line interception and point interception.

SPECIES	Cover (%)	
	Line Interception	Point Interception
Shrubs:		
<u>Artemisia tridentata</u>	39.34	33.93 ^a
<u>Chrysothamnus nauseosus</u>	0.02	0.04
<u>C. viscidiflorus</u>	11.25	10.21
<u>Eriogonum microthecum</u>	-	0.01
<u>Leptodactylon pungens</u>	-	0.02
<u>Opuntia polyacantha</u>	0.09	0.05
Grasses:		
<u>Elymus cinereus</u>	1.08	0.93
<u>Oryzopsis hymenoides</u>	0.01	0.02
<u>Sitanion hystrix</u>	0.65	1.27
Miscellaneous:		
Anthills	0.18	0.15
Bare areas around anthills	1.03	1.03
Bare ground	25.22	29.01 ^a
Litter	10.31	13.66 ^a
Dead sagebrush	12.85	8.99 ^a
Lichens	0.74	0.48
Mosses	7.23	5.24

^a Estimates significantly different ($P < 0.05$) by Wilcoxon's paired sample, signed-ranks test.

Chrysothamnus viscidiflorus, the other common shrub on the area, but the difference was not significant ($0.05 < p < 0.1$). The differences almost certainly resulted from assuming complete canopy coverage within the outlines of shrubs when using line interception. If live and dead sagebrush actually covered 86% and 70% of the areas within their outlines, respectively, the differences in cover estimates of the two techniques would be completely accounted for. It follows that the differences for bare ground and litter should have been nearly equal and opposite to those for live and dead sagebrush; this was the case (Table 1). In contrast, bare areas around anthills (Table 1) were marked out subjectively. Thus, cover estimates for these completely bare areas should have been identical for both methods, and they were.

Line interception and point interception gave comparable results, except for shrubs where the complete canopy coverage assumption is invalid. Point interception probably provides a better estimate of absolute cover in such cases. We found no tendency for this point interception technique to overestimate cover values, in contrast to the sliding wire or point contact method (Whitman and Siggeirsson, 1954). The point frame technique is more objective than quadrat estimation; observers are less likely to introduce systematic errors. The point frame technique also appears to give a more objective and consistent estimate of basal cover of rhizomatous grasses than line interception, and it seems less tedious for detailed analysis of forbs or rhizomatous grasses. Although we have tested the point frame technique only in sagebrush steppe, it should work equally well for estimating cover in grassland, tundra, or forest understories.

LITERATURE CITED

- Avery, T. E. 1975. Natural Resources Measurements. 2nd ed. McGraw-Hill, Inc. New York. p. 58.
- Braun-Blanquet, J. 1965. Plant Sociology: The Study of Plant Communities. (Transl., rev., and ed. by C. D. Fuller and H. S. Conrad.) Hafner, London. 439 p.
- Canfield, R. 1941. Application of line interception in sampling range vegetation. J. For. 39:388-394.
- Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. NW. Sci. 33:43-64.
- Daubenmire, R. F. 1968. Plant Communities: A Textbook of Plant Synecology. Harper & Row, New York. 300 p.
- Goodall, D. W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Aust. J. of Sci. Res., Series B 5:1-41.
- Hitchcock, C. L. and A. Cronquist. 1978. Flora of the Pacific Northwest. Univ. Washington Press, Seattle. 730 p.
- Levy, E. E. and E. A. Madden. 1933. The point method of pasture analysis. N. Z. Agric. J. 46:267-279.
- Morrison, R. G. and G. A. Yarranton. 1970. An instrument for rapid and precise point sampling of vegetation. Can. J. Bot. 48:293-297.
- Mueller-Dombois, D. and R. G. Cooray. 1968. Effects of elephant feeding on the short-grass covers in Rahuana National Park, Ceylon. Smithsonian-Ceylon ecology project mimeo-report number 11. 12 p.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 p.

- Rice, E. L. 1967. A statistical method of determining quadrat size and adequacy of sampling. *Ecology* 48:1047-1049.
- Stanton, F. W. 1960. Ocular point frame. *J. Range Manage.* 13:153.
- Warren-Wilson, J. 1960. Inclined point quadrats. *New Phytol.* 59:1-8.
- Whitman, W. C. and E. I. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass vegetation. *Ecology* 35:431-436.
- Winkworth, R. E. and D. W. Goodall. 1962. A crosswire sighting tube for point quadrat analysis. *Ecology* 43:342-343.
- Zar, J. H. 1974. *Biostatistical analysis*. Prentice Hall, Englewood Cliffs, N.J. p. 124-127.

A COMPARISON OF THREE METHODS FOR ESTIMATING VEGETAL COVER

Donald A. Floyd and Jay E. Anderson

ABSTRACT

Vegetal cover data were collected in sagebrush-steppe vegetation using three techniques: line interception, Daubenmire's cover-class estimation, and point interception, using a new point sighting method. Cover estimates and times required to obtain confidence limits by the three methods were compared. Daubenmire's cover-class estimation method gave high estimates of grass cover, because actual cover values of grasses tend to be asymmetrically distributed and thus violate a basic assumption of this method. Most of the significant differences among sets of cover estimates were a result of cover-class estimation giving estimates that were different from those of both the other methods. Cover-class estimation gave significantly different estimates for shrubs, grasses, forbs, lower plants, and litter. Line interception gave high estimates of shrub cover, because of the assumption that shrubs cover all the area within the outlines of their canopies. Line interception and point interception estimates of cover for most other species were not significantly different, but line interception required about 35 percent more sampling time to achieve the same precision as point interception. We concluded that the new point sighting method was the most effective method for estimating cover in sagebrush-steppe vegetation.

INTRODUCTION

Cover is the most widely used measure of plant species importance in studies of range vegetation. Frequency and density are also commonly used, but are greatly affected by the size and distribution of individuals of species (Rice, 1967; Daubenmire, 1968). Because cover is not biased by these factors, it can be used to compare species of widely different growth forms (Whittaker, 1975; Mueller-Dombois and Ellenberg, 1974). Numerous techniques for estimating cover have been developed. These fall into three categories, each based on a different geometric unit: lines, points, and quadrats.

Line interception was first used to estimate vegetal cover by Canfield (1941). A measuring tape is stretched across the area to be sampled, and the length of line intercepted by a species divided by the total length of line sampled is the proportion of the area occupied by that species. This method has firm theoretical backing, so long as the line is a true geometric line having no width (DeVries, 1979; Solomon, 1978; Lucas and Seber, 1977). Line interception is tedious when measuring many small individuals.

Point interception (also called dot grid or Monte Carlo method) has been widely used for measuring areas on maps, under curves, and in microscopic fields. In applying this method, a number of points are established on the area to be sampled. The number of points landing on a species divided by the total number of points sampled is the proportion of the area occupied by that species. The first method of establishing points in vegetation was point contact, where pins were slid through vertical guide holes in a rigid frame and hits were recorded (Levy and Madden, 1933). This method has been widely

used, but Goodall (1952) showed that cover estimates obtained in this way should be greatly affected by the diameter of the pins, and he then demonstrated that this was the case in a field test. Whitman and Siggeirsson (1960) also found that point contact gave higher estimates of cover than line interception. The second method of establishing points in vegetation is point sighting with two sets of crosshairs. In his field test, Goodall used a brass tube with a wire cross at each end, suspended in a ring by gimbals so that the tube hung vertically, for point sighting (Winkworth and Goodall, 1962). Point sighting adheres more closely to the Monte Carlo theoretical model because the points have no area, but none of the many attempts to apply point sighting (Morrison and Yarranton, 1970; Winkworth and Goodall, 1962; Stanton, 1960) have gained wide usage. We developed a new point sighting frame for use in this comparison (Floyd and Anderson, this volume).

Quadrat techniques are numerous, but the most widely used method in range vegetation is canopy-coverage or cover-class estimation (Daubenmire, 1959). A series of 20 x 50-cm quadrats are located on the area to be sampled. The area of each quadrat that is occupied by a species is estimated and recorded as having fallen into one of six unequal-sized cover-classes. All estimates in a cover class are given the value of the midpoint of that class; these midpoints are averaged to obtain the percent cover of that species. This procedure lacks a theoretical basis, but it has been field tested (Daubenmire, 1959; Hanley, 1978), and widely used subsequently. Although no attempt will be made to analyze all the theoretical flaws of this procedure, several special cases will be used to help explain the results of this study.

We used these three methods to estimate vegetal cover on the BLM/DOE controlled burn site (Floyd and Anderson, this volume), an area dominated by sagebrush-perennial grass vegetation. The objectives of the study were to: 1) test the new point sighting frame, 2) compare cover estimates obtained by the three methods, 3) determine the sampling time required by each method to obtain confidence intervals, and 4) determine which method should be used in follow-up studies.

METHODS

Sampling was done between 3 June and 31 July, 1980; 14 observers participated. One hundred twenty-eight 50-m lines were systematically located along eight transects (Floyd and Anderson, this volume). Eight additional lines were located on two transects west of the study area, collectively referred to as transect 9 in this analysis. The same randomly selected 20-m section of each line was sampled by all three methods. The methods were applied in a random order at each line. Several standard criteria were followed for all three methods: 1) grasses were estimated by basal area only, 2) a shrub was considered alive if any part of that shrub had green leaves on it, 3) inflorescences were not counted, 4) bare ground and litter were only counted if no vascular plant species occurred on the point being estimated, 5) bare areas around anthills were measured separately, and 6) rocks larger than 1 dm in length were counted separately from bare ground. Cover was estimated by line interception along the 20-m sample section (Canfield, 1941); a plumb line was used to facilitate vertical projection of the tape. When using line interception, shrubs and forbs were measured from one side to the other, ignoring breaks in their canopies.

Cover-class estimation (Daubenmire, 1959) was used to estimate cover by centering a 20 x 50-cm quadrat, long axis parallel to the tape, on the first half of each meter. The percentage of each quadrat occupied by each species was estimated and assigned to a cover-class from one to six. The cover-class breaks are at 5, 25, 50, 75, and 95 percent. The midpoints of the cover-classes (2.5, 15, 37.5, 62.5, 85, and 97.5) are used to calculate average cover values. Again, it is assumed that shrubs and forbs cover all the area within the outlines of their canopies.

A point sighting frame (Floyd and Anderson, this volume) with a 9 x 4-point double string-grid was centered, long axis parallel to the tape, to estimate cover on each meter along the 20-m section. No assumptions about shrub and forb canopies are necessary when using point interception; a species either falls under a point or it does not.

The cover estimates obtained by the three methods were compared for each of the nine transects, as well as for the entire area. For each species (or other appropriate group), a blocked analysis of variance (ANOVA) was applied, treating each 20-m line as a block and each method as a treatment. If ANOVA revealed a significant difference at $\alpha = 0.1$, a Student-Newman-Keuls multiple range test (SNK) was used ($\alpha = 0.05$) to confirm and locate the differences. Because the 0.05 alpha level represented the "experiment wise error rate," a higher alpha (0.1) was used for ANOVA to lessen the chance of making a type II error (failing to detect actual differences and subsequently failing to run the appropriate SNK tests) (Zar, 1974).

Cumulative averaging was used to assess the precision of the cover estimates. Our procedure is an extension of the one used by Daubenmire (1959) and Hanley (1978) in comparing estimates of shrub cover obtained by line interception and cover-class estimation, where the average percent cover is plotted against the number of sample units used to obtain that average. To increase the resolution of this technique, we have treated each meter of line as a sample unit (and concurrently, one point frame and one cover-class estimation quadrat). We then applied this procedure simultaneously to varying numbers of lines, and calculated 95 percent confidence intervals, treating all cover estimates obtained by sampling one meter as a sample, all cover estimates obtained by sampling two meters as a sample, all cover estimates obtained by sampling three meters as a sample, and so on to twenty meters. We then plotted the widths of these cumulative confidence intervals against the numbers of sample units required to obtain them and the time required by each method.

RESULTS AND DISCUSSION

Line interception gave estimates of shrub cover that were significantly higher than those obtained by the other two methods in the pooled analyses (Tables 1 and 2) and in 12 cases in the transect by transect analyses (for details see Floyd, 1982). This is almost surely a result of assuming that shrubs completely cover the area within the outlines of their canopies when using line interception.

In the pooled analyses, point interception gave an estimate for bareground/litter that was significantly higher than those obtained by the

other two methods (Table 1). Point interception overestimated bareground/litter by the same amount that line interception overestimated shrub cover. This was the only consistent difference between point interception and line interception estimates. The only other differences between line interception and point interception estimates were for mosses, lichens, and *Eriogonum microthecum* in the pooled analyses (Table 1) and *Agropyron spicatum* at transect 6 (Floyd, 1982). Mosses tend to occur under shrubs in this vegetation, and small gaps are ignored when using line interception. Line interception may underestimate lichens, which occur mostly on bare ground, because observers inadvertently push the tape sideways to miss lichens and avoid the tedium of measuring them. Cover-class estimation overestimates lichens for reasons to be explained later.

Table 1. Estimates of percent cover of major growth forms.

Growth Form	Method ^a			ANOVA ^b		
	LI	PI	CC	N	F	Log 10
Shrubs	40.49	35.56	35.50	128	35.7***	-
Grasses	<u>2.67</u>	<u>2.88</u>	<u>4.29</u>	125	31.9***	43.4***
Forbs	<u>3.92</u>	<u>3.97</u>	<u>3.44</u>	127	2.0	0.84
Bare ground/Litter	48.86	53.41	48.30	128	17.1***	-
Dead Sagebrush	<u>5.40</u>	<u>3.54</u>	<u>4.19</u>	127	18.4***	22.1***
Moss	<u>16.98</u>	<u>13.41</u>	<u>8.54</u>	128	58.2***	-
Lichen	<u>0.42</u>	<u>0.66</u>	<u>1.19</u>	113	34.6***	55.0***

a Estimates obtained by line interception (LI), point interception (PI), and cover-class estimation (CC). Values connected by unbroken lines or dashed superscript lines with no underline are not significantly different ($p = 0.05$).

b N = number of sample lines on which a species was found,
F = calculate critical value, Log 10 = F after transformation
*** $P < 0.001$

In the pooled analyses, cover-class estimation gave high estimates of grass cover (Tables 1 and 3) and two low and two high estimates of forb cover (Table 4). In the transect by transect analyses, in addition to the 12 cases where line interception gave high estimates of shrub cover, 51 significant differences were found. Thirty-six of these differences resulted from cover-class estimation giving an estimate that was significantly different from those obtained by both point interception and line interception. In ten cases line interception and cover-class estimates differed, and in five cases point interception and cover-class estimates differed. Overall, cover-class estimation gave some different estimates for shrubs (four low), forbs (six low and one high), grasses (19 high), lower plants (eight low and four high), and litter (four low). We conclude that cover-class estimation is unreliable. There is no clear and simple source of these problems, but invalid assumptions, upon which this method is based, may account for some of them.

Table 2. Estimates of percent cover of major shrub species.

Species	Method ^a			ANOVA ^b		
	LI	PI	CC	N	F	Log 10
<u>Artemisia</u> <u>tridentata</u>	20.46	26.15	26.71	128	27.86***	-
<u>Chrysothamnus</u> <u>viscidiflorus</u>	9.74	8.21	7.46	125	17.40***	-
<u>Leptodactylon</u> <u>pungens</u>	0.36	0.35	0.43	52	1.05	-
<u>Ceratoides</u> <u>lanata</u>	0.23	0.18	0.25	34	1.70	0.72
<u>Artemisia</u> <u>nova</u>	0.23	0.19	0.16	6	7.04*	4.3*
<u>Eriogonum</u> <u>microthecum</u>	0.10	0.13	0.18	52	3.97	5.43**
<u>Tetradymia</u> <u>canescens</u>	0.11	0.14	0.14	17	0.71	-
<u>Chrysothamnus</u> <u>nauseous</u>	0.01	0.09	0.05	20	1.9	-
<u>Opuntia</u> <u>polyacantha</u>	0.078	0.077	0.087	43	0.09	-
<u>Atriplex</u> <u>nuttallii</u>	0.027	0.026	0.021	1	-	-

a,b See Table 1, *P < 0.1, **P < 0.02, ***P < 0.001.

Table 3. Estimates of percent cover of grass species.

Species	Method ^a			ANOVA ^b		
	LI	PI	CC	N	F	Log 10
<u>Agropyron</u> <u>spicatum</u>	1.04	1.07	1.56	89	11.2****	8.6****
<u>Oryzopsis</u> <u>hymenoides</u>	0.557	0.552	1.127	98	37.3****	42.4****
<u>Sitanion</u> <u>hystrix</u>	0.53	0.66	0.79	111	3.9*	9.6****
<u>Poa</u> <u>nevadensis</u>	0.14	0.16	0.19	46	1.2	0.9
<u>Elymus</u> <u>cinereus</u>	0.152	0.118	0.208 ^c	7	4.3**	2.12
<u>Stipa</u> <u>comata</u>	0.121	0.124	0.168	48	1.0	0.8
<u>Agropyron</u> <u>dasytachyum</u>	0.101	0.142	0.201	26	3.5*	7.5***
<u>Poa</u> <u>sandbergii</u>	0.022	0.040	0.042	26	1.3	1.6
<u>Agropyron</u> <u>cristatum</u>	0.009	0.008	0.008	5	0.01	-

a, b See Table 1, *P < 0.01, **P < 0.05, ***P < 0.01, ****P < 0.001.

c SNK found no significant differences.

Consider the cover-classes of cover-class estimation and a population of grasses that cover a small percentage of a study area, where the actual cover values are represented by a Poisson-like distribution (Fig. 1). This is a common occurrence for many subdominant species. If cover-class estimation is used to estimate cover of this species, cover will be overestimated. The smaller the true mean of the population, the greater will be the over-estimation. The ratio of the number of lines on which a species was detected (N) to the resultant average cover value of that species gives a rough index of the average size of the individuals of that species. The amount by which cover-class estimation overestimated grass cover appears to be dependent on this ratio (linear regression $r = 0.78$, $\alpha = 0.05$). This is because it is assumed that the actual cover values (and resultant estimates) will be uniformly distributed about the midpoints of each cover-class, when there are actually far more values in the lower half of each class. The practice of adding a cover-class on each end of the scale (0 - 1 and 99 - 100), employed by many researchers, would not compensate well for this problem.

Table 4. Estimates of cover of common forb species.

Species	Method ^a			ANOVA ^b		
	LI	PI	CC	N	F	Log 10
<u>Phlox</u>	1.29	1.11	1.11	91	2.1	1.7
<u>hoodii</u>						
<u>Arenaria</u>	0.44	0.39	0.53	75	1.7	1.8
<u>franklinii</u>						
<u>Cryptantha</u>	0.51	0.44	0.25	29	3.1	2.9
<u>scoparia</u>						
<u>Lappula</u>	0.21	0.38	0.16	22	2.6	3.7*
<u>redowskii</u>						
<u>Schoenocrambe</u>	0.31	0.31	0.16	35	8.7***	9.5***
<u>linifolia</u>						
<u>Descurainia</u>	0.246	0.255	0.168	47	1.4	0.89
<u>pinnata</u>						
<u>Astragalus</u>	0.002	0.023	0.023	12	2.9	4.3*
<u>calycosus</u>						
<u>Astragalus</u>	0.150	0.169	0.154	54	0.2	0.92
<u>filipes</u>						
<u>Townsendia</u>	0.103	0.076	0.098	42	0.65	0.37
<u>florifer</u>						
<u>Penstemon</u>	0.014	0.091	0.080	4	0.84	-
<u>humilis</u>						
<u>Gilia</u>	0.037	0.064	0.061	20	2.04	2.26
<u>congesta</u>						
<u>Cordylanthus</u>	0.086	0.079	0.046	26	2.04	2.1
<u>ramosus</u>						
<u>Chaenactis</u>	0.049	0.055	0.043	44	0.65	0.82
<u>douglasii</u>						
<u>Astragalus</u>	0.035	0.041	0.044	32	0.21	0.55
<u>lentigenosus</u>						
<u>Arabis</u>	0.032	0.035	0.057	28	2.5	3.6*
<u>holboellii</u>						
<u>Astragalus</u>	0.044	0.026	0.011	16	5.95**	5.92**
<u>convallarius</u>						
<u>Cryptantha</u>	0.033	0.036	0.055	34	1.1	1.4
<u>interrupta</u>						

a,b See Table 1, *P < 0.1, **P < 0.002, ***P < 0.001.

Figure 1. Example of cover values for a small and/or rare species (e.g. grasses) and the associated distribution of Daubenmire's cover-classes.

Now, consider the six cover-classes and a species whose cover values are binomially distributed (symmetrically, with $p = 0.5$, $q = 0.5$ and $s = 10$), and whose true mean cover values increase linearly across a series of study areas (Fig. 2). Consider the estimates obtained by cover-class estimation as the true mean increases. Cover estimates at the low end will be higher than the actual values, until a mean of 37.5 is approached. It appears that any binomially distributed ($p = 0.5$ and $q = 0.5$) cover values with means between 37.5 and 62.5 would be estimated correctly. Cover estimates at the upper end would be low. The picture changes with symmetry of actual cover distributions and associated variances. It may not be valid to apply continuous statistical procedures to these data.

Another problem arises if estimates of more than one species are pooled. Consider two cases where it is desirable to pool estimates of *Descurainia pinnata* and *Descuraninia sophia*. Consider the estimates for one quadrat where the actual cover value for each species is one percent. Each species will be assigned to cover-class 1 and given a percent cover of 2.5. If these species were pooled before collecting data, the actual cover of the genus would have

Figure 2. True mean cover of a species increasing linearly across a series of sample plots (solid line), represented by sliding the binominal distribution ($p = 0.5$, $q = 0.5$, $s = 10$) along the y-axis, and the resultant estimates of cover-class estimation.

been two percent, giving an estimate of 2.5, but if the species were pooled after collecting data the estimate would be five percent. Now consider the same quadrat where each species covers four percent. If pooling took place before collecting data, the genus would be assigned to cover-class 2, for a cover estimate of 15 percent, but if pooling took place after collecting data, the genus would be given a cover estimate of five percent. Because of this, these data can not be validly treated as ratio-scale data. Having a large sample size would not necessarily correct this problem.

Because it is of little interest how fast one can obtain an unreliable estimate of vegetal cover, cover-class estimation has been excluded from the remainder of the analysis for the sake of brevity. It is discussed in Floyd (1982).

The cumulative confidence intervals (Fig. 3 and 4) show that the same precision is obtained by point interception with about half as many meters of sampling as line interception. It is important to note that this does not mean that point interception is more precise than line interception, since the sampling intensity of 36 points per meter was set arbitrarily. This ratio of 36 points being equal in precision to 2 m of line interception is consistent with the findings of Whitman and Siggeirsson (1954), who calculated the number of line interception and point contact samples required to sample at five percent accuracy and the ratio was 17 points to one meter of line. Sampling times for the two methods were 2.4 minutes/m for line interception and 3.2 minutes/m for point interception. Therefore, point interception achieves the same level of precision as line interception in about two thirds as much sampling time.

In contrast to other studies, line interception showed a surprisingly high precision at relatively low sampling intensity. The reason that line interception has shown an excessive time requirement in other studies (Daubenmire, 1959; Hanley, 1978) is that arbitrarily large sample sizes were used. Daubenmire placed 40 - 50 quadrats along a central 50-m line interception transect, then placed six additional transects parallel to the first, and concluded that line interception required more sampling time to achieve the same results as cover-class estimation. Using each meter of the 50-m central transect as a sample unit and discarding the data obtained from the six parallel transects would probably have provided the same estimates of cover in less than 20 percent of the time. The lack of a continued increase in precision as more transects are sampled, which would be required to show efficiency with large sample sizes of line interception, is a result of the increase in heterogeneity of the vegetation that is brought on by increased spatial separation of the transects, rather than any inherent lack of precision in the sampling technique. Hanley (1978) used a somewhat tighter sampling design in less complex vegetation and found that line interception was better if high levels of precision are desired, even though line interception samples were more widely spaced than cover-class estimation quadrats. These studies were based on Canfield's (1941) original recommendations, which appear to have leaned toward oversampling.

The point sighting frame (Floyd and Anderson, this volume) was much faster than other point interception methods, allowing one observer to sample 720 points/hour. The frame may be restrung to project any number of points. The frame may also be strung randomly if multiple random starts are preferred over systematic sampling (e.g. Bellhouse, 1980). Mueller-Dombois and Ellenberg (1974) state that contiguous strings of points should be better than isolated clusters of points. The spacing of the frames has no effect on the precision attained with a given number of frames (Fig. 5). The point frame is easy for an observer to use alone; its sampling time (in man-hours) improves more by working alone than do the times of the other two methods. Point interception does not bias the cover estimates of any particular taxon or growth form. We recommend this method for estimating cover in shrub-steppe vegetation.

Figure 3. Widths of the confidence intervals for shrub cover estimates obtained by point interception and line interception vs. the number of meters sampled (48 lines were used). The width obtained by line interception was obtained with about half as many meters by point interception.

Figure 4. Widths of the confidence intervals for Ceratoides lanata, a subdominant shrub species, obtained by line interception and point interception.

Figure 5. Widths of confidence intervals for shrub cover estimates obtained by point interception, but each successively shorter line was obtained by using the data from every meter, every other meter, and every fourth meter of point interception data.

LITERATURE CITED

- Bellhouse, D. R. 1981. Area estimation by point-counting techniques. *Biometrics* 37:303-312.
- Canfield, R. 1941. Application of line interception in sampling range vegetation. *J. of Forestry* 39:388-394.
- Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. *Northwest Science* 33:43-64.
- Daubenmire, R. F. 1968. *Plant communities: a textbook of plant synecology*. Harper & Row, New York. 300 p.
- DeVries, P. G. 1979. Line intersect sampling - statistical theory, applications, and suggestions for extended use in ecological inventory. In *Sampling Biological Populations*, vol. 5 of *Statistical Ecology*, pp. 1-70, R. M. Cormack, G. P. Patil, and D. S. Robson (eds.), International Co-operative Publishing House, Fairland, Maryland. 392 p.

- Floyd, D. A. 1982. A comparison of three methods used for estimating vegetal cover in sagebrush steppe communities. M. S. Thesis, Idaho State University, Pocatello.
- Goodall, D. W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. *Aust. J. of Sci. Res., Series B* 5:1-41.
- Hanley, T. A. 1978. A comparison of the line interception and quadrat estimation methods of determining shrub canopy coverage. *J. of Range Manage.* 31:60-62.
- Levy, E. E. and E. A. Madden. 1933. The point method of pasture analysis. *New Zealand Agr. J.* 46:267-279.
- Lucas, H. A. and G. A. F. Seber. 1977. Estimating coverage and particle density using the line intercept method. *Biometrika* 64:618-622.
- Morrison, R. G. and G. A. Yarranton. 1970. An instrument for rapid and precise point sampling of vegetation. *Can. J. of Bot.* 48:293-297.
- Mueller-Domboise, D. and H. Ellenberg. 1974. *Aims and methods of vegetation ecology.* John Wiley and Sons, New York. 547 p.
- Rice, E. L. 1967. A statistical method of determining quadrat size and adequacy of sampling. *Ecology* 48:1047-1049.
- Solomon, H. 1978. *Geometric probability.* Soc. for Ind. and App. Math. Penn. 174 p.
- Stanton, F. W. 1960. Ocular point frame. *J. of Range Manage.* 13:153.
- Whittaker, R. H. 1975. *Communities and ecosystems.* MacMillan Publishing Company, Inc., New York. 385 p.
- Whitman, W. C. and E. I. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass vegetation. *Ecology* 35:431-436.
- Winkworth, R. E. and D. W. Goodall. 1962. A crosswire sighting tube for point quadrat analysis. *Ecology* 43:342-343.
- Zar, J. H. 1974. *Biostatistical analysis.* Prentice Hall, Englewood Cliffs, N.J. 620p.

STABILITY AND SUCCESSION IN CRESTED WHEATGRASS SEEDINGS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

Crested wheatgrass (*Agropyron cristatum*) has been used extensively for the revegetation of disturbed and depleted lands in the western United States. Its importance will probably increase as energy and mineral resource development necessitates the reclamation of semiarid ecosystems. Many semiarid ecosystems are managed with the assumption that the recovery process deterministically converges to a native climax community. Yet, some crested wheatgrass seedings have resisted the invasion of native species for as long as 50 years. Competition for soil moisture is generally regarded to be the primary factor that precludes the invasion of crested wheatgrass seedings by native species. Competition can be a factor in the stability of crested wheatgrass only if native species are sufficiently dispersed into the seedings. Seed dispersal and seed reserve data suggest that native species are limited or unavailable for recruitment within crested wheatgrass seedings. The probabilities of recruitment from seed reserves may favor crested wheatgrass as a self-maintaining vegetation for prolonged periods. Chance favors the maintenance of the monoculture rather than its successional replacement.

INTRODUCTION

Many of the mineral and energy resources in the United States are located within relatively fragile semiarid ecosystems (SCSA, 1980; Stiller et al., 1980; Currie, 1981). The disturbance of these ecosystems by resource development often necessitates a reclamation effort. Reclamation presumes knowledge of community structure and the recovery process. The process by which a community recovers from a perturbation is termed ecological succession (Connell and Slatyer, 1977).

Classical theory (Clements, 1916) maintains that succession is a community or species replacement driven by autogenic environmental modification. It proposes that the vegetation at a given site deterministically converges to one stable and climatically adapted community, termed the climax (Miles, 1979). Many semiarid ecosystems are managed under the assumptions and interpretations of classical theory (Van Dyne, 1969; Heady, 1975; Stoddart et al., 1975). Yet, many investigators have rejected or seriously questioned classical theory (Gleason, 1917; Egler, 1954; Whittaker, 1953; McIntosh, 1967; Drury and Nisbet, 1973; Connell and Slatyer, 1977; Miles, 1979; Anderson and Holte, 1981). It is imperative to reexamine positions and ask if alternative models provide a better conceptual framework for reclamation and management strategy.

Crested wheatgrass (*Agropyron cristatum* [L.] Gaertn. and *Agropyron desertorum* [Fisch.] Schult.) is the primary vegetation used in the United States and Canada for the reclamation of semiarid ecosystems (Currie, 1970). It is a long lived (15-20 years) perennial bunchgrass native to the cold desert regions of Asia (Looman and Heinrichs, 1973). Crested

wheatgrass was introduced into America in 1898, but its use in extensive seeding programs did not begin until the 1930's (Dillman, 1946). Within 25 years an area of land equivalent to over half the size of Maine (4,000,000 ha) was seeded to crested wheatgrass (Newell, 1955). Current estimates are not readily available, but Idaho alone presently has over 850,000 ha (Reynolds and Trost, 1980).

Crested wheatgrass is considered to be an unstable vegetation since native species frequently reinvade seeded areas (Clements, 1935; Lewis, 1969). Stability is here defined as persistence. The life expectancy of crested wheatgrass seedings is considered to be 20 years or less (Bartolome and Heady, 1978). Most previous investigations either explicitly or implicitly assume that the reinvansion of native vegetation is in accordance with the deterministic succession of classical theory. There are, however, difficulties with this assumption.

It is generally recognized that crested wheatgrass spreads quickly by seed and is capable of invading native habitat (Hull and Klomp, 1967; Hull, 1971). When crested wheatgrass is sown in mixture with native grasses, it frequently becomes the dominant vegetation (Heinrichs and Bolton, 1950; Hull, 1971; Schuman, 1980; Holechek et al., 1981). Crested wheatgrass is considered to be competitively equal or superior to many of the native dominant species (Hubbard, 1957; Eckert et al., 1961; Robertson et al., 1966; Robertson, 1972; Holechek et al., 1981; U.S.U. Ecology Center, 1981). It is recognized as a permanent part of the vegetation even on its introduced range (Smoliak et al., 1967). The soils beneath some seedings may be evolving towards a different equilibrium than the soils beneath native species (Dorinaar et al., 1980). Some crested wheatgrass seedings have resisted the invasion of native species for as long as 30-50 years (Hull and Klomp, 1966; Looman and Heinrichs, 1973). Instead of a predictable convergence to a native climax community, these observations suggest that crested wheatgrass may occupy a site for prolonged or potentially indefinite periods.

Revegetation with crested wheatgrass will probably increase as America turns to its western energy reserves. Native vegetation is often emphasized in reclamation efforts, but native species are difficult to reestablish and their seeds are frequently unavailable (Monsen and Plummer, 1978; Power et al., 1978). The revegetation with crested wheatgrass, either alone or in mixture, does not ensure the recovery of the native wildlife habitat. On the contrary, seeding with crested wheatgrass may preclude, or at least delay, the recovery of the native vegetation. Crested wheatgrass monocultures are known to reduce both the density and diversity of native wildlife populations (Reynolds and Trost, 1980; Holechek, 1981). Therefore, it is desirable to understand the factors affecting succession in crested wheatgrass seedings and the management strategies that might be employed to hasten native revegetation.

Succession ultimately depends on whether a species replaces itself on a given site or is replaced by members of another species. This process is a function of two factors (Harper, 1977): 1) the propagule availability of the various species and 2) the environmental suitability for germination and growth of these propagules. Environmental suitability includes the presence

or absence of competition. Competition is here defined as the tendency of neighboring plants to utilize the same quantum of light, ion of mineral nutrient, molecule of water, or volume of space (Grime, 1977).

Seed dispersal by native species into a crested wheatgrass seeding is usually assumed to exist. Seed dispersal will refer to all propagules since fruits or even whole plants are frequently dispersed. Previous investigations have focused primarily on mechanisms associated with environmental suitability. The invasion of crested wheatgrass seedings by native species, and the seedings' resistance to invasion, are usually associated with competition (Clements, 1935; Robertson and Pearse, 1945; Blaisdell, 1949; Cook and Lewis, 1963; Frischknecht, 1963; Harris and Wilson, 1970; Hull and Klomp, 1974; Harris, 1977).

Competition can be a factor in the stability of crested wheatgrass only if native species are dispersed into the seedings. The assumption that a sufficient dispersal exists may not be justified. Little is known about seed dispersal, seed reserves, or seedling recruitment in common ecological situations (Harper, 1977). Some investigators argue that competition in field populations is still largely a product of faith rather than deduction from experiment (Connor and Simberloff, 1979; Antonovics, 1980).

Clearly, a knowledge of seed source, seed dispersal, and seed reserves is essential for addressing the questions about crested wheatgrass stability and succession. The objectives of this investigation were to: 1) assess the availability of native propagules within crested wheatgrass seedings and 2) determine the extent to which seed dispersal and seed reserves might influence the observed patterns of invasion by native species. This study indicates that native propagules were limited or unavailable for recruitment within crested wheatgrass seedings. Vegetal cover of dominant species was positively correlated with their seed reserves.

MATERIALS AND METHODS

Four study areas were established on the Idaho National Engineering Laboratory (INEL) during the summers of 1978 and 1979. Three were located on a remote section of the Site known as Tractor Flat. The Tractor Flat study areas will be referred to as TFA, TFB, and TFC. The fourth study area was located near the INEL Power Burst Facility and will be referred to as PBF.

Bureau of Land Management (BLM) records indicate that about 3600 ha of Tractor Flat was plowed and drilled to crested wheatgrass during the fall of 1956. The dominant vegetation prior to reseeding was big sagebrush (Artemisia tridentata Nutt.), green rabbitbrush (Chrysothamnus viscidiflorus (Hook.) Nutt.), bluebunch wheatgrass (Agropyron spicatum [Pursh] Scribn. & Smith), ryegrass (Elymus sp.), and intermixed annuals (BLM records). The plowing was estimated to have killed over 95% of the shrubs. The Tractor Flat seeding was first grazed by sheep in the fall of 1959, and has been moderately grazed each spring by sheep since 1959.

Approximately 100 ha of the PBF area was seeded to crested wheatgrass during the summer of 1960. The revegetation provided cover for an area where native vegetation had been killed by winter flooding (Reynolds and Trost, 1980). The frequency and severity of previous flooding is not known, but INEL vegetation maps suggest that previous flooding has occurred. The seeded area was typed an Elymus cinereus / Chrysothamnus viscidiflorus / Artemisia tridentata community, and the surrounding vegetation was typed an Artemisia tridentata / Chrysothamnus viscidiflorus / Sitanion hystrix community. Records are not available to document the seeding conditions or procedures. The PBF seeding has never been grazed by domestic livestock.

The native community and the adjacent crested wheatgrass seeding were sampled at each study area (Fig. 1). The study areas were selected so that the interface between the native community and the adjacent seeding was approximately perpendicular to the prevailing southwest to northeast wind directions. The crested wheatgrass portion of the PBF and TFB study areas appeared to be near monocultures. Invasion by native species was evident in the crested wheatgrass portion of the TFA and TFC plots. Each of the four study areas was 50 m in width, but their length varied from 115 to 550 m.

Dispersing seeds were captured in pitfall traps that were systematically placed in parallel rows on both sides of the native community / crested wheatgrass interface (Fig. 1). Six pitfall traps (#10 cans) were buried flush with the ground surface at 10 m intervals along each row. Each pitfall trap was lined with a plastic bag that was held open and in place by a wire loop. A wire mesh ladder was placed in each pitfall trap to help captured animals escape. There were 306 pitfall traps placed among the four study areas.

Bottlebrush squirreltail (Sitanion hystrix [Nutt.] Smith) was abundant in the native community of all study sites and is considered to be an excellent disperser (Hironaka and Tisdale, 1963). Seed counts were limited to Sitanion hystrix and to the monthly data collection that captured its peak dispersal during the summer of 1979. Florets with caryopsis development were considered fertile.

Seed reserves within the crested wheatgrass seedings and the adjacent native communities were assessed in the spring of 1979. Undisturbed topsoil was sampled to a depth of 6 cm with cylinders that were 15.2 cm in diameter. Paired samples, one from a bare area and the other from a littered area, were collected adjacent to each pitfall trap. The 612 samples were brought back to the laboratory and watered regularly. The seedlings that emerged were identified, counted, and removed from the samples. The seedling counts will be referred to as seed reserve data, but it should be noted that these data measured seedling emergence and indirectly measured seed reserves. Some seeds may have remained dormant, and not all the seeds that germinated necessarily emerged (Harper, 1977).

Vegetal cover and frequency data were collected during the summer of 1979. A 1 m x 0.5 m gridded sampling frame was used to estimate absolute cover. The grid system was divided into square decimeters. Sample points at each study area were systematically located along three transects (Fig. 1). There were over 1100 cover samples among the four study areas.

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Figure 1. The study plot design consisted of pitfall traps systematically placed along parallel rows on both sides of a native community / crested wheatgrass interface. Seed reserves were assessed from paired topsoil samples collected adjacent to each pitfall trap. Vegetal cover was systematically sampled on both sides of the interface along three transects.

Dominance-diversity curves (Whittaker, 1975) were graphed for the native community portion and the crested wheatgrass portion of each study area. Seedling emergence (No./m²) and absolute cover (dm²/m²) were used as importance-values. Data collected at the native community / crested wheatgrass interfaces could not be assigned to either the native community or the seeding and were therefore omitted from the dominance-diversity analyses.

Nonparametric statistical tests were chosen for the data analysis to avoid the assumption of normal distributions. The Wilcoxon signed ranks test (Sokal and Rohlf, 1973) was used to test a null hypothesis of no significant median difference in the number of seedlings emerging from clear and littered area samples. The number of species emerging was similarly tested. We predicted that a greater number of seedlings and species would emerge from littered area samples, so a one-tailed test was used ($p < 0.05$ level of significance).

Spearman's rank correlation (Zar, 1974), corrected for tied ranks (Scheffler, 1979), was used to test a null hypothesis of no association between vegetal cover and seed reserves (two-tailed, $p < 0.05$ level of significance). The vegetal cover and seed reserves of Sitanion hystrix were also tested for correlation with its seed dispersal. All nomenclature follows Hitchcock and Cronquist (1974).

RESULTS

Over 17,000 seedlings of 46 taxa were identified from the topsoil samples collected from the four study areas. Agropyron cristatum and Artemisia tridentata each contributed about 6500 seedlings to the total count. These two species and Sitanion hystrix were the three most important species in both the seed reserves and vegetal cover. Some 46 taxa were identified along the cover transects. The seed reserves had 36 (78%) of the taxa identified in the vegetal cover samples.

With two exceptions, the total number of species and the total number of seedlings were significantly ($p < 0.05$) greater in littered area as opposed to clear area samples. No difference was noted for the number of species emerging within the seeded portion of the TFA and TFB study areas. This was mainly a result of forb species emerging from clear area samples collected near disturbed sites. The sample size for the statistical test was also reduced in the TFA and TFB seedings since Agropyron cristatum was often the only species emerging from the paired samples.

The number of seedlings emerging and the seedling density of reserves within the native community and crested wheatgrass portion of each study area are listed in Table 1. The PBF study area was the only site with a greater seedling density in the native community than in the crested

Table 1. Number of seedlings emerging and the seedling density of reserves within the native community and crested wheatgrass portion of the Power Burst Facility (PBF) and Tractor Flat (TFA, TFB, TFC) study areas.

Study Area	CLEAR		LITTER		TOTAL	
	No.	No./m ²	No.	No./m ²	No.	No./m ²
PBF NATIVE	354	809	727	1660	1081	1230
PBF SEEDING	202	264	519	677	721	471
TFA NATIVE	175	320	836	1530	1011	924
TFA SEEDING	402	918	770	1760	1172	1340
TFB NATIVE	679	1240	828	1510	1507	1380
TFB SEEDING	526	1310	713	1780	1239	1540
TFC NATIVE	406	742	829	1510	1235	1130
TFC SEEDING	1295	1310	5042	5120	6337	3220

wheatgrass seeding. The relatively low seedling density within the PBF seeding is probably a result of its ungrazed status (Harper, 1977). The PBF native community also had the greatest number of forb species among the four study areas.

Dominance-diversity curves revealed a strong contrast between the native community and crested wheatgrass portions of the study areas. The native community at the PBF site had about twice the species richness of the PBF seeding for both cover and seed reserves (Fig. 2). Species richness was biased in favor of the PBF seeding since nearly three times more area within the seeding was sampled for cover, and about two times more area within the seeding was sampled for seed reserves. Artemisia tridentata ranked first in both cover and seed reserves of the native community, but several species were important. In contrast, Agropyron cristatum strongly dominated the PBF seeding with 95% of the cover and 92% of the seed reserves. The species invading the PBF seeding were primarily rhizomatous or deeply rooted.

Agropyron cristatum dominated the seed reserves throughout the PBF seeding (Fig. 3). The small areas of native seed reserve within the seeding were associated with invading plants rather than dispersal from the native community. Thus, native species were limited or unavailable for recruitment within the PBF seeding. They offered little if any competition to the recruitment of Agropyron cristatum seedlings.

Vegetal cover of Agropyron cristatum was closely correlated with its seed reserves at the PBF study area (Fig. 4). This suggests that the monocultural characteristic of the PBF seeding was related to Agropyron.

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Figure 2. Dominance-diversity curves for the Power Burst Facility (PBF) study area. The relative vegetal cover and relative seed reserves in percent for species in the native community are plotted in graphs A and B. Relative values for species within the crested wheatgrass seeding are plotted in graphs C and D.

cristatum's dominance of the seed reserves. Cover of Artemisia tridentata, Sitanion hystrix, and the other dominant species at the PBF site was also positively correlated with their seed reserves (Table 2). Positive correlations generally existed between cover and seed reserves of dominant species at the other study areas.

The dominance-diversity patterns at the TFB study area were similar to the patterns at the PBF site. Agropyron cristatum dominated the seeding with 93% of the cover and 85% of the seed reserves. Halogeton glomeratus Meyer and Lappula redowskii (Hornem.) Greene accounted for all but 2% of the remaining seed reserves within the TFB seeding. These annual forbs were primarily associated with disturbed areas.

Figure 3. Agropyron cristatum seed reserves and total seed reserves vs. distance from the Power Burst Facility (PBF) native community / crested wheatgrass interface. Native species were limited or unavailable for recruitment within the crested wheatgrass seeding.

The vegetation in the TFA and TFC seedings consisted almost entirely of Agropyron cristatum and deeply rooted or sprouting shrub species. Agropyron cristatum dominated the vegetation in each of these seedings with 73% of the cover. Artemisia tridentata was generally a co-dominant in both cover and seed reserves. The potential for recruitment of other native species was negligible since Agropyron cristatum and Artemisia tridentata accounted for 96% of the seed reserves within the TFA seeding and 97% of the reserves for the majority of the TFC seeding. A small portion of the TFC seeding was dominated by Halogeton glomeratus and Lappula redowskii. If these two annual forbs and the area they dominated are included, then 97% of the seed reserves for the entire TFC seeding were accounted for.

Figure 4. Agropyron cristatum vegetative cover and seed reserves vs. distance from the Power Burst Facility (PBF) native community / crested wheatgrass interface. Agropyron cristatum cover was positively correlated with its seed reserves ($r_s = 0.93$).

The pitfall traps placed among the four study areas captured over 40,000 florets of Sitanion hystrix (Table 3). About 12,000 of these florets were fertile. Less than 300 (2%) of the fertile florets were captured within the crested wheatgrass seedlings. The vegetative cover and seed reserves of Sitanion hystrix were positively correlated with its seed dispersal at all study sites. The patterns at the PBF site were similar to those at the other study areas (Fig. 5). Thus, the seed dispersal of Sitanion hystrix was limited despite an abundant seed source, and its actual distribution and potential for recruitment were significantly associated with its seed dispersal.

Table 2. Spearman's rank correlation test results for vegetal cover vs. seed reserves at the Power Burst Facility (PBF) study area. The taxa are ranked by the mean of their relative cover and relative seed reserves.

Rank	Taxa	Form	Mean	r_s
1.	<u>Agropyron cristatum</u>	Grass	53.24%	0.93**
2.	<u>Artemisia tridentata</u>	Shrub	20.47%	0.86**
3.	<u>Sitanion hystrix</u>	Grass	5.51%	1.00**
4.	<u>Gilia sinuata</u>	Forb	2.37%	0.74*
5.	<u>Descurainia pinnata</u>	Forb	2.17%	0.83**
6.	<u>Mentzelia albicaulis</u>	Forb	2.00%	0.71*
7.	<u>Eriastrum sparsiflorum</u>	Forb	1.84%	0.57
8.	<u>Lappula redowskii</u>	Forb	1.34%	0.82**
9.	<u>Elymus triticoides</u>	Grass	1.27%	0.21
10.	<u>Stipa comata</u>	Grass	0.88%	0.74*
11.	<u>Astragalus filipes</u>	Forb	0.66%	0.08
12.	<u>Descurainia sophia</u>	Forb	0.62%	0.66*
13.	<u>Poa sp.</u>	Grass	0.38%	0.73*
14.	<u>Erigeron pumilus</u>	Forb	0.35%	0.95**
15.	<u>Carex douglasii</u>	Sedge	0.25%	0.58
16.	<u>Phlox hoodii</u>	Forb	0.22%	0.69*
17.	<u>Gayophytum nuttallii</u>	Forb	0.20%	0.45
18.	<u>Oryzopsis hymenoides</u>	Grass	0.18%	0.45
19.	<u>Bromus tectorum</u>	Grass	0.14%	1.00**
20.	<u>Machaeranthera canescens</u>	Forb	0.12%	0.58
21.	<u>Tragopogon dubius</u>	Forb	0.07%	-0.15
22.	<u>Sphaeralcea munroana</u>	Forb	0.03%	-0.10

*Significant at $p < 0.05$ level.

**Significant at $p < 0.01$ level.

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Figure 5. Graph A: Seed dispersal and vegetal cover of Sitanion hystrix vs. distance from the Power Burst Facility (PBF) native community / crested wheatgrass interface. Sitanion hystrix cover was positively correlated with its seed dispersal ($r_s = 0.86$).

Graph B: Seed dispersal and seed reserves of Sitanion hystrix vs. distance from the PBF interface. Seed reserves of Sitanion hystrix were positively correlated with its seed dispersal ($r_s = 0.86$).

Table 3. Seed dispersal of *Sitanion hystrix* at the Power Burst Facility (PBF) and Tractor Flat (TFA, TFB, TFC) study areas. Florets captured in the native community and along the native community / crested wheatgrass interface are grouped. Florets with caryopsis development were considered fertile. Sterile florets were divided into lemma with palea and lemma only categories. The number of florets captured is listed. The mean number of florets captured per pitfall trap is given in parentheses.

STUDY AREA	FLORETS			TOTAL
	FERTILE	LEMMA & PALEA	LEMMA ONLY	
PBF NATIVE & INTERFACE	3930 (93.57)	4466 (106.33)	4167 (99.21)	12,563 (299.1)
PBF SEEDING	26 (0.62)	48 (1.14)	35 (0.83)	109 (2.6)
TFA NATIVE & INTERFACE	1053 (25.07)	2232 (53.14)	1751 (41.69)	5036 (119.9)
TFA SEEDING	23 (0.96)	36 (1.50)	15 (0.62)	74 (3.1)
TFB NATIVE & INTERFACE	1237 (29.45)	2411 (57.40)	1564 (37.24)	5212 (124.1)
TFB SEEDING	15 (0.62)	26 (1.08)	10 (0.42)	51 (2.1)
TFC NATIVE & INTERFACE	5890 (163.61)	7503 (208.42)	6909 (191.92)	20,302 (563.9)
TFC SEEDING	189 (3.50)	189 (3.50)	210 (3.89)	588 (10.9)
TOTAL	12,363 (40.4)	16,911 (55.3)	14,661 (47.9)	43,935 (143.6)

DISCUSSION

An unsuitable environment would be clearly responsible for the stability of the monocultural seedlings studied in this investigation if a potential for recruitment of native species existed within the seedlings. There was no test of competition since the native species had seed reserves that were too transient or insufficient to ensure an opportunity for their recruitment. Therefore, the results of this investigation do not support the assumption that competition was the factor of utmost importance governing the population distributions. This does not mean that competition was nonexistent or unimportant. Rather, the effects of competition were indeterminant since they were embedded within a limited distribution of native propagules.

The failure of native grasses to persist when sown in mixture with Agropyron cristatum suggests that ecological conditions are more important than the availability of native propagules. Success in mixtures is rarely correlated positively with seed yield in pure stands and seems to be determined more by vegetative attributes, such as plant size, leaf production, and root phenology than by reproductive attributes (Snaydon, 1980). The root phenology of Agropyron cristatum seedlings may give them an important competitive advantage over native grass seedlings (Harris and Wilson, 1970; Harris, 1977). Competition, however, is not the only factor of importance. Survival in a stressful environment is often more dependent on tolerance or dormancy than on competitive ability (Grime, 1977). Seed production is still extremely important in determining the success of a species sown in mixture (Jain and Marshall, 1967). Agropyron cristatum has an advantage over many of the native grasses in seed production (Harlan, 1960). Any physiological characteristic that favors the survival of Agropyron cristatum over native grasses is undoubtedly significant for the stability of crested wheatgrass seedings. Agropyron cristatum seems to have an advantage over native grasses in both vegetative and reproductive attributes.

Propagule availability and a suitable environment are necessary conditions for the establishment of a species, but neither by itself is sufficient. Assuming one factor to be more important than the other is subject to exception as various sites and ecological conditions are considered. Instead of assuming competition to be the factor of utmost importance governing the population distributions within crested wheatgrass seedings, it is reasonable to ask what effect the limited availability of native propagules may have on successional trends. The results of this study question the importance of the native community as a seed source for the reinvasion of seeded areas. The number of seeds deposited as a function of distance from a parent plant generally exhibits a negative exponential function (Cook, 1980). Even the achene-pappus dispersal of composites is usually very local and ineffective for long distance dispersal (Cook, 1980). Johnson and Payne (1968) reported that sagebrush plants adjacent to seedings were of no practical importance as a seed source for reinvasion.

Frischknecht and Bleak (1975) found that about 20% of the Artemisia tridentata plants reinvading a crested wheatgrass seeding had survived the revegetation treatment. Artemisia tridentata, Chrysothamnus viscidiflorus, and other species surviving a revegetation disturbance generally increase their seed production and become the primary seed source for the reestablishment of their species (Robertson and Pearse, 1945; Bleak and Miller, 1955; McKell and Chilcote, 1957; Robertson and Cords, 1957; Young and Evans, 1974). Native plants that survive a revegetation treatment are the most important factor related to the reinvasion of crested wheatgrass seedings (Johnson and Payne, 1968; Bartolome and Heady, 1978). The survival of dominant species is particularly important because they often lack persistent seed reserves (Cook, 1980).

There are several important implications for management. The nature of a disturbance and the differential survival of the vegetation are important factors in determining subsequent population distributions. Plants surviving a revegetation treatment are the primary seed source for the reestablishment of their species. Seed dispersal from a native community into a crested wheatgrass seeding is too transient or limited to ensure an opportunity for the recruitment of native species. This is especially true if large areas are seeded. Thus, a crested wheatgrass monoculture can be maintained with minimum effort if the native vegetation (including rhizomes, sprouting roots, and seed reserves) is initially eliminated from the seeded area. Crested wheatgrass monocultures may be helpful in the management of hazardous waste burial sites or other areas that must preclude deeply rooted species.

The vegetation surviving a strip mining disturbance will be primarily limited to species that persist in the seed reserves. These species are generally annuals and are often considered to be undesirable. Rhizomes and seeds of dominant species will perish if the topsoil is stored for long periods. If undesirable species establish, they will probably inhibit rather than facilitate further recruitment. Therefore, the removal of undesirable vegetation may be necessary for the establishment of desirable species.

Many of the native dominant species are dependent on specific populations of mycorrhizal fungi, and soil disturbance can reduce or eliminate these populations (Reeves et al., 1979). Propagules of mycorrhizal fungi must disperse from the native community if the fungi are eliminated from the disturbed area. The establishment of a crested wheatgrass monoculture provides only a limited host range for the fungi. Recruitment of native species will be inhibited by the lack of diversity in mycorrhizal fungi populations within a crested wheatgrass monoculture (Reeves et al., 1979).

Competition may play an important role in the stability of crested wheatgrass seedings, but it should not be assumed to be the factor of utmost importance simply by default. The limited dispersal from the native community and the abundant seed production of Agropyron cristatum also favor its persistence. If a successional trend exists, it is not sufficient for restoring the native vegetation to the many sites where this is desirable. Management strategies designed for the restoration of native habitat should not assume that a deterministic convergence to a native climax community exists. The probabilities of recruitment may favor Agropyron cristatum as a self-maintaining vegetation for prolonged periods. Chance favors the maintenance of the monoculture rather than its successional replacement.

A follow-up study will investigate the potential for seeding disturbed areas on the INEL with a mixture of native species. A demonstration reclamation plot will be seeded in the fall of 1982. Seedling emergence and establishment will be assessed. An experimental garden is being planned for establishing collections of INEL endemics and determining their potential for revegetation projects. The experimental garden will be used to assess

other species and varieties of native plants that are well adapted and potentially useful for INEL reclamation. Native species will also be interseeded or transplanted in a crested wheatgrass monoculture and the feasibility of the procedure examined. The long term objective of these projects is to eventually recommend an economic mixture of native species with a high probability of successful establishment.

LITERATURE CITED

- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *J. Range Manage.* 34:25-29.
- Antonovics, J. 1980. The study of plant populations. *Science* 208:587-589.
- Bartolome, J. W. and H. F. Heady. 1978. Ages of big sagebrush following brush control. *J. Range Manage.* 31:403-406.
- Blaisdell, J. P. 1949. Competition between sagebrush seedlings and reseeded grasses. *Ecology* 30:512-519.
- Bleak, A. T. and W. G. Miller. 1955. Sagebrush seedling production as related to time of mechanical eradication. *J. Range Manage.* 8:66-69.
- Clements, F. E. 1916. Plant succession. Publ. 242, Carnegie Inst. Wash., Washington, D.C., USA. 512 p.
- Clements, F. E. 1935. Experimental ecology in the public service. *Ecology* 16:342-363.
- Connell, J. H. and R. O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *Am. Nat.* 111:1119-1144.
- Connor, E. F. and D. Simberloff. 1979. Assembly of species communities: chance or competition? *Ecology* 60:1132-1140.
- Cook, C. W. and C. E. Lewis. 1963. Competition between big sagebrush and seeded grasses on foothill ranges in Utah. *J. Range Manage.* 16:245-250.
- Cook, R. E. 1980. The biology of seeds in the soil. P. 107-129. In O. T. Solbrig (ed.). *Demography and evolution in plant populations*. University of California Press, Berkeley, California, USA.
- Currie, P. O. 1970. Influence of spring, fall, and spring-fall grazing on crested wheatgrass range. *J. Range Manage.* 23:103-108.
- Currie, P. O. 1981. Revegetating mined land for grazing. *J. Soil and Water Cons.* 36:213-215.
- Dillman, A. C. 1946. The beginning of crested wheatgrass in North America. *J. Amer. Soc. Agron.* 38:237-250.

- Dormaar, J. F., A. Johnston, and S. Smoliak. 1980. Organic solvent-soluble organic matter from soils underlying native range and crested wheatgrass in southeastern Alberta, Canada. *J. Range Manage.* 33:99-101.
- Drury, W. H. and I. C. T. Nisbet. 1973. Succession. *J. Arn. Arbor.* 54:331-368.
- Eckert, R. E., Jr., A. T. Bleak, J. H. Robertson, and E. A. Naphan. 1961. Responses of Agropyron cristatum, A. desertorum, and other range grasses to three different sites in eastern Nevada. *Ecology* 42:775-783.
- Egler, F. E. 1954. Vegetation science concepts I. Initial floristic composition, a factor in old-field vegetation development. *Vegetatio* 4:412-417.
- Frischknecht, N. C. 1963. Contrasting effects of big sagebrush and rubber rabbitbrush on production of crested wheatgrass. *J. Range Manage.* 16:70-74.
- Frischknecht, N. C. and A. F. Bleak. 1957. Encroachment of big sagebrush on seeded range in northeastern Nevada. *J. Range Manage.* 10:165-170.
- Gleason, H. A. 1917. The structure and development of the plant association. *Bull. Torrey Bot. Club* 44:463-481.
- Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *Am. Nat.* 111:1169-1194.
- Harlan, J. R. 1960. Breeding superior forage plants for the great plains. *J. Range Manage.* 13:86-89.
- Harper, J. L. 1977. Population biology of plants. Academic Press, New York, New York, USA. 892 p.
- Harris, G. A. 1977. Root phenology as a factor of competition among grass seedlings. *J. Range Manage.* 30:172-177.
- Harris, G. A. and A. M. Wilson. 1970. Competition for moisture among seedlings of annual and perennial grasses as influenced by root elongation at low temperature. *Ecology* 51:530-534.
- Heady, H. F. 1975. Rangeland management. McGraw-Hill Book Co., New York, New York, USA. 460 p.
- Heinrichs, D. H. and J. L. Bolton. 1950. Studies on the competition of crested wheatgrass with perennial native species. *Sci. Agric.* 30:428-443.
- Hironaka, M. and E. W. Tisdale. 1963. Secondary succession in annual vegetation in southern Idaho. *Ecology* 44:810-812.

- Hitchcock, C. L. and A. Cronquist. 1974. Flora of the Pacific Northwest. University of Washington Press, Seattle, Washington, USA. 730 p.
- Holechek, J. L. 1981. Brush control impacts on rangeland wildlife. J. Soil & Water Cons. 36:265-269.
- Holechek, J. L., E. J. Depuit, J. G. Coenenberg, and R. Valdez. 1981. Fertilizer effects on establishment of two seed mixtures on mined land in southeastern Montana. J. Soil & Water Cons. 36:241-244.
- Hubbard, R. L. 1957. The effects of plant competition on growth and survival of bitterbrush seedlings. J. Range Manage. 10:135-137.
- Hull, A. C., Jr. 1971. Grass mixtures for seeding sagebrush lands. J. Range Manage. 24:150-152.
- Hull, A. C., Jr. and G. J. Klomp. 1966. Longevity of crested wheatgrass in the sagebrush-grass type in southern Idaho. J. Range Manage. 19:5-11.
- Hull, A. C., Jr. and G. J. Klomp. 1967. Thickening and spread of crested wheatgrass stands on southern Idaho ranges. J. Range Manage. 20:222-227.
- Hull, A. C., Jr. and G. J. Klomp. 1974. Yield of crested wheatgrass under four densities of big sagebrush in southern Idaho. Tech. Bull. No. 1483, Agricultural Research Service, U. S. Dept. of Agriculture. 38 p.
- Jain, S. K. and D. R. Marshall. 1967. Genetic changes in a barley population analysed in terms of some life cycle components of selection. Genetica 38:355-374.
- Johnson, J. R. and G. F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. J. Range Manage. 21:209-213.
- Lewis, G. E. 1969. Range management. In G. M. Van Dyne (ed.). The ecosystem concept in natural resource management. Academic Press, New York, New York, USA. 383 p.
- Looman, J. and D. H. Heinrichs. 1973. Stability of crested wheatgrass pastures under long-term pasture use. Can. J. Plant Sci. 53:501-506.
- McIntosh, R. P. 1967. The continuum concept of vegetation. Bot. Rev. 33:130-187.
- McKell, C. M. and W. W. Chilcote. 1957. Response of rabbitbrush following removal of competing vegetation. J. Range Manage. 10:228-230.
- Miles, J. 1979. Vegetation dynamics. Chapman and Hall, London, England. 80 p.

- Monsen, S. B. and A. P. Plummer. 1978. Plants and treatment for revegetation of disturbed sites in the intermountain area. P. 155-173. In R. A. Wright (ed.). The reclamation of disturbed arid lands. University New Mexico Press, Albuquerque, New Mexico, USA.
- Newell, L. C. 1955. Wheatgrass in west. Crops & Soils 8:7-9.
- Power, J. F., R. E. Ries, and F. M. Sandoval. 1978. Reclamation of coal-mined land in the northern great plains. J. Soil & Water Cons. 33:69-74.
- Reeves, F. B., D. Wagner, T. Moorman, and J. Kiel. 1979. The role of endomycorrhizae in revegetation practices in the semi-arid west. I. A comparison of incidence of mycorrhizae in severely disturbed vs. natural environments. Am. J. Bot. 66:6-13.
- Reynolds, T. D. and C. H. Trost. 1980. The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. J. Range Manage. 33:122-125.
- Robertson, J. H. 1972. Competition between big sagebrush and crested wheatgrass. J. Range Manage. 25:156-157.
- Robertson, J. H. and H. P. Cords. 1957. Survival of rabbitbrush, Chrysothamnus Spp., following chemical, burning, and mechanical treatments. J. Range Manage. 10:83-89.
- Robertson, J. H. and C. K. Pearse. 1945. Artificial reseeding and the closed community. NW. Sci. 19:58-66.
- Robertson, J. H., R. E. Eckert, Jr., and A. T. Bleak. 1966. Responses of grasses seeded in an Artemisia tridentata habitat in Nevada. Ecology 47:187-194.
- Scheffler, W. C. 1979. Statistics for the biological sciences. Addison-Wesley Publishing Co., Reading, Massachusetts, USA. 230 p.
- Schuman, G. E. 1980. Production, composition and longevity of crested wheatgrass/native grass mixture. In Abstracts and position statements. Society for Range Management, 33rd Annual Meeting. 55 p.
- Smoliak, S., A. Johnston, and L. E. Lutwick. 1967. Productivity and durability of crested wheatgrass in southeastern Alberta. Can. J. Plant Sci. 47:539-548.
- Snaydon, R. W. 1980. Plant demography in agricultural systems. In O. T. Solbrig (ed.). Demography and evolution in plant populations. University of California Press, Berkeley, California, USA. 222 p.
- Soil Conservation Society of America. 1980. Surface mine reclamation: a position statement by the Soil Conservation Society of America. J. Soil & Water Cons. 35(suppl.):1-6.

- Sokal, R. R. and F. J. Rohlf. 1973. Introduction to biostatistics. W. H. Freeman and Co., San Francisco, California, USA. 368 p.
- Stiller, D. M., G. L. Zimpfer, and M. Bishop. 1980. Application of geomorphic principles to surface mine reclamation in the semiarid west. J. Soil & Water Cons. 35:274-277.
- Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range management. McGraw-Hill Book Co., New York, New York, USA. 532 p.
- Utah State University Ecology Center. 1981. Project to study effects of grazing defoliation. Ecotone 10:1.
- Van Dyne, G. M. 1969. The ecosystem concept in natural resource management. Academic Press, New York, New York, USA. 383 p.
- Whittaker, R. H. 1953. A consideration of climax theory: the climax as a population and pattern. Ecol. Monogr. 23:41-78.
- Whittaker, R. H. 1975. Communities and ecosystems. MacMillan Publishing Co., New York, New York, USA. 385 p.
- Young, J. A. and R. A. Evans. 1974. Population dynamics of green rabbit-brush in disturbed big sagebrush communities. J. Range Manage. 27:127-132.
- Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey, USA. 620 p.

IDAHO NATIONAL ENGINEERING LABORATORY
VEGETATION DATA FILE

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ABSTRACT

This report explains and describes the format of a computerized file of vegetation data from three studies conducted on the Idaho National Engineering Laboratory. The major objective of this project was to produce an error-free computerized record of the long term vegetation data from the macrotransects that were established in 1950. The data are stored on magnetic tape. A list of the scientific names that correspond to the species codes used in the data file is included.

INTRODUCTION

Collection of vegetal information from the Idaho National Engineering Laboratory (INEL) was begun in 1950 with the establishment of 99 permanent sample plots at 1.6 km (1 mile) intervals along two perpendicular "macrotransects" that bisect the area from north to south and from east to west. Additional plots, numbered 100 - 149, were established in 1957 to sample vegetation types that were not intersected by the macrotransects. Plot locations and a description of the plot layout and data collection techniques can be found in Harniss (1968) and Anderson et al. (1978). Approximate plot locations are shown on the INEL Environmental Monitoring Map.

Data from the macrotransect plots were collected in 1950, 1957, 1965, 1975, and 1978. Data from plots numbered 102 and above were collected only in 1957 and 1965. Only 38 plots were read in 1978. These data will be referred to collectively as the Long Term Vegetation (LTV) data.

In 1976, LTV data were keypunched onto IBM cards. Subsequently, these computerized data were used for vegetation trend studies (Anderson et al., 1978, Anderson and Holte, 1981). While completing the trend studies, we became aware of numerous transcription errors resulting in false data on the IBM cards. Further, we discovered numerous inconsistencies in the way that data were recorded and compiled from one sampling year to another.

The present project was undertaken to develop an error-free permanent record of the data from the LTV plots. The data set is stored on a nine-track 1600 BPI ASCII magnetic tape; copies of the tape are on file at Idaho State University and at the Radiological and Environmental Sciences Laboratory, INEL. A printout of the final data file was proofread against the original data sheets. Important idiosyncrasies of each data subset for each of the five sampling years are identified and discussed herein. In addition, data from two other vegetation studies on the INEL are included on the tape and described in this report.

LONG TERM VEGETATION PLOT DATA

The format for the LTV data is as follows: Each line or record contains information for a single plant species from one plot for one sample year. The first three columns in each record identify the plot number (Table 1). The date on which the data were collected is listed in columns 5 - 10. Columns 12 - 18 contain a seven character code for the plant genus and species (Table 2). The letters "sp" followed by two blanks in columns 15 - 18 indicate that the plant was identified to genus only.

The quantitative data are recorded in columns 19 - 78. Three different measures have been used; the type of data is indicated in column 80. A "1" in column 80 indicates density data; a "2" indicates line interception (cover) data; a "3" indicates cover class data.

For each density record there are 20 fields of data; each field is three columns wide (columns 19 - 78). The number in each field corresponds to the total number of individuals of that species found in each of the 20 0.3-m² density quadrats at that plot (see Anderson et al., 1978 for plot layout).

Cover class records also have 20 data fields, and each field is three columns wide. The number in each field corresponds to a coverage class as described by Daubenmire (1959). Cover class data were gathered only for 38 plots in 1978.

The line interception data contain considerable year-to-year variation in method of recording the information. Units of measure have been different, and the length of line actually read has varied due to inadvertant destruction of sample lines or portions of them over the years. There were instances when researchers chose not to record data because of rocky conditions on a particular site. Also, the number of significant digits in the line interception data has varied among the five sample periods. These incongruities can be readily accomodated with simple mathematical transformations. The line interception data have been left in a form identical to that on the original data sheets. If questions should arise in the future, the data are directly comparable to that on the raw data sheets. Because of the variation, the line interception data for each sample year are described separately.

Each line interception record lists the amount of a 30.48 m (100 ft) line intercepted by a plant species on an individual plot (Anderson et al., 1978). Data from the years 1950, 1957, and 1965 were recorded as the total interception on four 7.62 m (25 ft) lines. Thus, for these three sampling years, the line interception records are four fields wide. The standard Fortran format for the 1950 data is 4 F5.1; for 1957 it is 4 F4.2; for 1965 it is 4 F4.1. The unit of measure recorded for these three years is feet.

For 1975, the line interception records are two fields wide. Each contains the amount of interception in inches (2.54 cm) along a 50 ft (15.24 m) line. The format is 2 F8.4. The line interception records for 1978 are only one field wide and record cm of intercept per 30.48 m (100 ft) of line.

Table 1. Examples of the three types of LTV vegetal data: (A) = density data, (B) = line interception data, (C) = cover class data. Format for line interception data varies from year to year; see text for details.

	Plot Number	Date	Species Code	Quantitative Fields															Type of Data
(A)	048	072650	AGRDASY	1	2	9	30	21	10	6	25	4	3	3	6	2	1	1	
(B)	103	080557	ARTTRID	1.271.314.143.62														2	
(C)	088	072578	ARTTRID	5		5	4	3	3	3	3	6	2	4	3	2	4	1 3	

Table 2. Computer codes for plant species and other entities.

ACEGLAB	<u>Acer glabrum</u> Torr.
ACHMILL	<u>Achillea millefolium</u> L.
AGAURTI	<u>Agastache urticifolia</u> (Benth.) Kuntze
AGOGLAU	<u>Agoseris glauca</u> (Pursh) Raf.
AGOSP	<u>Agoseris</u> species Raf.
AGRCRIS	<u>Agropyron cristatum</u> (L.) Gaertn.
AGRDAY	<u>Agropyron dasytachyum</u> (Hook.) Scribn.
AGRSMT	<u>Agropyron smithii</u> Rydb.
AGRSP	<u>Agropyron</u> species Gaertn.
AGRSPIC	<u>Agropyron spicatum</u> (Pursh) Scribn. & Smith
ALLSP	<u>Allium</u> species L.
AMBACAN	<u>Ambrosia acanthicarpa</u> Hook.
ANTDIMO	<u>Antennaria dimorpha</u> (Nutt.) T. & G.
ANTMICR	<u>Antennaria microphylla</u> Rydb.
ANTSP	<u>Antennaria</u> species Gaertn.
AOSSP	Undecipherable species
ARAHOLB	<u>Arabis holboellii</u> Hornem.
ARALIGN	<u>Arabis lignifera</u> Nels.
ARASP	<u>Arabis</u> species L.
ARECONG	<u>Arenaria congesta</u> Nutt.
AREFRAN	<u>Arenaria franklinii</u> Dougl.
ARENUTT	<u>Arenaria nuttallii</u> Pax.
ARESP	<u>Arenaria</u> species L.
ARIFEND	<u>Aristida fendleriana</u> Steud.
ARILONG	<u>Aristida longiseta</u> Steud.
ARISP	<u>Aristida</u> species L.
ARTARBU	<u>Artemisia arbuscula</u> Nutt.
ARTCANA	<u>Artemisia cana</u> Pursh
ARTNOVA	<u>Artemisia nova</u> (A. Nels.) Cronq.
ARTSP	<u>Artemisia</u> species L.
ARTTRID	<u>Artemisia tridentata</u> Nutt.
ARTTRIP	<u>Artemisia tripartita</u> Rydb.
ASCSPEC	<u>Asclepias speciosa</u> Torr.
ASTCERA	<u>Astragalus ceramicus</u> Sheld.
ASTCONV	<u>Astragalus convallarius</u> Greene
ASTCURV	<u>Astragalus curvicaupus</u> (A. Hell.) Macbr.
ASTCUSI	<u>Astragalus cusickii</u> Gray
ASTFILI	<u>Astragalus filipes</u> Torr.
ASTGEYE	<u>Astragalus geyeri</u> Gray
ASTLENT	<u>Astragalus lentiginosus</u> Dougl.
ASTMISE	<u>Astragalus miser</u> Dougl.
ASTPURS	<u>Astragalus purshii</u> Dougl.
ASTSP	<u>Astragalus</u> species L.
ASTSP1	<u>Astragalus</u> species #1
ASTSP2	<u>Astragalus</u> species #2
ATRCANE	<u>Atriplex canescens</u> (Pursh) Nutt.
ATRCNF	<u>Atriplex confertifolia</u> (Torr. & Frem.) Wats.
ATRNUTT	<u>Atriplex nuttallii</u> Wats.
ATRSP	<u>Atriplex</u> species L.

Table 2 (continued).

ATRSPIN	<u>Atriplex spinosa</u> (Hook.) Collotzi
BALSAGI	<u>Balsamorhiza sagittata</u> (Pursh) Nutt.
BARGROU	Bare ground
BROTECT	<u>Bromus tectorum</u> L.
CALELEG	<u>Calochortus elegans</u> Pursh
CALSP	<u>Calochortus</u> species Pursh
CARSP	<u>Carex</u> species L.
CASANGU	<u>Castelleja angustifolia</u> (Nutt.) G. Don
CASCHRO	<u>Castelleja chromosa</u> A. Nels.
CASSP	<u>Castelleja</u> species Mutis ex L.F.
CEAVELU	<u>Ceanothus velutinus</u> L.
CERLANA	<u>Ceratoides lanata</u> (Pursh) J. T. Howell
CHADOUG	<u>Chaenactis doglasii</u> (Hook.) H. & A.
CHASP	<u>Chaenactis</u> species DC.
CHEALBU	<u>Chenopodium album</u> L.
CHESP	<u>Chenopodium</u> species L.
CHRNAUS	<u>Chrysothamnus nauseosus</u> (Pall.) Britt.
CHRSP	<u>Chrysothamnus</u> species L.
CHRVICI	<u>Chrysothamnus vicsidiflorus</u> (Hook.) Nutt.
CIRSP	<u>Cirsium</u> species Mill.
COLNUTT	<u>Coldenia nuttallii</u> Hook.
COLSP	<u>Collinsia</u> species Nutt.
COLTENE	<u>Collomia tenella</u> Gray
COMSP	Unknown Compositae
COMUMBE	<u>Comandra umbellata</u> (L.) Nutt.
CORSP	<u>Cordylanthus</u> species Nutt.
CREACUM	<u>Crepis acuminata</u> Nutt.
CRERUNC	<u>Crepis runcinata</u> (James) T. & G.
CRESP	<u>Crepis</u> species L.
CRUSP	Unknown Cruciferae
CRYAFFI	<u>Cryptantha affinis</u> (Gray) Greene
CRYCIRC	<u>Cryptantha circumsicissa</u> (H. & A.) Johnst.
CRYINTE	<u>Cryptantha interrupta</u> (Greene) Pays.
CRYSP	<u>Cryptantha</u> species Lehm.
CYSSP	<u>Cystopteris</u> species Bernh.
DANSP	<u>Danthonia</u> species Lam. & DC.
DEASHRU	Dead shrub
DELANDE	<u>Delphinium andersonii</u> Gray
DELNUTT	<u>Delphinium nuttalianum</u> Pritz.
DESSOPH	<u>Descurainia sophia</u> (L.) Webb
DESSP	<u>Descurainia</u> species Webb & Berth.
DRAVERN	<u>Draba verna</u> L.
ELYAMBI	<u>Elymus ambiguus</u> Vasey & Scribn.
ELYCINE	<u>Elymus cinereus</u> Scribn. & Merr.
ELYSP	<u>Elymus</u> species L.
ELYTRIT	<u>Elymus triticoides</u> Buckl.
EPIALPI	<u>Epilobium alpinum</u> L.
EPISP	<u>Epilobium</u> species L.
ERICERN	<u>Eriogonum cernuum</u> Nutt.
ERIDIVE	<u>Erigeron divergens</u> T. & G.
ERIFILI	<u>Erigeron filifolius</u> Nutt.
ERIFOLI	<u>Erigeron foliosus</u> Nutt.
ERIGSP	<u>Erigeron</u> species L.

Table 2 (continued).

ERIHERA	<u>Eriogonum heracleoides</u> Nutt.
ERIHUMI	<u>Erigeron humilis</u> Graham
ERIMICR	<u>Eriogonum microthecum</u> Nutt.
ERIOSP	<u>Eriogonum</u> species Michx.
ERIOVAL	<u>Eriogonum ovalifolium</u> Nutt.
ERIPUMI	<u>Erigeron pumilus</u> Nutt.
ERISPAR	<u>Eriastrum sparsiflorum</u> (Eastw.) Mason
ERIUMBE	<u>Eriogonum umbellatum</u> Torr.
FERSP	Unknown fern
FESIDAH	<u>Festuca idahoensis</u> Elmer
FESOCTO	<u>Festuca octoflora</u> Walt.
FESSP	<u>Festuca</u> species L.
FRIPUDI	<u>Fritillaria pudica</u> (Pursh) Spreng.
GALAPAR	<u>Galium aparine</u> L.
GALASPE	<u>Galium asperrimum</u> Gray
GALBIFO	<u>Galium bifolium</u> Wats.
GAYRAMO	<u>Gayophytum ramosissimum</u> Nutt.
GAYSP	<u>Gayophytum</u> species Juss.
GILCONG	<u>Gilia congesta</u> Hook.
GILLEPT	<u>Gilia leptomeria</u> Gray
GILSP	<u>Gilia</u> species R. & P.
HALGLOM	<u>Halogeton glomeratus</u> C. A. Meyer
HAPACAU	<u>Haplopappus acaulis</u> (Nutt.) Gray
HAPNANU	<u>Haplopappus nanus</u> (Nutt.) Eat.
HAPRESI	<u>Haplopappus resinosus</u> (Nutt.) Gray
HAPSP	<u>Haplopappus</u> species Cass.
HESKING	<u>Hesperochloa kingii</u> (Wats.) Rydb.
HOLDUMO	<u>Holdiscus dumosus</u> (Hook.) Heller
HYDSP	<u>Hydrophyllum</u> species L.
IVAAXIL	<u>Iva axillaris</u> Pursh
JUNOSTE	<u>Juniperus osteosperma</u> (Torr.) Little
JUNSP	<u>Juniperus</u> species L.
KOCAMER	<u>Kochia americana</u> Wats.
KOECRIS	<u>Koeleria cristata</u> Pers.
LACSERR	<u>Lactuca serriola</u> L.
LACSP	<u>Lactuca</u> species L.
LAPREDO	<u>Lappula redowski</u> (Hornem.) Greene
LAPSP	<u>Lappula</u> species Gilib
LATSP	<u>Lathyrus</u> species L.
LEPPUNG	<u>Leptodactylon pungens</u> (Torr.) Nutt.
LIGSP	<u>Ligusticum</u> species L.
LITSP	<u>Lithophragma</u> species Nutt.
LITTER	Litter
LOMDISS	<u>Lomatium dissectum</u> (Nutt.) Math. & Const.
LOMFOEN	<u>Lomatium foeniculaceum</u> (Nutt.) Coult. & Rose
LOMMACR	<u>Lomatium macrocarpum</u> (Nutt.) Coult. & Rose
LOMSP	<u>Lomatium</u> species Raf.
LOMTRIT	<u>Lomatium triternatum</u> (Pursh) Coult. & Rose
LUPSERI	<u>Lupinus sericeus</u> Pursh
LUPSP	<u>Lupinus</u> species L.
LYGGRAN	<u>Lygodesmia grandiflora</u> (Nutt.) T. & G.
LYGJUNC	<u>Lygodesmia juncea</u> (Pursh) D. Don
LYGSP	<u>Lygodesmia</u> species D. Don

Table 2 (continued).

LYGSPIN	<u>Lygodesmia spinosa</u> Nutt.
MENALBI	<u>Mentzelia albicaulis</u> Dougl.
MENLAEV	<u>Mentzelia laevicaulis</u> (Dougl.) T. & G.
MENSP	<u>Mentzelia</u> species L.
MITSP	<u>Mitella</u> species L.
MOLVERT	<u>Mollugo verticillata</u> L.
NAMDENS	<u>Nama densum</u> Lemmon
NAVSP	<u>Navarretia</u> species R. & P.
OENBOOT	<u>Oenothera boothii</u> Dougl.
OENCAES	<u>Oenothera caespitosa</u> Nutt.
OENSCAP	<u>Oenothera scapoidea</u> Nutt.
OENSP	<u>Oenothera</u> species L.
OPUPOLY	<u>Opuntia polyacantha</u> Haw.
OROFASC	<u>Orobanche fasciculata</u> Nutt.
ORTSP	<u>Orthocarpus</u> species Nutt.
ORYHYME	<u>Oryzopsis hymenoides</u> (R. & S.) Ricker
PENSP	<u>Penstemon</u> species Mitch.
PHAHAST	<u>Phacelia hastata</u> Dougl.
PHAHETE	<u>Phacelia heterophylla</u> Pursh
PHASP	<u>Phacelia</u> species Juss.
PHLHOOD	<u>Phlox hoodii</u> Rich.
PHLLONG	<u>Phlox longifolia</u> Nutt.
PHLSP	<u>Phlox</u> species L.
PHLSP1	<u>Phlox</u> species #1
PHLSP2	<u>Phlox</u> species #2
PINCONT	<u>Pinus contorta</u> Dougl.
PLAHIST	<u>Plagiobothrys hispidus</u> Gray
PLANSP	<u>Plantago</u> species L.
POACOMP	<u>Poa compressa</u> L.
POAFEND	<u>Poa fendleriana</u> (Steud.) Vasey
POAJUNC	<u>Poa juncifolia</u> Scribn.
POANEVA	<u>Poa nevadensis</u> Vasey
POAPRAT	<u>Poa pratensis</u> L.
POASAND	<u>Poa sandbergii</u> Vasey
POASP	<u>Poa</u> species L.
POLDOUN	<u>Polygonum douglasii</u> Greene
POLSP	<u>Polygonum</u> species L.
POPTREM	<u>Populus tremuloides</u> Michx.
POTGLAN	<u>Potentilla glandulosa</u> Lindl.
PSEMENZ	<u>Pseudotsuga menziesii</u> (Mirbel) Franco.
PSOLANC	<u>Psoralea lanceolata</u> Pursh
PSOSP	<u>Psoralea</u> species L.
PURTRID	<u>Pursia tridentata</u> (Pursh) DC.
RIBCERE	<u>Ribes cereum</u> Dougl.
RIBSP	<u>Ribes</u> species L.
ROCKS	Rocks
RUMSP	<u>Rumex</u> species L.
SALKALI	<u>Salsola kali</u> L.
SAPSP	Unknown saprophyte
SARVERM	<u>Sarcobatus vermiculatus</u> (Hook.) Torr.
SAXSP	<u>Saxifraga</u> species L.
SCHLINI	<u>Schoenocrambe linifolia</u> (Nutt.) Greene

Table 2 (continued).

SEDSTEN	<u>Sedum stenopetalum</u> Pursh
SILDOUG	<u>Silene douglasii</u> Hook.
SILSCOU	<u>Silene scouleri</u> Hook.
SILSP	<u>Silene species</u> L.
SISALTI	<u>Sisymbrium altissimum</u> L.
SITHYST	<u>Sitanion hystrix</u> (Nutt.) J. G. Smith
SMISP	<u>Smilacina species</u> Desf.
SPHMUNR	<u>Sphaeralcea munroana</u> (Dougl.) Spach.
SPHSP	<u>Sphaeralcea species</u> St. Hil.
STAVIRI	<u>Stanleya viridiflora</u> Nutt.
STESP	<u>Stephanomeria species</u> Nutt.
STETENU	<u>Stephanomeria tenuifolia</u> (Torr.) Hall
STICOMA	<u>Stipa comata</u> Trin. & Rupr.
STILETT	<u>Stipa lettermanii</u> Vasey
STIOCCI	<u>Stipa occidentalis</u> Thurb.
STISP	<u>Stipa species</u> L.
STITHUR	<u>Stipa thurberiana</u> Piper
SUNSP	Uncipherable record
SYMOREO	<u>Symphoricarpos oreophilus</u> Gray
TETCANE	<u>Tetradymia canescens</u> D.D.
TETGLAB	<u>Tetradymia glabrata</u> Gray
THELACI	<u>Thelypodium laciniatum</u> (Hook.) Endl.
TOWFLOR	<u>Townsendia florifer</u> (Hook.) Gray
TOWSP	<u>Townsendia species</u> Hook.
TRADUBI	<u>Tragopogon dubius</u> Scop.
UNKCOMP	Unknown Compositae
UNKGRAS	Unknown grass
UNKLEGU	Unknown Leguminosae
UNKNOWN	Unknown genus and species
UNKNOWN1	Unknown #1
UNKNOWN2	Unknown #2
UNKNOWN3	Unknown #3
UNKNOWN4	Unknown #4
VICSP	<u>Vicia species</u> L.
VIOPURP	<u>Viola purpurea</u> Kell.
VIOSP	<u>Viola species</u> L.
XANSARO	<u>Xanthocephalum sarothrae</u> Shinnars
ZIGPANI	<u>Zigadenus paniculatus</u> Wats.
ZIGVENE	<u>Zigadenus venenosus</u> Wats.

There are numerous cases where the line interception data for individual plots was incomplete (Table 3). This was true for every sample year except 1978. Future users should note the idiosyncrasies (Table 3), and then refer to the raw data sheets to learn the reasons for the incomplete record. It should be noted that the actual data were collected from two parallel 15.24 m (50 ft) lines, regardless of whether the data were recorded as coming from four 7.62 m lines, two 15.24 m lines, or one 30.48 m line. Information on the fate of some of the original plots can be found in Harniss (1968).

Table 3. Number and length of lines read per plot by year for the line interception data from the macrotransect plots.

YEAR	NO. LINES/PLOT & LINE LENGTH	PLOT NUMBERS INVOLVED
1950	1 ----- 25 ft	33
	2 ----- 25 ft	4, 5, 6, 13, 52, 60, 66 - 70
	3 ----- 25 ft	29
	4 ----- 25 ft	all others
1957	2 ----- 25 ft	1, 4, 5, 6, 10, 52
	4 ----- 25 ft	all others
1965	1 ----- 25 ft	25, 70
	2 ----- 25 ft	9, 10, 52
	3 ----- 25 ft	98
	4 ----- 25 ft	all others
1975	2 ----- 50 ft	all plots listed
1978	2 ----- 50 ft	all plots listed

EXCLOSURE PLOTS

During the summer of 1979, two clusters of enclosure plots were established on the INEL. Details of plot layout and methods of data collection can be found in Anderson and Johnson (this volume); a brief summary follows: One cluster is located near the intersection of Road T-9 and East Monument Road; plots in this cluster are designated "RM". The second cluster is located along Road T-4 to the north of Tractor Flat; these plots are designated "TF". Each cluster consists of six pairs of plots, numbered 1a, 1b, 2a, 2b, ..., 6b. Pairs were subjectively chosen to be as similar vegetatively as possible, and one member of each pair was randomly chosen to be fenced with a rabbit-proof enclosure. The open plots in the TF cluster were fenced as well, but only to exclude livestock and not rabbits. Enclosure plots are RM 1a, 2b, 3a, 4a, 5b, 6a; TF 1a, 2b, 3b, 4a, 5b, 6b.

The record format for the exclosure data is essentially the same as that for the LTV data, with two exceptions. The date is only two columns wide, listing only the year of data collection. Thus the species code and quantitative data are shifted four columns to the left. An "RM" or "TF" in columns 79 and 80 identify the exclosure cluster. The quantitative data is only one field wide and records the absolute cover for that species in cm² summed across the 15 m² quadrats of that plot.

COYOTE HABITAT STUDY

The final data set included on the tape is from a study of coyote habitats on the INEL (Wilkosz 1980). Data from this study is identified by C/V (coyote/vegetation) in columns 78 - 80. Otherwise, the format is identical to that of the exclosure data. The quantitative data are one field wide and record the average percent cover for that species on that plot. Details of the sampling methods and data analysis can be found in Wilkosz (1980). The legal descriptions of the 22 plots are found in Appendix B of Wilkosz (1980).

LITERATURE CITED

- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *J. Range Manage.* 34:25-29.
- Anderson, J. E., R. J. Jeppson, R. J. Wilkosz, G. M. Marlette, and K. E. Holte. 1978. Trends in vegetation development on the Idaho National Engineering Laboratory Site. p. 144-166. In *Ecological Studies on the Idaho National Engineering Laboratory Site T978 Progress Report*, IDO-12087 Nat. Tech. Inf. Serv., Springfield, VA.
- Daubenmire, R. F. 1959. A canopy-coverage method of vegetation analysis. *Northwest Sci.* 33:43-64.
- Harniss, R. O. 1968. Vegetation changes following livestock exclusion on the National Reactor Testing Station, southeastern Idaho. M.S. Thesis. Utah State University, Logan. 164 p.
- Wilkosz, R. J. 1980. Coyote habitat preferences on the Idaho National Engineering Laboratory Site in southeastern Idaho. M.S. Thesis. Idaho State University, Pocatello. 111 p.

SAGEBRUSH DISTRIBUTIONS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Mark L. Shumar

ABSTRACT

Sagebrush shrubs of the genus Artemisia are dominant in vegetation on many western rangelands. At least six shrub species of the genus and three subspecies of Artemisia tridentata are found on rangelands of the upper Snake River Plain in southeast Idaho. This project produced a map showing the approximate distributions of species and subspecies of Artemisia on the central and eastern portions of the Idaho National Engineering Laboratory in southeastern Idaho. Sagebrush samples were collected along roads and trails within the Site boundary and taken to the laboratory for identification. Three species of Artemisia and two subspecies of A. tridentata have been collected and identified to date. The distributions of A. tridentata subspecies tridentata and A. tridentata subspecies wyomingensis form a complex pattern on eastern portions of the INEL. A. nova and A. tripartita have also been encountered. Plans for future sampling are discussed.

INTRODUCTION

Sagebrush shrubs of the genus Artemisia are dominant in vegetation on many western rangelands. Sagebrush occupies over 1.09×10^8 ha (422,000 sq. miles) in the 11 western states (Beetle, 1960). At least six shrub species of the genus Artemisia and three subspecies of Artemisia tridentata are found on rangelands of the upper Snake River Plain in southeast Idaho. They are: Artemisia arbuscula, A. frigida, A. spinescens, A. tridentata subspecies tridentata (ATT), A. tridentata subspecies wyomingensis (ATW), A. tridentata subspecies vaseyana (ATV), A. tripartita, and A. nova (Jeppson and Holte, 1978). Their distributions are affected by climatic and edaphic factors. Hironaka (1978) suggests that ATT is found on "deep soils" with "low to moderate precipitation" and ATW is found on moderately deep soils with "low to moderate precipitation at lower elevations". A. nova is usually associated with shallow soils that are calcareous or limestone derivatives (Hironaka, 1978; Beetle, 1978). A. arbuscula occurs on shallow soils that are slightly more moist and cooler than soils supporting stands of A. nova (Hironaka, 1978). A. tripartita occupies deeper soils, steeper slopes and moister aspects than ATW (Hironaka, 1978; Lovejoy, 1980). Brunner (1972) found A. spinescens only in alkaline areas.

The site factors that affect distributions of sagebrush are relatively consistent for each species or subspecies; therefore, information about distributions of these taxa is indicative of differences in soil type and soil moisture content.

The purpose of this project was to develop a map showing the approximate distributions of species and subspecies of sagebrush on the INEL in southeastern Idaho. This map will serve as a reference for future ecological research on the Site and as a starting point for an investigation of site differences related to spacial patterns in the distribution of these sagebrush taxa (Shumar, this volume).

METHODS AND MATERIALS

The INEL is located on the upper Snake River Plain near the southeastern ends of the Lost River and Lemhi mountain ranges. Average annual precipitation of the Site is 21 cm, and the mean annual temperature is about 5.5 C (Anderson and Holte, 1981). The vegetation is predominantly sagebrush-bunchgrass associations.

Several paved highways and roads cross the Site and numerous unpaved roads and trails traverse much of the area (Fig. 1). These provide relatively easy access to most portions of the INEL. Between February and

Figure 1. Sagebrush distributions on the central and eastern portions of the Idaho National Engineering Laboratory Site. Distributions are inferred from roadside sampling (see text). Solid lines inside the Site boundary are paved roads; dashed lines are unpaved roads and trails.

June, 1980, sagebrush samples were collected along roads and trails within the INEL boundary. At half-mile intervals from predetermined starting points, branches were collected from every apparently different sagebrush taxon that occurred within approximately 25 m of the road. The sample points were recorded on topographic maps at the time of sampling.

The sagebrush samples were taken to the laboratory and identified to species using morphological characteristics such as plant height, growth form (both recorded in the field) and leaf morphology (McArthur et al., 1979; Winward and Tisdale, 1977). The subspecies of A. tridentata were determined by ultraviolet spectrophotometry (Shumar et al., 1982).

RESULTS AND DISCUSSION

Three species of Artemisia and two subspecies of A. tridentata have been collected and identified on the INEL. The distributions of ATT and ATW form a complex pattern on the central and eastern portions of the Site (Fig. 1). Although the collections have been limited to roadsides, some impression of the actual distributions between roads is apparent. ATT appears to be the only form growing on an area that extends from the end of Tractor Flat Road (T-4) to the southwest and includes most of the area adjacent to EBR II Road (T-22) and part of Birch Creek Road (T-23) (Fig. 1). To the west and south of this area, an area is found where ATT and ATW occur together. There are small pockets of ATT north and east of SPERT, on sand dunes along Canal Road just south of Circular Butte, and on the west end of Shell Road. Similar isolated stands probably occur over much of the Site.

Stands of A. nova mixed with ATW occur near the junction of Route 33 and Lincoln Blvd., along the western borders of the Site, and north of Circular Butte. A. tripartita exists on the south end of Tractor Flat Road and on the lower slopes of East, Middle, and Big Southern Buttes.

Sagebrush samples have been collected, but not yet identified, for most of the area bordered by Route 33 to the north and west, Lincoln Blvd. to the east, and U.S. Routes 20/26 to the south. The "panhandle region", north of Route 33, the area south of Routes 20/26 (Fig. 1), and the north-south macrotransect line (Anderson et al., 1978) have not yet been sampled. McBride et al. (1978) reported that A. arbuscula occurred in the northern "panhandle", but this species was not encountered in this study. A. arbuscula was also recorded in the data from some of the macrotransect plots (Wilkosz and Anderson, this volume); however, I have been unable to confirm its occurrence on these plots.

Sagebrush distribution patterns are important to land managers because of differences in both palatability and response to control among taxa (Winward, 1970; McDonough et al., 1975; Frischknecht, 1978). Powell (1970) suggests that sage grouse (Centrocercus urophasianus) utilize the "low-growing forms of big sagebrush" more than the "tall-growing forms". McArthur and Plummer (1978) list the palatability to deer and sheep as "low" for ATT, "high" for ATW and "intermediate" for ATW. Brunner (1972) found that ATW, A. nova and A. arbuscula were grazed heavily by livestock, but ATT and A. tripartita were apparently never grazed.

Two subspecies of big sagebrush (ATT and ATW), A. nova, A. arbuscula, and A. tripartita are severely damaged by fire (Britton and Ralphs, 1978). However, A. arbuscula and A. nova stands are only rarely exposed to fires because of their low growth forms. A. cana and A. tripartita plants are capable of resprouting after fire (Britton and Ralphs, 1978). Thus, ATW and ATT seem to be affected most by fires.

Literature Cited

- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *J. of Range Manage.* 34:25-29.
- Anderson, J. E., R. J. Jeppson, R. J. Wilkosz, G. M. Marlette and K. E. Holte. 1978. Trends in vegetation development on the Idaho National Engineering Laboratory Site. p. 144-166. *In:* O. D. Markham, ed. *Ecological Studies on the Idaho National Engineering Laboratory Site 1978 Progress Report*. IDO-12087. U.S. Department of Energy. Nat. Tech. Inf. Ser., Springfield, VA.
- Beetle, A. A. 1960. A study of sagebrush. The Section *Tridentatae* of Artemisia. University of Wyoming Agriculture Experiment Station Bulletin No. 368. 83 p.
- Beetle, A. A. 1978. Autecology of selected woody sagebrush species. *In:* Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. *Sagebrush Ecosystem Symposium*. Utah State University Press, Logan.
- Britton, C. M. and M. H. Ralphs. 1978. Use of fire as a management tool in sagebrush ecosystems. *In:* Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. *Sagebrush Ecosystem Symposium*. Utah State University Press, Logan.
- Brunner, J. R. 1972. Observations on Artemisia in Nevada. *J. of Range Manage.* 25:205-208.
- Frischknecht, N. C. 1978. Biological methods: a tool for sagebrush management. *In:* Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. *Sagebrush Ecosystem Symposium*. Utah State University Press, Logan.
- Hironaka, M. 1978. Basic synecological relationships of the Columbia River sagebrush type. *In:* Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. *Sagebrush Ecosystem Symposium*. Utah State University Press, Logan.
- Jeppson, R. J. and K. E. Holte. 1978. Flora of the Idaho National Engineering Laboratory Site. *In:* Markham, O. D. ed. *Ecological Studies on the Idaho National Engineering Laboratory Site 1978 Progress Report*. IDO-12087. U. S. Department of Energy. Nat. Tech. Inf. Ser., Springfield, VA.
- Lovejoy, S. H. 1980. Patterns in the distribution of plants and animals on lava flows and kipukas of the proposed Great Rift Wilderness Area. M.S. Thesis, Idaho State University, Pocatello.

- McArthur, E. D. and A. P. Plummer. 1978. Biogeography and management of native western shrubs: A case study, section Tridentatae of Artemisia. Great Basin Natur. Memoirs 2:229-243.
- McArthur, E. D., A. C. Blauer, A. P. Plummer and R. Stevens. 1979. Characteristics and hybridization of important intermountain shrubs: III. Sunflower family. USDA Forest Service Research Paper INT-220. 82 p.
- McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. Nat. Tech. Inf. Ser., Springfield, VA. 29 p.
- McDonough, W. T., R. O. Harniss and R. B. Campbell. 1975. Morphology of ephemeral and persistent leaves of three subspecies of big sagebrush grown in a uniform environment. Great Basin Natur. 35:325-326.
- Powell, J. 1970. Site factor relationships with volatile oils in big sagebrush. J. of Range Manage. 23:42-46.
- Shumar, M. L., J. E. Anderson and T. D. Reynolds. 1982. Identification of subspecies of big sagebrush by ultraviolet spectrophotometry. J. of Range Manage. 35:60-62.
- Winward, A. H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. Ph.D. Dissertation, University of Idaho, Moscow. 80 p.
- Winward, A. H. and E. W. Tisdale. 1977. Taxonomy of the Artemisia tridentata complex in Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station Bulletin No. 19. 15 p.

LATE-PLEISTOCENE VEGETATION HISTORY OF THE IDAHO NATIONAL ENGINEERING LABORATORY

Owen K. Davis and Robert C. Bright

ABSTRACT

Pollen diagrams and woodrat-midden fossils show the vegetation history of the Idaho National Engineering Laboratory. About 18,000 years ago the vegetation near Rattlesnake Cave was sagebrush steppe. The vegetation became more similar to shadscale steppe about 11,400 years ago and changed back toward sagebrush steppe about 5200 years ago. The timing of vegetation change at Middle Butte Cave is similar, but this site is presently at the sagebrush-steppe juniper-woodland ecotone and the change was from juniper woodland to sagebrush steppe and back. From about 28,000 to 12,000 years ago the vegetation near Middle Butte Cave was juniper woodland or sagebrush steppe. The vegetation changes at the sites may have resulted from severe summer drought 7000 years ago and the timing agrees with the astronomical theory of climatic change.

INTRODUCTION

Fossil pollen and spores provide reliable insight into regional vegetation changes that have taken place because of past climatic changes, and woodrat middens can provide precise information for vegetation on a local scale. Pollen and spores from lava-tube sediments and plant remains from woodrat middens in and around the Idaho National Engineering Laboratory (INEL) were studied to determine vegetation changes that have taken place during the last 25,000 years.

Cave sediments on the INEL provide much information concerning the biotic history of southern Idaho. The sediments of Rattlesnake Cave have provided remains of birds, reptiles and mammals, which are now being sorted and identified. The sediments also have yielded pollen, which provides direct evidence on the vegetation history at the INEL during the last 18,000 years. A second locality, Middle Butte Cave, has provided an even longer record of the vegetation sequence.

The two sites are in low-elevation sagebrush steppe (Rattlesnake Cave) and at the sagebrush-steppe juniper-woodland ecotone (Middle Butte Cave). There are very few pollen diagrams for low-elevation vegetation types in the northern Great Basin, so the diagrams from these sites provide valuable information for climatic reconstruction and for determining the environmental context of human history in the area.

The interpretation of pollen diagrams has been greatly improved in the last 20 years by the use of pollen samples from the modern vegetation. Comparison of the samples and the local vegetation objectively demonstrate the relationship between vegetation and the pollen it produces. This relationship can then be used to interpret pollen from ancient sediments.

METHODS

Pollen samples from the modern vegetation were collected in March 1981 before the flowering season started. Six samples were collected in a north-south transect beginning near TAN and ending at Middle Butte (Fig. 1). Pollen samples were taken in shadscale steppe, sagebrush steppe and juniper woodland. These three categories are broader than those recognized by Harniss and West (1973) and contain 10 vegetation types described by them. The procedure for extracting pollen from these samples is the same used for fossil samples.

Fossil samples from Rattlesnake Cave (Fig. 1) were taken from the east wall of pit III during the 1978 paleontological-archeological excavation (Bright *et al.*, 1978) and in March 1981. Pit III is 175 cm deep and is 6 m east of the south wall and 17 m east of the mouth of the cave. The sediments are silt and clayey silt except for a sandy layer at 78 to 86 cm and a basalt cobble layer from 138 to 159 cm. Plant and animal remains are abundant above 11 cm, and the sediments are calcareous from 32 to 138 cm. Mt. Mazama volcanic ash is present in a thin layer at 65.4 to 66.0 cm; it is approximately 6710 years old (Mehring *et al.*, 1977). Sediment samples at 25-35, 55-65, 65-75, and 120-130 cm have been submitted to J. C. Sheppard, Washington State University, for radiocarbon dating.

Figure 1. Location of Rattlesnake Cave (R), Middle Butte Cave (M), and modern pollen samples (1-6).

Pollen samples from Middle Butte Cave were collected in August 1979 along the south wall of a pit excavated by John White, Idaho State University (McDonald et al., 1980). The pit is 310 cm deep and is about 10 m southwest of the cave opening. The sediments, calcareous throughout, are very uniform silt with few plant and animal fossils in the upper 20 cm. Mt. Mazama volcanic ash is present in a layer at 29 cm and a second volcanic ash, tentatively identified as Glacier Peak volcanic ash (Sue Robertson, pers. comm.), is present at 120 cm in the sediment. Sediment samples at 24-29, 29-34, 115-120, 120-125, and 220-225 cm have been submitted to J. C. Sheppard, Washington State University, for radiocarbon dating.

The pollen-extraction procedure was modified from that of Faegri and Iversen (1975). Eucalyptus tracers were added to permit calculation of pollen concentration and the samples were treated with (1) HCl, (2) HF, (3) acetolysis mixture, and (4) 5% KOH. The pollen-rich residue was then mounted in silicone oil. Approximately 500 pollen grains were counted at 400 X for each sample.

The only area within the boundary of the INEL that has well-preserved woodrat middens is East Butte and it was sampled carefully to obtain the widest range of ages possible. Aside from one sample from the lava tube southeast of EBR-II (Bright et al., 1978), the remainder of our collecting was done in the foothills and mountains north of the INEL Site. The modern vegetation zones from Artemisia steppe to lower parts of the coniferous forest were sampled. At each midden site the geology, topography, soils, and vegetation were described.

All of the middens were found in caves where they were protected from dissolution by precipitation. The middens ranged in mass from less than a kilogram to nearly a ton. A sample (ca 1 kg) was taken from each midden, usually from the base. In the laboratory the sample was cleaned, dissolved in water, and sorted by hand-picking with tweezers. Plant remains from 16 of the middens were submitted to John Sheppard, Washington State University, for radiocarbon dating.

RESULTS

Figure 2 presents the relationship between the modern vegetation of the INEL and the pollen it produces. At the transition from shadscale vegetation to sagebrush steppe, Chenopodiaceae-Amaranthus percentages drop from 50% to 14% and Artemisia percentages increase from 22% to 43%. These pollen changes correlate with changes in vegetation composition. Altriplex confertifolia, A. falcata, and Erotia lanata (members of the Chenopodiaceae family) are common shadscale steppe, and Artemisia tridentata and A. tripartita are common in sagebrush steppe (Harniss and West, 1973).

Gramineae, Tubuliflorae, and Pinus percentages are also higher in sagebrush vegetation than in shadscale steppe. The higher Gramineae and Tubuliflorae percentages reflect greater coverage (% cover) by those taxa in sagebrush steppe (Harniss and West, 1973), but pines are not found in either vegetation type so higher Pinus percentages cannot be similarly explained. Rather, the percentages of Pinus pollen are probably higher in

Figure 2. Pollen percentages in samples from modern vegetation.

sagebrush steppe because the plants in sagebrush steppe produce fewer pollen grains than plants in shadscale steppe. The actual number of Pinus pollen grains being deposited in the two vegetation types is probably the same (blown down from the surrounding mountains), but the relative percentage of Pinus is greater in sagebrush steppe because fewer other grains are deposited there.

The transition from sagebrush steppe to juniper woodland is accompanied by an increase in Juniperus percentages from 3.3% to 18.0%. At the transition, the decline in Pinus, Gramineae, Tubuliflorae, and Artemisia percentages probably results from the addition of Juniperus pollen to the local pollen rain as much as from decreased coverage of these four taxa in the local vegetation.

The pollen percentages in the sediments of the two caves are similar to those found in the modern vegetaton. In the Rattlesnake Cave diagram (Fig. 3) Chenopodiaceae-Amaranthus pollen percentages are greatest (35%) just below the Mt. Mazama volcanic ash. From 50 to 100 cm the Chenopodiaceae-Amaranthus percentages are higher than those found in sagebrush steppe today. Pinus, Gramineae, and Tubuliflorae pollen percentages show a reciprocal trend to Chenopodiaceae-Amaranthus, being highest about 50 cm and below 110 cm. The percentages of these three taxa are higher today in sagebrush steppe than in shadscale steppe (Fig. 2).

RATTLESNAKE CAVE, INEL

BINGHAM CO., IDAHO

POLLEN PERCENT

Figure 3. Pollen percentage diagram for Rattlesnake Cave. Dashed line at 65 cm indicates Mt. Mazama volcanic ash, 6710 years old.

Comparison of the fossil pollen percentages (Fig. 3) with modern pollen percentages (Fig. 2), indicates that the vegetation at Rattlesnake Cave has remained sagebrush steppe from the beginning of the record until today, with a trend toward shadscale steppe reaching maximum development about 6700 years ago.

The vegetation represented by pollen from 50 to 110 cm probably was transitional from sagebrush steppe to shadscale steppe; with the coverage of Atriplex spp. higher than in modern vegetation at Rattlesnake Cave and the boundary between shadscale and sagebrush steppes at higher elevation than today. The 50 to 110 cm interval is not exactly dated, but based on interpolation and extrapolation from the age of Mt. Mazama volcanic ash (Mehring *et al.*, 1977) the interval lasted from about 5200 to 11,400 years ago, and the basal sediments are estimated as 18,000 years old.

The upper portion (above 200 cm) of the Middle Butte Cave diagram (Fig. 4) resembles the Rattlesnake Cave diagram in that Chenopodiaceae-Amaranthus percentages are highest (14%) just below Mt. Mazama ash, and Gramineae and Tubuliflorae percentages show a reciprocal trend. During the interval of high Chenopodiaceae-Amaranthus values, pollen proportions are similar to those found in modern sagebrush steppe. Before and after the interval, Juniperus percentages are higher than found in sagebrush steppe today (Fig. 2). The vegetation history at Middle Butte Cave probably started with juniper woodland (near the lower ecotone), then changed to sagebrush steppe, and back toward the sagebrush-juniper ecotone in modern times. The timing of vegetation change was similar to that at Rattlesnake Cave.

The differences in the two vegetation histories are consistent with differences in the modern vegetation at the sites. Middle Butte Cave is near the ecotone between sagebrush steppe and juniper woodland, and Rattlesnake Cave lies within sagebrush steppe. At both sites vegetation ecotones were at higher elevation during the mid-Holocene, but at Rattlesnake Cave the lower vegetation is shadscale steppe and at Middle Butte Cave the lower vegetation is sagebrush steppe.

The Middle Butte Cave sediments below 200 cm are apparently older than any at Rattlesnake Cave. The sediments are not yet dated, but the "Glacier Peak" ash at 120 cm is about 11,000 to 12,700 years old (Sue Robertson, pers. comm.). Assuming a uniform sedimentation rate, the lowest sediments may be 28,000 years old. During this older interval, the pollen percentages of Pinus, Pseudotsuga, Abies, and Picea do not increase, so these high-elevation conifers probably did not invade the valley floor.

A detailed discussion of the two middens dated thus far is in Bright and Davis (1982), so only a brief summary is given here. The base of large midden in a lava tube near the eastern boundary of the INEL is 5690 $\pm$ 90 years old. A comparison of the fossils and the modern vegetation indicate a sagebrush steppe at the site 5690 $\pm$ 90 years ago, but that elements of the shadscale vegetation (e.g. Atriplex confertifolia) had invaded the site. That, in turn, suggests the ecotone between shadscale and sagebrush steppe was a little higher than now.

MIDDLE BUTTE CAVE, INEL
BINGHAM CO., IDAHO
POLLEN PERCENT

Figure 4. Pollen percentage diagram for Middle Butte Cave. Lines indicate Mt. Mazama volcanic ash (29 cm), 6710 years old and "Glacier Peak" volcanic ash (120 cm), 11,000-12,500 years old.

The second dated midden was collected from a large rock overhang on the west flank of east Butte and its base is 1620 ± 90 years old. The fossils indicate a vegetation at the site essentially the same as now.

DISCUSSION

The vegetation changes on the INEL during the last 28,000 years can be explained by climatic change. Today the elevation of the boundaries between vegetation zones in the Rocky Mountains is controlled by summer drought (McMinn, 1952; Billings, 1949). Changes in the elevational gradient of moisture should be accompanied by displacement of zone boundaries; increased moisture would result in downward movement of vegetation zones, decreased moisture would result in upward movement.

Currently, the summer dry period (drought) at the INEL lasts from June to October when precipitation drops below 15 mm per month and mean monthly temperatures exceed 15°C (Harniss and West, 1973). Seven thousand years ago summer temperatures were higher than today (Kukla, 1975), and the summer drought would have been intensified. The decrease in moisture would result in the upward displacement of vegetation zones interpreted from pollen, spores, and plant fossils at the INEL.

The timing of the vegetation changes fits the astronomical model of climatic change (Milankovitch, 1941; Imbrie and Imbrie, 1980). According to this model, changes in the earth's orbit are responsible for long-term climatic variation. Variation in the perihelion, the eccentricity of the orbit, and the tilt of the axis of rotation all interact to affect the amount of radiation received over the earth's surface. The amount of radiation received in northern latitudes seems to be the crucial factor determining the timing of climatic change, but several other mechanisms regulate the final climatic outcome (Imbrie and Imbrie, 1980).

The astronomical model calls for very low temperatures about 18,000 years ago during the last glaciation, which is in good agreement with several indicators of past climate (Hays *et al.*, 1976). The model also estimates seasonal climatic trends. Today the northern hemisphere is closest to the sun on January 3. However, 7000 years ago the perihelion came in August (Kukla, 1975; Kutzbach, 1981). At that time summer temperatures were higher and winter temperatures were lower than today (Kukla, 1975).

Butler (1972) postulated that vegetation changes on the Snake River Plain were abrupt. There is no evidence for abrupt changes in the pollen diagrams from the INEL. Butler (1976) has also proposed that sagebrush steppe in its modern form was absent from the eastern Snake River Plain before 7000 years ago. The pollen diagrams from the INEL clearly show the continued presence of sagebrush steppe with grasses throughout the late Wisconsin and Holocene.

If the estimate of the age (28,000 years old) is correct, the lower part of the diagram from Middle Butte Cave certainly represents all or part of the last major Wisconsin glaciation in southern Idaho about 25,000 to about 14,000 years ago. It was surprising, therefore, to discover the existence

of sagebrush steppe on the INEL similar to the present one during that glaciation. We would have expected high proportions of pollen of cold-indicating plants. Apparently the last cold, glacial climate did not produce major vegetation changes on the eastern Snake River Plain that can be distinguished at the two sites reported here.

LITERATURE CITED

- Butler, B. R. 1972. The Holocene or postglacial ecological crisis on the eastern Snake River Plain. *Tebiwa* 15:49-63.
- Butler, B. R. 1976. The evolution of the modern sagebrush-grass steppe biome on the eastern Snake River Plain. pp. 4-39 In R. Elston and P. Headrick (eds.), *Holocene Environmental Change in the Great Basin*. Nev. Arch. Surv. Res. Paper 6.
- Billings, W. D. 1949. The shadscale vegetation zone of Nevada and eastern California in relation to climate and soils. *Amer. Midl. Nat.* 42:87-109.
- Bright, R. C., O. K. Davis, and B. K. Eikum 1978. Paleontology of the Idaho National Engineering Laboratory Site. p. 209-217 In O. D. Markham (ed.), *Ecological studies on the Idaho National Engineering Laboratory Site*. IDO-12087. Nat. Tech. Inform. Serv., Springfield VA.
- Bright, R. C. and O. K. Davis 1982. Quaternary paleoecology of the Idaho National Engineering Laboratory, Snake River Plain, Idaho. *Amer. Midl. Nat.* 108:21-33..
- Davis, O. K. 1982. Vegetation migration in southern Idaho during the late Quaternary and Holocene. Ph.D Thesis Univ. Minnesota 252 p.
- Fægri, K. and J. Iversen 1975. *Textbook of Pollen Analysis* (3rd Ed.). Hafner Press, New York. 295 p.
- Harniss, R. O. and N. E. West 1973. Vegetation patterns of the National Reactor Testing Station, southeastern Idaho. *Northwest Sci.* 47:30-43.
- Hays, J. D., J. Imbrie and N. J. Shackleton 1976. Variations in the earth's orbit: pacemaker of the ice ages. *Science* 194:1121-1132.
- Imbrie, J. and J. Z. Imbrie 1980. Modeling the climatic response to orbital variations. *Science* 207:943-953.
- Kukla, G. J. 1975. Missing link between Milankovitch and climate. *Nature* 253: 600-603.
- Kutzbach, J. E. 1981. Monsoon climate of the early Holocene: climate experiment with the earth's orbital parameters for 9000 years ago. *Science* 214:59-61.
- McDonald, H. G., E. Anderson, J. A. White and J. M. Soiset 1980. Lava blisters as carnivore traps. *Geol. Soc. Amer. Progr.* 12:280 (abstr.).

- McMinn, R. G. 1952. The role of soil drought in the distribution of vegetation in the Rocky Mountains. *Ecology* 33:1-15.
- Milankovitch, M. 1941. Canon of Insolation and the Ice Age Problem: K. Serb. Aka. Beogr. Spec. Publ. 132 (Transl. Israel Progr. Sci. Transl., Jerusalem, 1969).
- Mehring, P. J. Jr., S. F. Arno and K. L. Peterson 1977. Post-glacial history of Lost Trail Pass Bog, Bitterroot Mountains, Montana. *Arc. & Alp. Res.* 9:345-368.

FACTORS AFFECTING THE DISTRIBUTIONS OF TWO SUBSPECIES OF BIG SAGEBRUSH

Mark L. Shumar

ABSTRACT

The distributions of sagebrush taxa are affected by climate and soil factors. This study was designed to determine whether the distributions of pure and mixed stands of Artemisia tridentata tridentata and Artemisia tridentata wyomingensis are related to soil moisture, plant water stress, or various other soil factors and to relate the distributions of these sagebrush taxa to distributional patterns of co-occurring plant species on the Idaho National Engineering Laboratory in southeastern Idaho. At each of these areas, on the INEL where the two subspecies co-occur, vegetative cover was estimated by point interception, species association was tested with a plotless method, soils were described and samples collected for laboratory analyses, and sagebrush water stress was measured on both subspecies. Vegetation pattern analysis was performed with Reciprocal Averaging ordination. The results of vegetation pattern analysis for one of the study areas are discussed and indicate that a sand gradient exists that corresponds with the distributions of the two sagebrush subspecies. Preliminary data indicated that diurnal water stress patterns for the two subspecies were similar during June. Predawn measurements of sagebrush water stress also do not differ significantly for the two sagebrush subspecies.

INTRODUCTION

The distributions of various species of sagebrush (Artemisia spp.) are affected by climate and soil factors. Beetle (1978) wrote, "Sagebrush species and subspecies ... exhibit such a remarkable sensitivity to substrate that they represent in all cases a community which is an edaphic climax." Robertson et al. (1966) found sharp boundaries between stands of Artemisia tridentata and A. longiloba that were apparently caused by the depth to claypan. A similar situation was described by Fosberg and Hironaka (1964) for A. arbuscula and A. tridentata. Sabinske and Knight (1978) investigated soils associated with A. arbuscula and A. tridentata subspecies vaseyana (Atv); differences in the distribution of these species were related to the amount of coarse material in the soil. Artemisia arbuscula grew on soils having more coarse material.

West et al. (1978) seemed to refute the idea that distributions of various sagebrush taxa are closely related to soils. They reported that, for the entire Great Basin, sagebrush distributions were correlated with temperature and moisture, but not with soils. They recognized that on a smaller scale sagebrush distributions may be affected by many variables. Such factors as depth to the claypan or the amount of coarse material present may indirectly affect distributional patterns through effects on moisture holding capacity.

A study of sagebrush distributions on the Idaho National Engineering Laboratory (INEL) (Shumar, this volume) identified both mixed and pure stands of A. tridentata subspecies tridentata (Att) and A. tridentata subspecies wyomingensis (Atw). This was somewhat unexpected because previous reports suggested that the expansive lava flows of the upper Snake

River Plain would harbor Atw almost exclusively, whereas along the drainages of the Big and Little Lost Rivers and Birch Creek Att would be expected (Winward, 1970; McBride et al., 1978).

General descriptions of the soil properties that affect the distributions of these two subspecies occur often in the literature. Att occurs on deep (Beetle, 1960; Hironaka, 1978; Winward and Tisdale, 1977), well drained (Winward and Tisdale, 1977; Tisdale and Hironaka, 1981), often sandy soils (Morris et al., 1976) in valley bottoms or foothills (Winward and Tisdale, 1977) or along drainages (Morris et al., 1976). Its distribution often coincides with low to moderate precipitation zones (Beetle and Young, 1965; Hironaka, 1978), high water tables, or deep moisture accumulations (Morris et al., 1976).

Atw can be found on moderately deep to shallow soils (Hironaka, 1978) of medium texture that often limit water penetration (Morris et al., 1976). These plants sometimes occur on immature soils (Morris et al., 1976) or slightly saline soils (Tisdale and Hironaka, 1981). This subspecies can be found on lower slopes of major drainages (Winward and Tisdale, 1977) or on hilltops and flats (Beetle and Young, 1965) within the low to moderate precipitation zone (Hironaka, 1978).

The purposes of this investigation were to 1) describe the vegetation, soils, and moisture regimes for stands of the two subspecies (Att and Atw) and the area of intergradation between them, 2) determine whether the distributions of the two subspecies are related to soil moisture, plant water stress, or various other soil factors, and 3) relate the distributions of these two sagebrush subspecies to distributional patterns of co-occurring plant species.

METHODS

The INEL is located on the upper Snake River Plain near the southeastern ends of the Lost River and Lemhi Mountain ranges. The average annual precipitation is 21 cm, and the mean annual temperature is about 5.5 C (Anderson and Holte, 1981). The vegetation is predominantly sagebrush-bunchgrass associations.

Based on the study of sagebrush distributional patterns (Shumar, this volume), three areas where Att and Atw are found were chosen for study in 1981. The first was along Canal Road (T-9) south of Circular Butte (see Fig. 1 in Shumar, this volume). This area had rows of sand dunes extending in a northeasterly direction. Each dune row was made up of a complex of dunes that range from a few metres to about 100 m in length. Four dune complexes, (identified here as D-1, D-2, D-3, and D-4) were selected for study. D-1 was located in the eastern half of Section 9 (T5N, R33E) on the north side of road T-9. The D-2 study area was a single dune located in the northern portion of Section 8 (T5N, R33E) approximately 1.2 km from where road T-9 crosses the Second Owsley Canal. The D-3 study area, a large dune complex, was in the northeast corner of Section 6 (T5N, R33E) and the southeast corner of Section 31 (T6N, R33E). The D-4 study area was also in Section 31, beginning in the southeast corner about 3.3 km from where road T-9 crosses road T-17.

The second study site (T-22) was along T-22 road, about 2.8 km from where T-22 crosses T-9. It was in the southeast corner of Section 15 (T5N, R33E). This site was at the northern tip of a large lava flow that covers much of the eastern portion of the Site. The area was characterized by gently rolling lava ridges and depressions.

The third study site (T-24) was in the southeast corner of Section 26 (T3N, R30E) approximately 2.8 km from Wilson Blvd. This area was a large depression in the southern part of the same lava flow that extends over the eastern portion of the Site.

Vegetative cover in each study area was estimated by point interception (Floyd and Anderson, this volume). Twenty point frames, each having 36 points in a decimeter grid, were placed systematically at 2.5-m intervals along 50-m transects. "Hits" on all plant species and on litter, rock, and bare ground were recorded. Percent cover was estimated by dividing the number of points intercepting a particular item by the total number of points.

At the four dune complexes, baselines were established perpendicular to the long axis of the dune rows; these extended from the slack on one side of the dune to the slack on the other side. Slack refers to the areas that contain no dune sand between dune rows. Transects, 50-m in length, were placed at regular intervals perpendicular to the baseline such that both the slacks and the dunes would be sampled.

At the T-22 study site, the baseline was placed in an east-west direction traversing approximately 1500 m of the north edge of the lava flow. The baseline was selected such that several pure stands of the two subspecies as well as mixed stands in the area between them would be sampled. Thirty 50-m transects were placed at regular intervals perpendicular to the baseline.

The baseline for the T-24 study site began at the center of the basin and ran in a northeasterly direction up a lava ridge and across a plateau to the base of a second lava ridge. Twenty-one 50-m transects were placed perpendicular to the baseline at regular intervals.

A species association test (Yarronton, 1966) involving plants physically touching one another was employed. After many contacts between species are recorded, Chi-squared 2x2 contingency tables are used to test for association. Yarronton used this technique to test for associations between lichen and bryophyte species, thus his vegetation was in one plane. I have adapted the technique to a three dimensional shrub community by visually reducing the canopy to a flat plane. In this situation, a plant species under a shrub can be recorded as a contact species even though it did not physically touch the shrub. I chose one point on the point frame prior to any vegetation sampling for recording plant-contact data.

At subjectively selected transects, soils were sampled, and soil profiles were described. These transects were selected from the three study sites such that pure stands of Att, Atw, and some mixed stands were

represented. Soil pH, horizon depth and classification, wet and dry colors, texture, reaction, rockiness, and structure were recorded. Laboratory soil analyses included percent organic carbon, particle size fraction, amounts of nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and sodium. Cation exchange capacity and electrical conductivity were also measured. The topography at all transects was briefly described.

Plant moisture stress was measured for the two sagebrush subspecies with a PMS Co. (Corvallis, Oregon) pressure bomb (Waring and Cleary, 1967). Diurnal patterns of plant water potential were determined three times during the month of June, 1981 at site D-4. Sagebrush water potential was measured during the hot part of the day at each transect in the T-22, T-24, and D-4 study sites between 28 July and 25 August. Predawn measurements were also taken for each subspecies at each study site during that time period.

Reciprocal Averaging (RA) ordination (Hill, 1973; Gauch, 1977) of all vascular plant species was used to analyze vegetation pattern. Data from each of the three study sites were ordinated. The vegetative cover data from the four dune study areas were treated as one data set (hereafter referred to as "Dunes"). ORDIFLEX, a computer package developed by the Cornell Ecology Program (Gauch, 1977), was used to perform all ordinations.

RESULTS AND DISCUSSION

The results of the RA ordinations for the three study areas were similar, and only those for the Dunes will be presented here. The Dunes data included 38 transects with 36 plant species. Transects are labeled 1 through 38 in order of their rank on the first RA axis (Fig. 1). The sequence does not represent their relative positions in the field. The transects separate into three rather distinct groups. The group at the lower left (Fig. 1) are transects that occur primarily on the tops of the dunes. The top, center group is comprised of transects that occur at the dune margins on shallow sand as opposed to the deep sand at the tops of the dunes. The third group, at the lower right corner of the figure, are slack transects.

This separation into groups corresponds with the presence of one sagebrush subspecies or the other, or both. Transects 1-15 have *Att.* Transects 32 - 38 contain *Atw.* The group at the top of Fig. 1 (remaining transects) corresponds with the zone of co-occurrence of both sagebrush subspecies. The distinctness of the groups is a function of the presence of the sagebrush subspecies. When the ordinations were repeated with the sagebrush data deleted, the grouping became less distinct. However, the overall patterns persisted, indicating that other species tend to follow the distributional pattern of the two sagebrush subspecies. Transect 24 occurs between the slack group and the dune group because half of the transect occurred on a dune and half on a slack.

The first axis of the ordination suggests that a gradient exists from areas having deep sand to areas with no loose sand (Table 1). The distributional patterns along the gradient are evidenced by the diagonal band of matrix values from upper left to lower right in the shrub class

Figure 1. Results of Reciprocal Averaging ordination, based on vegetative cover, of transects from Dunes study sites. Transects are numbered according to rank on first Reciprocal Averaging axis.

(Table 1). If more than one gradient had existed, this band would not be apparent. The band is less visible in the forb and grass classes because of low occurrence and hence low matrix values in the figure.

The percent cover for species within each growth form was summed and then plotted along the sand-slack gradient (Fig. 2). The two sagebrush subspecies were left out of the shrub class and are presented separately. Along the gradient, from the dunes to the slacks, Att cover decreases and Atw cover increases. At the center of the gradient, which corresponds to the dune margins, the two subspecies co-occur with about equal abundance. The cover of other shrubs and total grass cover tend to increase in this zone of co-occurrence of the two subspecies. Total forb cover tends to increase towards the sand end of the gradient. Increased shrub cover in the zone of co-occurrence was the result of increased Chrysothamnus viscidiflorus cover (Table 1). Likewise, increased grass cover in this zone is due to increased Agropyron dasytachyum cover.

Forbs tend to divide into three groups: those occurring primarily on sand, those occurring primarily on the slacks, and those that occur on most all transects (Table 1). Greater forb cover on sand than on slack (Fig. 2) was the result of more forb species and increased cover of Descurainia pinnata on sand.

SHRUBS

GRASSES

FORBSTRANSECT Number

SAND GRADIENT

DUNE ----- SLACK-----

Figure 2. Percent vegetative cover of sagebrush, other shrubs, forbs and grasses along a sand gradient from dune to slack. Transects are ordered according to rank on first Reciprocal Averaging ordination axis. Att = Artemisia tridentata tridentata ; Atw = Artemisia tridentata wyomingensis.

Future analyses will compare these vegetation patterns with each of the soil factors investigated. This will be done primarily by correlation analysis between soil factors and RA arranged transects.

Diurnal water stress values of the two sagebrush subspecies consistently increased from June 3, 1981 to June 29, 1981 (Fig. 3). The values for the subspecies were within 0.3 MPa (3×10^5 Pascals) of each other. On June 3, 1981, Att and Atw reached maximum stresses at 2pm of 1.57 MPa and 1.38 MPa, respectively. On June 17, 1981, Atw reached 1.98 MPa at 2pm and Att reached 1.89 MPa at 3pm. Maximum stresses were 2.49 MPa for Att at 2pm and 2.68 MPa for Atw at 5pm on June 29, 1981. Predawn water stress was measured for the two sagebrush subspecies on July 22, 1981 at the T-24 study site, July 31, 1981 at the T-22 study site and August 25, 1981 at the D-4 study site (Table 2). A two-way analysis of variance with replication applied to these data resulted in values for the two subspecies not differing significantly but the values between areas were significantly different ($p < .05$). This difference between areas was the result of different sampling dates or differing soil moisture regimes between the three areas.

Figure 3. Diurnal pattern of twig water potential for the two subspecies of big sagebrush on three days during June, 1981.

Table 2. Predawn water potential (MPa) ($\bar{x}$ + SEM) for the two subspecies of big sagebrush, Artemisia tridentata tridentata (Att) and A. t. wyomingensis (Atw).

Att			Atw		
T-24	T-22	D-4	T-24	T-22	D-4
(July 22)	(July 31)	(Aug. 25)	(July 22)	(July 31)	(Aug. 25)
2.4 + .2	2.8 + .24	1.9 + .08	2.4 + .07	2.3 + .2	2.1 + .06

These preliminary data suggest that the two subspecies have similar water stress. Miller et al. (1982) recently indicated that these two subspecies did not have different water stresses even though their Att site had more soil water storage. Additional work is needed at this point to determine if the two subspecies at my study sites remain similar for the rest of the growing season and whether or not they reflect soil moisture content. In the summer of 1982, diurnal patterns will be measured from June through September and soil moisture will be monitored at the same time and location.

LITERATURE CITED

- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. J. of Range Manage. 34:25-29.
- Beetle, A. A. 1960. A study of sagebrush. The section Tridentatae of Artemisia. University of Wyoming Agriculture Expt. Sta. Bull. No. 368. 83 p.
- Beetle, A. A. 1978. Autecology of selected woody sagebrush species. In: Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. Sagebrush Ecosystem Symposium. Utah State Univ. Press. Logan.
- Beetle, A. A. and A. Young. 1965. a third subspecies in the Artemisia tridentata complex. Rhodora 67 No. 772:405-406.
- Fosberg, M. A. and M. Hironaka. 1964. Soil properties affecting the distributions of big and low sagebrush communities in southern Idaho. Forage Plant Physiology and Soil-Range Relationships. Amer. Soc. of Argon. Special Publication No. 5:230-236.
- Gauch, H. G. 1977. Ordiflex: A flexible computer program for four ordination techniques; weighted averages, polar ordination, principal components analysis, and reciprocal averaging. Cornell Ecology Program. Release B. Cornell University. Ithaca, New York.

- Hill, M. O. 1973. Reciprocal averaging: an eigenvector method of ordination. *J. of Ecology* 61:237-249.
- Hironaka, M. 1978. Basic synecological relationships of the Columbia River sagebrush type. In Gifford, G. F., F. E. Busby, and J. D. Shaw, eds. *Sagebrush Ecosystems Symposium*. Utah State University Press. Logan.
- McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. Nat. Tech. Inform. Serv. Springfield, VA. 29 p.
- Miller, R. F., P. S. Doescher, and T. Svejcar. 1982. Diurnal leaf water potentials for three subspecies of Artemisia tridentata. Abstracts, Society for Range Management 35th Annual Meeting. Calgary, Alberta, Canada.
- Morris, M. S., R. G. Kelsey, and D. Griggs. 1976. The geographic and ecological distribution of big sagebrush and other wood Artemisias in Montana. *Proc. of the Montana Acad. of Sci.* 36:56-79.
- Robertson, D. R., J. L. Nielsen, and N. H. Bare. 1966. Vegetation and soils of alkali sagebrush and adjacent big sagebrush ranges in North Park, Colorado. *J. of Range Manage.* 19:17-20.
- Sabinske, D. W. and D. H. Knight. 1978. Variation within the sagebrush vegetation of Grand Teton National Park, Wyoming. *Northwest Sci.* 52:195-204.
- Tisdale, E. W. and M. Hironaka. 1981. The sagebrush-grass region: A review of the ecological literature. Univ. of Idaho, Forest, Wildlife and Range Expt. Sta. Bull. No. 33. 31 p.
- Waring, R. H. and B. D. Cleary. 1967. Plant moisture stress: evaluation by pressure bomb. *Science* 155:1248-1254.
- West, N. E., R. J. Tausch, K. H. Rea, and P. T. Tueller. 1978. Taxonomic determination, distribution, and ecological indicator value of sagebrush within the pinyon-juniper woodlands of the Great Basin. *J. of Range Manage.* 31:87-91.
- Winward, A. H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. Ph.D. Dissertation, Univ. of Idaho, Moscow. 80 p.
- Winward, A. H. and E. W. Tisdale. 1977. Taxonomy of the Artemisia tridentata complex in Idaho. Univ. of Idaho, Forest, Wildlife and Range Expt. Sta. Bull. No. 19. 15 p.
- Yarranton, G. A. 1966. A plotless method of sampling vegetation. *J. of Ecology* 54:229-237.

BASELINE VEGETATION DATA FOR A CONTROLLED BURN SITE

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ABSTRACT

Vegetal cover data were collected between June 3 and July 31, 1980 on an area that was selected for studying the effects of a controlled burn on the Idaho National Engineering Laboratory. The study area is located on a broad alluvial fan, which results in gradients of elevation, soil characteristics, and vegetation. The purpose of this project was to collect baseline data on the vegetation along this gradient. This report describes the sampling regime and location of sample plots. Summary tables of plant species and their cover estimates are included. The study area was dominated by Artemisia tridentata and Chrysothamnus viscidiflorus. Ten additional shrub species were identified. The most abundant grasses were Agropyron spicatum, Oryzopsis hymenoides, and Sitanion hystrix. Ten additional species of grasses were identified. Fifty forb species were identified on the area; the most abundant was Phlox hoodii. A discussion of the expected results of burning this area, based on the current literature, is included.

INTRODUCTION

In the spring of 1980, an area for studying the response of an ecosystem to prescribed burning was selected by the Bureau of Land Management and the Department of Energy on the Idaho National Engineering Laboratory (INEL). The study area is located near the northwestern border of the INEL, in Sections 4, 5, 8, 9, 10, and 16, T4N, R29E. It is bordered on the north by Road T-5, the south by Road T-3, and the west by U.S. Highway 22/33. The study area is on an alluvial fan that extends eastward from the foothills below Howe Peak. The elevation ranges from 1480 m at the bottom of the fan to 1550 m at the top; both soil and vegetation change along this elevational gradient. The vegetation on the study area is dominated by Wyoming big sagebrush (Artemisia tridentata var. wyomingensis Beetle¹) and green rabbitbrush (Chrysothamnus viscidiflorus). The vegetal understory is composed of perennial grasses and perennial and annual forbs.

The objective of this project was to characterize the vegetation on the study area prior to burning. Specifically, we sought to: 1) prepare a list of plant species found on the study area, 2) estimate the percent cover of each plant species, 3) collect detailed data on shrub height, density, and crown diameter, 4) measure soil parameters along the elevational gradient, and 5) establish permanent sample plots. This report also presents instructions that will be useful to investigators who work on future phases of this project.

METHODS

Ten transects were systematically located at 0.16-km (0.1-mile) intervals along Road T-3, beginning at the bottom of the alluvial fan

¹ Nomenclature follows Hitchcock and Cronquist (1978) for most species. Names not following this source are accompanied by authority.

(Fig. 1). The transects ran south to north, perpendicular to the elevational gradient, and were oriented toward a small peak north of the study area. On each of transects 1 through 8, a control plot was located 100 m south of Road T-3, and three "burn" plots were located 150 m, 250 m, and 350 m north of Road T-3 (Fig. 1).

Figure 1. Sampling design. Each plot is a cluster of four lines. Transects are labeled 1 through 10 (east to west); plots are labeled 1 through 4 (south to north); lines are labeled a, b, c, d (south to north). A line drawing of the landmarks to the north of the area is shown as seen from transect 5. Positions of soil sampling pits are shown by an "S". At plot 5-1 (*), there is a 20-m interval between lines A and B. At plot 3-2 (*), line B was moved 5 m to the north.

Steel fenceposts were placed on the transects at the southwestern corner of each plot (the fenceposts were red with white tops except for one or two that were green with white tops). At each plot, four 50-m lines were located 10 m, 20 m, 30 m, and 40 m north of the fencepost. These lines were oriented toward the northernmost peak on East Butte, so that they ran west to east, and were perpendicular to the transects (Fig. 1). Plots that would have fallen on major breaks in the vegetation (e.g. large washouts) were moved 50 m to the north. This was an apriori part of the design. Plot 1-1, which would have been on the lava rock, was moved 40 m closer to road 23, and the lines were oriented to the west. It is still somewhat of an outlier and may be a poor control plot with respect to some species. A random 20-m section of each line was selected for sampling (Fig. 2). This resulted in

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Figure 2. Example of sample plot layout. This is the actual layout of plot 4-3, showing placement of the fence post (X), line stakes (r), and tags. The darkest lines are the 20-m sample sections. The column labeled starts gives the distance from the transect to the western line stake (for a complete list of starts see Floyd 1982, Appendix D).

16 20-m sample lines (four sample plots with four lines at each sample plot) along each of transects 1 through 8. Transects 9 and 10 were above the burn area (west of highway 22/33); one sample plot (four 20-m sample lines) was placed on each, 150 m north of Road T-3. These plots were included so that an analysis of species distributions along the elevational gradient could be completed.

Vegetation was sampled between June 3 and July 31, 1980. The plots were sampled in a random order to allow analyses of altitudinal and seasonal gradients to be performed independently. Systematic sampling along the elevational gradient may have resulted in a seasonal bias for some species at certain transects. Throughout the entire sampling period, plants were sampled opportunistically as well as systematically to compile the species list for the area.

At each sample line, a steel tape was tightly stretched between two steel fenceposts so that the 5-m and 25-m marks were at each end of the sample section. An 80-cm stake, made from 1.3-cm steel reinforcing rod, was driven into the ground 5 m beyond each end of the sample sections (directly beneath the 0-m and 30-m marks). Vegetal cover was estimated along the sample section, using a point sighting frame that projects a 9 by 4 matrix of points at each metre of line, for a total of 720 points per line (Floyd and Anderson, this volume). The point frame was centered over the tape with its long axis parallel to the tape. The height and species of the tallest shrub intercepting the line were recorded. At 50 randomly selected lines, a 2-m x 5-m quadrat was centered, long axis parallel to the tape, between the 20-m and 25-m marks. Each shrub in these quadrats was identified and counted; its crown diameter was then estimated by measuring the greatest horizontal dimension of the crown and then measuring the greatest horizontal dimension of its crown perpendicular to its first dimension (Mueller-Dombois and Ellenberg, 1974).

Brass or aluminum tags were attached with wire to the fencepost and to each of the eight stakes marking the ends of the four sample lines (Fig. 2). Western stakes were labeled with transect and plot numbers as well as line letters; eastern stakes were only labeled with line letters. This should enable subsequent researchers to locate and sample precisely the same lines during follow up studies. This design allows the use of pairing design statistical treatments without assuming that the vegetation is randomly distributed.

The vegetal data were filed and processed on the Hewlett-Packard 3000 computer system at Idaho State University (for details on programming, file forming, and data storage, see Floyd, 1982, Appendix C).

Fourteen soil sampling pits were dug on the study area using a backhoe (Fig. 1). Standard profile descriptions for each pit were completed (see Floyd, 1982, Appendix 1). Photographs were taken of each profile, and a sample of each horizon was collected for laboratory analysis. The Walkey-Black titration method was used to determine the percentage of organic carbon in each A horizon (Black et al., 1965). Percentages of sand were determined for all horizons by wet-sieving 5.0 g of soil (dry weight) through a 63 micron sieve with 1L of distilled water and obtaining the dry

weight of the soil that did not pass through the sieve. Percentages of silt and clay in the filtered solution were determined with a Hiac particle size analyzer; clay particles were defined as those 2 microns or smaller (for details see Floyd 1982, Appendix B). A parallel set of samples was sent to the soil laboratory at the Department of Agronomy and Horticulture, Brigham Young University and analyzed for phosphorus, calcium, magnesium, potassium, and sodium content and cation exchange capacity.

RESULTS

The dominant shrubs on the area were Artemisia tridentata ssp. wyomingensis Beetle, and Chrysothamnus viscidiflorus. Ten other shrub species were identified; Leptodactylon pungens occurred in moderate amounts at all transects, and Artemisia nova was common on transects 5 - 10 (Table 1). Maximum shrub height on a line ranged from 32 cm to 133 cm; the average for a transect ranged from 103 cm at transect 1 to 49 cm at transect 9 (Table 1). Of 113 shrub height measurements, all but five were for Artemisia tridentata. The five exceptions were Chrysothamnus nauseosus at lines 8-4C and 7-3A, Eriogonum microthecum at lines 8-1B and C, and Artemisia tripartita at line 9-2B.

Shrub density in a single quadrat ranged from 2.6 per m² to 25 per m²; the average for a transect ranged from 2.95 per m² to 14.1 per m² (Table 2). Most of the variation in density from transect to transect resulted from differences in seedling density (e.g. transect 2 was characterized by high seedling density for both big sagebrush and green rabbitbrush, while transect 3 was almost completely lacking in seedlings of these species). No distinction was made between various size classes of shrubs, but a list of the crown dimensions of each shrub that was counted is given in Floyd (1982, Appendix F). These data will allow analysis of changes in the population structure of the shrub component of the vegetation after burning. Arbitrarily omitting seedling size classes would have limited the analyses available to future investigators.

The dominant grasses were Agropyron spicatum, Oryzopsis hymenoides, and Sitanion hystrix. Other species, including Poa nevadensis, Agropyron dasytachyum, Stipa comata, and Elymus cinereus, had lower average cover values but were abundant on certain transects. Six additional grass species were identified (Table 3).

The dominant forbs at transects 1 and 2 were Cryptantha scoparia, Lappula redowski, Descurainia pinnata, and Schoenocrambe linifolia. At transects 4 - 7, these gave way to Phlox hoodii, Astragalus filipes, and Arenaria franklinii. At transects 8 - 10, these three species were also abundant, but Erigeron filifolius, and Astragalus calycosus became dominants. Townsendia florifer, Erigeron pumilus ssp. intermedius, and Gilia congesta were also abundant at these transects. Fifty forb species were identified (Table 4).

Table 1. Shrub cover and maximum height. Transect numbers are shown in Figure 1. Species are listed in order of the positions of the central moments of their distributions along the elevational gradient. Ranks are based on average cover across all transects. Shrub height is the average height of the tallest shrubs on a transect (see Methods).

SPECIES	PERCENT COVER TRANSECT									RANK
	1	2	3	4	5	6	7	8	9 & 10	
<i>Atriplex nutallii</i>	0.15	0	0	0	0.01	0	0	0	0	12
<i>Artemisia tridentata</i>	32.38	26.09	33.06	29.30	19.29	22.45	23.25	22.87	11.56	1
<i>Chrysothamnus viscidiflorus</i>	7.29	15.90	4.92	6.08	6.73	7.72	7.59	8.28	2.68	2
<i>Opuntia polyacantha</i>	0	0.18	0.04	0.14	0.10	0.13	0.09	0.07	0.04	10
<i>Ceratoides lanata</i>	0	0	0.06	0.32	0.48	0.04	0.42	0.14	0.30	5
<i>Leptodactylon pungens</i>	0.02	0.04	0.04	0.02	0.51	1.05	0.45	0.60	0.97	3
<i>Eriogonum microthecum</i>	0.01	0	0.02	0.04	0.22	0.20	0.30	0.34	0.11	7
<i>Tetrademia canescens</i>	0	0	0	0.05	0.07	0.40	0.24	0.33	0.02	8
<i>Artemisia nova</i>	0	0	0	0	0.71	0.16	0.59	0.08	1.15	4
<i>Chrysothamnus nauseosus</i>	0.04	0.01	0	0	0.01	0.13	0.01	0.51	0.38	9
<i>Atriplex spinosa</i>	0	0	0	0	0	0	0.21	0	0.54	11
<i>Artemisia tripartita</i>	0	0	0	0	0	0	0	0	1.44	6
Total shrub cover	40.39	42.22	38.14	35.95	28.13	32.28	33.15	33.22	19.19	
SHRUB HEIGHT (cm)	103	84	78	68	52	64	63	64	49	

Table 2. Shrub density by transect. Species are ordered as in Table 1.

SPECIES	DENSITY (#/m ²) TRANSECT									RANK
	1	2	3	4	5	6	7	8	9 & 10	
<u>Artemisia tridentata</u>	4.15	9.14	2.55	2.89	2.55	3.16	3.23	-	7.60	1
<u>Chrysothamnus viscidiflorus</u>	0.45	4.91	0.38	1.69	1.88	2.83	2.38	-	0.83	2
<u>Ceratoides lanata</u>	0	0	0	0.15	1.48	0.06	0.18	-	0	4
<u>Opuntia polyacantha</u>	0	0	0.02	0.06	0.18	0.09	0.13	-	0.08	6
<u>Artemisia nova</u>	0	0	0	0	0	0.09	0	-	0	10
<u>Eriogonum microthecum</u>	0	0	0	0.09	0.28	0.14	0.28	-	0.18	5
<u>Tetrademia canescens</u>	0	0	0	0	0	0.08	0.08	-	0	9
<u>Leptodactylon pungens</u>	0	0.05	0	0.01	0	1.01	0.60	-	0.83	3
<u>Artemisia tripartita</u>	0	0	0	0	0	0	0.10	-	0.15	8
<u>Chrysothamnus nauseosus</u>	0	0	0	0	0	0	0.03	-	0.40	7
TOTAL SHRUB DENSITY	4.6	14.10	2.95	4.89	6.35	7.46	6.91	-	10.07	
N (# of 2-m x 5-m quadrats)	8	8	6	8	4	8	4	0	4	

Table 3. Cover of grasses by transect. Species are ordered as in Table 1. Ranks are based on average cover across all transects.

SPECIES	PERCENT COVER TRANSECT									RANK
	1	2	3	4	5	6	7	8	9 & 10	
<u>Elymus cinereus</u>	0.95	0	0	0	0	0	0	0	0	7
<u>Sitanion hystrix</u>	1.29	1.43	0.28	0.41	0.51	0.40	0.21	0.51	0.16	3
<u>Agropyron cristatum</u>	0	0	0	0.04	0.02	0.01	0	0	0	10
<u>Elymus flavescens</u>	0	0	0	0	0.02	0	0	0	0	11
<u>Agropyron dasytachyum</u>	0	0	0.01	0.17	0.16	0.71	0.10	0	0	5
<u>Poa nevadensis</u>	0	0.01	0.02	0	0.23	0.36	0.27	0.43	0.35	4
<u>Stipa comata</u>	0	0	0	0.12	0.15	0.41	0.11	0.23	0.12	6
<u>Poa sandbergii</u>	0	0	0	0.04	0.03	0.02	0.12	0.12	0.19	8
<u>Oryzopsis hymenoides</u>	0.02	0.07	0.21	0.31	1.10	1.11	0.70	1.19	2.17	2
<u>Agropyron spicatum</u>	0	0.01	0.35	0.58	2.16	1.49	2.00	2.08	6.13	1
<u>Elymus x Agropyron</u>	0	0	0	0	0	0	0	0	0.09	9
<u>Bromus tectorum</u>	0	0	0	0	0	0	0	a	a	12
<u>Horaceum jubatum</u>	0	0	0	0	0	0	0	0	a	13
Total grass cover	2.26	1.52	0.87	1.63	4.38	4.51	3.51	4.56	9.21	

^a Locations of species that were not detected by systematic sampling.

Table 4. Cover of forbs by transect. Species are listed in the order they occurred along the elevational gradient. Ranks are based on average cover across all transects. + is used to indicate positions of species not found by sampling transect plots.

SPECIES	PERCENT COVER TRANSECT									RANK
	1	2	3	4	5	6	7	8	9 & 10	
<u>Cryptantha scoparia</u>	3.19	0.10	0.02	0	0.01	0.31	0	0	0	3
<u>Lappula redowskii</u>	2.74	0.11	0	0	0	0	0.03	0.17	0	4
<u>Descurainia pinnata</u>	1.18	0.64	0.09	0.01	0.04	0.34	0.06	0	0	7
<u>Schoenocrambe linifolia</u>	0.88	1.20	0.13	0.14	0.10	0	0.07	0.01	0	5
<u>Cordylanthus ramosus</u>	0.41	0.19	0	0	0.01	0	0	0.03	0	14
<u>Descurainia sophia</u>	0.13	0	0	0	0	0.02	0	0.01	0.04	22
<u>Sphaeralcea munroana</u>	0.05	0	0	0	0	0	0	0	0	35
<u>Cryptantha interrupta</u>	0.04	0.02	0.01	0.01	0.11	0.03	0.05	0.04	0.02	19
<u>Astragalus lentiginosus</u>	0.03	0.04	0.02	0.01	0.07	0.06	0.05	0.11	0.07	16
<u>Arenaria franklinii</u>	0.02	0.01	0.04	0.17	0.46	0.68	1.00	0.74	0.87	2
<u>Mentzelia albicaulis</u>	0.02	0.01	0	0.01	0.02	0.10	0.07	0.04	0	21
<u>Monolepsis nuttalliana</u>	0.02	0.01	0	0	0	0	0	0	0	39
<u>Arabis holboellii</u>	0.01	0.12	0.03	0.04	0.14	0.03	0.02	0.02	0	17
<u>Phlox hoodii</u>	0.01	0.11	0.81	1.35	1.13	1.45	2.48	1.53	1.36	1
<u>Chaenactis douglasii</u>	0.01	0.02	0	0.06	0.10	0.08	0.10	0.08	0.09	15
<u>Amsinckia menziesii</u>	0.01	0	0	0	0	0	0	0	0	47
<u>A. tessellata</u>	+	0	0	0	0	0	0	0	0	51
<u>Gilia congesta</u>	0	0.04	0	0	0.11	0.09	0.07	0.20	0.21	13
<u>Arabis lignifera</u>	0	0.02	0.31	0.06	0.01	0	0	0	0	30
<u>Machaeranthera canescens</u>	0	0.02	0	0	0.03	0.03	0	0.02	0.09	24
unknown rosette	0	0.01	0.02	0	0.04	0.10	0	0	0	25
unknown scroph.	0	0.01	0	0	0	0	0	0	0	50
<u>Lactuca seriola</u>	0	+	0	0	0	0	0	0	0	52

Table 4. Forb cover (cont'd)

	1	2	3	4	5	6	7	8	9 & 10	
<u>Astragalus filipes</u>	0	0	0.05	0.25	0.25	0.34	0.11	0.39	0	9
<u>Astragalus purshii</u>	0	0	0.02	0	0.02	0	0.02	0.03	0.02	28
<u>Erysimum asperum</u>	0	0	0.01	0	0	0.06	0.02	0	0	31
<u>Lomatium dissectum</u>	0	0	0.01	0	0	0.01	0.02	0.08	0.02	26
<u>Astragalus calycosus</u>	0	0	0.01	0	0	0	0.01	0.17	1.46	8
<u>Townsendia florifer</u>	0	0	0	0.02	0.03	0.19	0.25	0.14	0.42	11
<u>Eriogonum ovalifolium</u>	0	0	0	0.02	0.04	0.11	0.03	0	0	23
<u>Astragalus convallarius</u>	0	0	0	0.01	0.06	0.04	0.02	0.09	0.19	18
<u>Melilotus officinalis</u>	0	0	0	+	0	0	0	0	0	53
<u>Erigeron pumilus</u>	0	0	0	0	0.04	0.43	0.24	0.11	0.42	10
unknown mustard	0	0	0	0	0.04	0	0	0	0	38
<u>Castilleja angustifolia</u>	0	0	0	0	0.03	0.08	0	0.01	0	27
<u>Cymopterus acaulis</u>	0	0	0	0	0.02	0.02	0	0	0	37
<u>Sisymbrium altissimum</u>	0	0	0	0	0.02	0	0	0.05	0	32
<u>Crepis acuminata</u>	0	0	0	0	0.01	0.02	0.06	0.10	0.11	20
<u>Antennaria dimorpha</u>	0	0	0	0	0.01	0.02	0	0	0	40
<u>Oenothera andina</u>	0	0	0	0	0.01	0	0	0	0	43
<u>Thelypodium laciniatum</u>	0	0	0	0	+	0	0	0	0	54
<u>Orobanche fasciculata</u>	0	0	0	0	+	0	0	0	0	55
unknown #2	0	0	0	0	0	0.05	0	0	0	36
<u>Eriastrum sparsiflorum</u>	0	0	0	0	0	0.04	0	0.02	0	33
<u>Allium textile</u>	0	0	0	0	0	0.03	0	0.03	0	34
unknown #4	0	0	0	0	0	0.01	0	0.02	0	42
<u>Erysimum inconspicuum</u>	0	0	0	0	0	0.01	0	0	0	44
<u>Lupinus wyethii</u>	0	0	0	0	0	0.01	0	0	0	45
unknown #3	0	0	0	0	0	0.01	0	0	0	48
<u>Oenothera caespitosa</u>	0	0	0	0	0	+	0	0	0	56
<u>Phlox longifolia</u>	0	0	0	0	0	+	0	0	0	57
unknown Polemoniaceae	0	0	0	0	0	+	0	0	0	0

Table 4. Forb cover (cont'd)

	1	2	3	4	5	6	7	8	9 & 10	
<u>Penstemon humilis</u>	0	0	0	0	0	0	0.04	0.69	0	12
<u>Oenothera minor</u>	0	0	0	0	0	0	0.01	0	0	46
drup	0	0	0	0	0	0	0.01	0	0	48
yellow flower	0	0	0	0	0	0	0	0.11	0	29
<u>Calochortus nuttallii</u>	0	0	0	0	0	0	0	0.01	0.02	41
<u>Erigeron filifolius</u>	0	0	0	0	0	0	0	0	2.15	6
<u>Tragopogon dubious</u>	0	0	0	0	0	0	0	0	0.02	43
Total forb cover	7.87	2.68	1.28	2.16	2.96	4.20	4.89	5.05	7.58	

Bare ground occurred on 30 percent of the area at transect 1 and steadily increased to 50 percent at transects 9 and 10. Litter and dead sagebrush covered 14 percent and 9 percent of the area at transect 1, respectively, and then decreased to 10 percent and 3 percent at transect 2; these values then remained about the same for the remaining transects. The bare areas associated with anthills, which were measured separately, reached five percent cover at transects 4 and 5. Mosses (predominantly Tortula ruralis) covered about 15 percent of all but transect 1, where they covered only three percent. Lichens covered one percent of the area at transect 1 and decreased to 0.1 percent at transects 9 and 10. Mushrooms were present in small numbers (Table 5).

The soils were mostly loamy sands and sandy loams, resulting from a mixture of limestone and eolian loess parent materials. Most of the soils were calcic, and much of the area was underlain by a calcium carbonate hardpan at depths ranging from 40 cm to 160 cm. Penetration of the B horizons by plant roots was generally poor.

Soil erosion was evident on the upper portion of the fan. Perennial plants commonly had soil pedestals 5 cm to 7 cm in height, and washouts up to 1 m in depth were found on the middle portion of the fan. Soil loss from the upper portion was estimated at 10 to 20 t/ha/year (Mark Jensen, personal communication).

The soils had low concentrations of organic carbon (generally less than one percent). Concentrations of calcium were high, resulting in high pH (8.0 - 8.6) and reduced phosphorus availability. Most soil parameters changed in response to the elevational gradient along the fan, with pH and salt concentrations being highest at the top of the fan. Cation exchange capacity, organic carbon content, phosphorus availability, and depth to the hardpan were greatest at the bottom of the fan (for details, see Floyd 1982, Appendices A and E).

DISCUSSION

The changes in elevation and soil characteristics along the alluvial fan exert a great influence on the vegetation at the study area. This gradient should be considered when interpreting the emergent patterns of post burn vegetation. Because of the sampling intensity used in this inventory, each transect should be treated as a separate study area, since this will allow monitoring of vegetal recovery on each transect. For example, Astragalus convallarius was reported to benefit from burning (Mueggler and Blaisdell, 1958). A. convallarius was abundant on transects 5 - 10, rare on transect 4, and absent from transects 1 - 3. Its ability to recover, increase, and invade after fire can be monitored separately on these three areas.

Table 5. Cover of other entities.

COVER TYPE	PERCENT COVER TRANSECT								
	1	2	3	4	5	6	7	8	9 & 10
Bare ground	29.86	39.52	39.16	40.79	43.76	44.55	44.96	40.03	50.17
Bare areas around ant hills	1.16	1.19	2.00	4.27	3.32	1.86	0.62	0.65	0.83
Anthills	0	0	0	0.07	0.30	0	0	0	0
Rock (>1 dm)	0	0	0	0	0	0	0	0.04	0
Total bare area	31.02	40.71	41.16	45.13	47.38	46.41	45.58	40.72	51.00
Litter	13.79	9.67	10.68	10.75	8.46	10.17	10.72	10.05	7.41
Standing dead sagebrush	9.30	3.09	4.49	2.85	2.14	2.86	2.66	2.07	3.26
Total dead organic cover	23.09	12.76	15.17	13.60	10.60	13.03	13.38	12.12	10.77
Mosses (<i>Tortula ruralis</i>)	3.24	16.91	18.27	14.65	13.16	14.46	13.67	12.17	15.68
Lichens	0.64	0.96	0.74	0.69	0.83	0.29	0.85	0.27	0.07
Mushrooms	0	0	0	0	0	0	+	0	0
Total lower plant cover	3.88	17.87	19.01	15.34	13.99	14.75	14.52	12.44	15.75

Transect 1 was burned in August 1981 at relatively low wind velocity. At higher wind velocities, transects 2 - 4 should burn readily in 1982; the burned strip at transect 1 will aid in controlling this burn. It is unlikely that other transects will burn under the present prescription (especially transect 5). Britton and Ralphs (1979) note that sagebrush-grass vegetation usually will not burn if cover of Artemisia tridentata is less than 20 percent. This is the case at transect 5. Other conditions at transect 5 that are not conducive to burning are: 1) decreased shrub height, 2) increased total bare ground, 3) decreased litter and standing dead sagebrush, 4) decreased forb cover, 5) increased cover of Artemisia nova, and 6) increased numbers of anthills and associated bare areas. All these conditions improved at transects 6, 7, and 8; these transects may be successfully burned if aggressive efforts are made. If these transects are burned, modifications in the sampling design may be appropriate to expedite the field work (e.g. reading every other meter of line and/or reading a reduced number of points per meter for certain species; see Floyd 1982, Chapter III). Plots should be read in the same order during follow-up studies that was used in the collection of baseline data (for order of reading and missing or suspect data, see Floyd, 1982, Appendix D).

Removal of Artemisia tridentata by fire should have the most noticeable effects at transect 1, where it was most dominant. Chrysothamnus viscidiflorus is a vigorous sprouter (Plummer, 1977); its density should be unchanged immediately following the burn, but decreased competition may result in an increase in cover and seed production (Chadwick and Dalke, 1965; Blaisdell, 1953), which may then lead to an increase in density. Chrysothamnus nauseosus is killed by intense fires (Robertson and Cords, 1957); it may be completely eliminated from transects 1 and 2. Tetrademia canescens sprouts vigorously and reproduces abundantly from seed following fire (Wright et al., 1979). It was present on transects 4 - 10 and would be expected to increase in importance following the fire. Ceratoides lanata is another vigorous sprouter (Wright et al., 1979); it may increase where it occurred on other transects that are successfully burned.

Sitanion hystrix responds favorably to fire (Wright and Klemmedson, 1965; Countryman and Cornelius, 1957); its seed production increases drastically (Young and Miller, 1982). Though it does not cover a high percentage of the burn area, it is quite evenly distributed and should play a major role in the revegetation process. Oryzopsis hymenoides, Agropyron spicatum, and Poa nevadensis should recover in 1 - 3 years after the burn and then increase (Wright et al., 1979). Elmus cinereus is only slightly damaged by fire (Wright et al., 1979); because it occurred in localized monocultural stands, it will probably be undamaged. Agropyron dasytachyum is usually completely undamaged by fire (Blaisdell, 1953); it will probably increase on the transect where it occurred. Several other grass species may increase after burning but only to the extent that competition from Artemisia tridentata was restricting their distributions. If one or more of the soil parameters along the fan was a major restricting factor to these species, they cannot be expected to increase.

Effects of fire on most individual forb species have not been well documented (Wright et al., 1979), but forbs generally respond favorably to fires (Mueggler and Blaisdell, 1958). Several borages and mustards can be expected to increase at transect 1, depending largely on how well their seeds survive the fire. This study provides an excellent opportunity to document in detail the effects of burning on many unstudied forb species.

LITERATURE CITED

- Black, C. A. 1965. Methods of soil analysis. Amer. Soc. of Agron., monograph no. 9.
- Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. USDA, Tech. Bull. 1075. 39 p.
- Britton, C. M. and M. H. Ralphs. 1979. Use of fire as a management tool in sagebrush ecosystems. p. 106. In The Sagebrush Ecosystem: A Symposium. Utah State University, College of Natural Resources.
- Chadwick, H. W. and P. D. Dalke. 1965. Plant succession on dune sands in Fremont County, Idaho. Ecology 46:765-780.
- Countryman, C. M. and D. R. Cornelius. 1957. Some effects of fire on a perennial range type. J. of Range Manage. 10:39-41.
- Floyd, D. A. 1982. A comparison of three methods for estimating vegetal cover in sagebrush steppe communities. M.S. Thesis, Idaho State Univ., Pocatello.
- Hitchcock, C. L. and A. Cronquist. 1978. Flora of the Pacific Northwest. University of Washington Press, Seattle. 735 p.
- Mueggler, W. F. and J. P. Blaisdell. 1958. Effects on associated species of burning, rotobating, spraying, and railing sagebrush. J. of Range Manage. 11:61-66.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation analysis. John Wiley and Sons, New York. 547 p.
- Plummer, A. P. 1977. Revegetation of disturbed Intermountain area sites. p 320-337. In J. C. Thames (ed). Re-vegetation of disturbed lands of the southwest University of Arizona Press, Tuscon.
- Robertson, J. H. and H. P. Cords. 1957. Survival of rabbitbrush, Chrysothamnus sp., following chemical, burning, and mechanical treatments. J. of Range Manage. 10:83-89.
- Wright, H. A. and J. O. Klemmedson. 1965. Effects of fire on bunchgrasses of sagebrush-grass region in southern Idaho. Ecology 46:680-688.

Wright, H. A., L. F. Neuenschwander and C. M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities, a state-of-the-art review. USDA Forest Service, Gen. Tech. Rep. INT-58. 48 p.

Young, R. P. and R. F. Miller. 1982. Effects of prescribed burning on Sitanion hystrix (Nutt.) Smith in southeastern Oregon. In Abstracts for the 35th annual meeting of the Soc. for Range Manage. Paper No. 179.

EVALUATING THE EFFECTS OF A PRESCRIBED BURN ON THE FORAGING ECOLOGY OF SAGE AND BREWER'S SPARROWS

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ABSTRACT

The effects of a prescribed burn on the foraging ecology of the Brewer's sparrow (*Spizella breweri*) and sage sparrow (*Amphispiza belli*) will be studied. Foraging patterns, feeding behavior, and feeding frequency of adults during the nestling period will be documented for pre- and post-burn conditions. Details of the field methodology are discussed.

INTRODUCTION

Although the foraging patterns and feeding behavior of some sparrow species have been well documented (e.g., Judd, 1901; Post, 1974; Best, 1977; Knapton, 1980), the foraging ecology of sage and Brewer's sparrows is virtually unknown. Both species commonly occur in the western sagebrush desert and are considered to be "sagebrush obligates" (Braun et al., 1976). The response of these birds to sagebrush alteration by chaining (Castrale, 1981), grazing (Olson, 1974; Reynolds, 1978), and herbicide spraying (Best, 1972; Schroeder and Sturges, 1975) has been studied. Although changes in population densities after fire have been documented (McGee, 1976; Castrale, 1981), effects of prescribed burning on the foraging ecology of the two species have not been recorded.

After a prescribed burn, the sagebrush community likely will be a mosaic of patches that vary in size and burn intensity. The proximity of areas with suitable food resources may place constraints on where nests can be located, and the patchiness of the habitat may require parents to fly greater distances to secure food, thereby affecting feeding frequency and nestling growth. Vegetation changes may affect the associated insect fauna, potentially altering the nestling diet.

To assess the effect of prescribed burning on Brewer's and sage sparrows, extensive pre- and post-burn data will be collected. The pre-burn data will serve as a control and will provide baseline information on "normal" foraging patterns, which can be compared to post-burn results.

The objectives of this study are to: (1) document the foraging patterns, general feeding behavior, and feeding frequency of Brewer's and sage sparrows during the nestling period, (2) evaluate the effects of the above on nestling growth and development, (3) determine foraging preferences in relation to the vegetation and associated insect fauna, (4) assess the effect of foraging preferences on nest-site location, and (5) evaluate the effect of a prescribed burn on objectives 1-4 by comparing pre-burn and post-burn data.

METHODOLOGY

A 9-ha pre-burn study plot, gridded throughout at 25-m intervals, will be established in an area not being used for other research in order to minimize disturbance and to maintain natural foraging patterns. Because the burn likely will have a patchy distribution, the study plot may be shifted after the fire so that it includes areas of different burn intensities.

Nests will be located primarily by a rope-dragging technique (Rodenhouse, 1982); additional nests will be found incidental to other activities. Each nest site will be marked, and the status of all active nests will be monitored daily.

Territories of male sage and Brewer's sparrows will be delineated by using a modification of the "flush" technique (Wiens, 1969). As foraging generally occurs within territories, the confines of the territory will be used to evaluate foraging-site preferences. In the event that foraging extends beyond the defended territory, the area delineated by foraging locations will be used in evaluating preferences.

Sage and Brewer's sparrows will be captured by flushing them from their nests into a mist net placed nearby. Captured birds will be sexed, measured, weighed, and marked. Each adult will be marked by using colored leg bands and a Federal band; in addition, white enamel paint will be applied to the head feathers of females. Nestlings will be marked by applying a spot of paint on the top of the beak (Johnson and Best, 1982).

Sage and Brewer's sparrow foraging will be observed from a portable 7-foot tall tower and blind. In addition, a mirror will be positioned above each nest to facilitate observing its contents (Best, 1977). Observations, using binoculars and a spotting scope, will be made in 3-hour time periods: dawn-09:00, 09:00-12:00, 12:00-15:00, 15:00-18:00, and 18:00-dusk. Observations will be conducted during alternate time periods with the schedule reversed each day; thus, all periods will be represented every 2 days (Johnson and Best, 1982). Brewer's and sage sparrow nests will be observed in an alternating pattern. The foraging patterns, feeding behavior, and feeding frequency of adult males and females will be documented during the first and second hours, respectively, of each 3-hour period. During the third hour, the nestlings will be observed and food will be collected.

Adult foraging patterns will be documented by recording the direction, distance, and duration of foraging bouts, and the location of foraging sites (Knapton, 1980). Foraging ecology information will be recorded on tape in the field and later transcribed to computer coding forms. Adult foraging behavior will be documented by recording the search path (Zach and Falls, 1977), search velocity, and prey capturing methods (probing, jabbing, snatching, and gleaning; Curio, 1976). When feasible, direct observations of the prey type and quantity fed to nestlings also will be recorded. During the third hour, nestlings will be weighed, measured, and fitted with constrictive neck ligatures to enable food samples to be collected (Johnson et al., 1980).

Vegetation will be measured on the study plot in June. Four quadrat samples will be taken 6-m from each grid marker (in the four cardinal directions) by using the Daubenmire (1959) canopy coverage technique. Height and canopy coverage will be recorded for each species and vegetation growth form. Status of sagebrush plants will be noted as live, dead, or partly dead.

Arthropod data will be obtained from a concomitant insect study being conducted by a graduate student from the University of Idaho. Information on insect abundance and diversity will be used to assess prey preferences in the two sparrows. Insect-vegetation associations will be considered in determining foraging-site preferences.

The data will be analyzed statistically, and the foraging ecology of the two sparrows will be compared. Pre-burn and post-burn data will be used to determine effects of prescribed burning.

LITERATURE CITED

- Best, L. B. 1972. First-year effects of sagebrush control on two sparrows. *J. Wildl. Manage.* 36:534-544.
- Best, L. B. 1977. Nestling biology of the field sparrow. *Auk* 94: 308-319.
- Braun, C. E., M. F. Baker, R. L. Eng, J. S. Gashwiler, and M. H. Schroeder. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. *Wilson Bull.* 88:165-171.
- Castrale, J. S. 1981. Use of managed sagebrush grasslands by bird populations. Ph.D. Diss., Brigham Young University, Provo, Utah.
- Curio, E. 1976. The ethology of predation. Berlin: Springer. Verlog.
- Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. *Northwest Sci.* 33:43-64.
- Johnson, E. J., L. B. Best, and P. A. Heagy. 1980. Food sampling biases associated with the "ligature method". *Condor* 82:186-192.
- Johnson, E. J. and L. B. Best. 1982. Factors affecting feeding and brooding of gray catbird nestlings. *Auk* 99:148-156.
- Judd, S. D. 1901. The relations of sparrows to agriculture. U.S. Dept. Agric., Div. Biol. Surv., Bull. 15.
- Knapton, R. W. 1980. Nestling foods and foraging patterns in the clay-colored sparrow. *Wilson Bull.* 92:458-465.
- McGee, J. M. 1976. Some effects of fire suppression and prescribed burning on birds and small mammals in sagebrush. Ph.D. Diss., Univ. Wyoming, Laramie.
- Olson, R. A. 1974. Bird populations in relation to change in land use in Curlew Valley, Idaho and Utah. M.S. thesis, Idaho State Univ., Pocatello.

- Post, W. 1974. Functional analysis of space-related behavior in the seaside sparrow. *Ecology* 55:564-575.
- Reynolds, T. D. 1978. The response of native vertebrate populations to different land management practices on the Idaho National Engineering Laboratory Site. Ph.D. Diss., Idaho State Univ., Pocatello.
- Rodenhouse, N. L. 1982. Breeding ecology of vesper sparrows in corn and soybean fields. M.S. thesis, Iowa State Univ., Ames.
- Schroeder, M. H. and D. L. Sturges. 1975. The effect on the Brewer's sparrow of spraying big sagebrush. *J. Range Manage.* 28:294-297.
- Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. *Ornithol. Monogr.* 8:1-93.
- Zach, R. and J. B. Falls. 1977. Influence of capturing a prey on subsequent search in the Ovenbird (Aves: Parulidae). *Can. J. Zool.* 55:1958-1969.

EFFECTS OF PRESCRIBED BURNING ON NONGAME BIRDS BREEDING IN SAGEBRUSH COMMUNITIES - PRE-BURN PHASE

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ABSTRACT

In 1980 and 1981, we studied the breeding ecology of nongame birds inhabiting a sagebrush (*Artemisia* spp.) - dominated community in southeastern Idaho. The bird community was comprised primarily of sage sparrows (*Amphispiza belli*) and Brewer's sparrows (*Spizella breweri*); only three other nongame species nested on the study area. Most male sage sparrows present in 1980 returned in 1981. Sage sparrow territories were contiguous and averaged 0.75 ha. Brewer's sparrow territories were not contiguous and averaged 0.51 ha. Most males of all species acquired mates. Nesting success was very high (70-90%) in 1980, but decreased to 40-60% in 1981. Brewer's sparrows nested in areas with relatively large, dense sagebrush and low herbaceous plant coverage; sage sparrows preferred areas with clumped sagebrush. The two sparrow species chose similar nesting substrates, preferring relatively large, living shrubs. Nestling diet was entirely Arthropodan, but adult diets have yet to be analyzed. After eliminating sagebrush by prescribed burning, population densities of sparrows and sage thrashers (*Oreoscoptes montanus*) likely will decrease, but those of species more characteristic of grasslands probably will increase.

INTRODUCTION

Although much of western U.S. rangeland is dominated by sagebrush (*Artemisia* spp.), the breeding ecology of passerine species characteristic of this habitat has received only limited attention. The most common nongame bird species breeding on the Idaho National Engineering Laboratory (INEL) in southeastern Idaho are the sage sparrow (*Amphispiza belli*), Brewer's sparrow (*Spizella breweri*), and sage thrasher (*Oreoscoptes montanus*). These species are considered sagebrush obligates (Braun et al., 1976), although Beaver (1976), McGee (1976), Hill (1980), and Green (1981) reported sage sparrows and (or) Brewer's sparrows nesting in fields with little or no sagebrush.

Feist (1968), Best (1972), Rich (1980a), Reynolds (1981), and others reported limited information on nest-site selection by these species. Rich (1980b) investigated territorial behavior of sage sparrows, and Tuckfield (1979) studied territory size of sage and Brewer's sparrows in relation to food abundance. Reynolds (1981) reported territory sizes and mating success information for the three species. Studies of the effects of grazing (Olson, 1974; Reynolds, 1978), herbicide applications (Best, 1972; Pyrah and Jorgensen, 1974; Schroeder and Sturges, 1975), chaining (Castrale, 1981), and fire (McGee, 1976; Castrale, 1981) on sage thrashers, sage sparrows, and Brewer's sparrows have augmented our knowledge of their breeding ecology, although many of these studies focused only on changes in population densities and species diversity.

Our objectives are to 1) determine population densities and species composition of nongame bird communities inhabiting proposed-burn and control areas of the INEL; and for the dominant species (sage sparrows and Brewer's sparrows): 2) document territory dynamics and territory characteristics; 3) determine factors influencing nesting success; 4) evaluate nest-site selection; 5) determine nestling and adult diet composition; 6) evaluate niche breadth and overlap between these species; and 7) assess the impact of prescribed burning on these species' breeding ecology.

STUDY AREA AND METHODS

The study area is located within the western boundary of the INEL. In 1980 and 1981, the vegetation was dominated by shrubs and bunchgrasses, but there was substantial bare ground. Dominant woody species were big sagebrush (A. tridentata) and rabbitbrush (Chrysothamnus viscidiflorus), and dominant grasses included bluebunch wheatgrass (Agropyron spicatum), Indian rice grass (Oryzopsis hymenoides), and bottle brush squirreltail (Sitanion hystrix). Four, 6.25-ha plots were established on the study area and gridded throughout at 25-m intervals. Two plots occupy a proposed-burn site, and two (control) plots are on an adjacent area of similar vegetational composition.

Adult sparrows were captured with mist nets and fitted with colored leg bands for individual identification. Territories of male sparrows were mapped by using the "flush" technique (Wiens, 1969). Territories were delineated only generally in 1980, but we attempted to accurately determine all boundaries in 1981. Sparrow population densities were determined by counting territories and fractions of territories lying within plot boundaries. Population densities of all other nongame species were determined from weekly, early-morning censuses (9 June - 8 July 1980, 5 May - 2 July 1981) conducted on all plots; the spot-map method (Robbins, 1970) was employed.

Systematic nest searches were conducted on all study plots periodically throughout May and June by using a modification of Reynolds' (1981) rope-dragging technique. Nests also were discovered incidental to other activities. Active nests were monitored at 1-2 day intervals; if present, nestlings were weighed and their tarsal lengths measured. Nestling diet was sampled by using constrictive neck ligatures (Johnson et al., 1980). Ligatures were affixed after weighing and measuring the young and were left on the nestlings for about 1 hour. For adult diet analysis, sage sparrows and Brewer's sparrows were collected in the morning (0730-1000) by shotgun from areas with vegetational composition similar to the study plots. Four to eight individuals of each species were collected monthly (April-July).

Vegetation was sampled on all plots in June. Canopy coverage and dispersion of sagebrush were estimated by line intercept (Canfield, 1941); each year, 100, regularly-spaced samples were taken near grid markers, using different grid markers in 1980 and 1981. Line intercept and the distance between adjacent shrubs were recorded along a tape extending 5 m from each sampling point in the four cardinal directions. For each sampling locus, the coefficient of variation of intershrub distances was used as an index of dispersion.

We measured percent coverage of herbaceous vegetation on the study area in June by using 20 x 50-cm sample quadrats (Daubenmire, 1959). In 1980 two samples were taken near each grid marker; in 1981, four were taken. Additional information recorded for all sagebrush plants occurring within quadrats included height and crown girth (maximum and minimum). Shrub volume was calculated by the formula $V = (4/3) \pi a^2 b$, where a is half the average of the two girth measurements and b is half the height (Selby, 1967). The condition of each shrub was recorded as dead, approximately 25% of the shrub living, 50% living, 75% living, or all living. The same data were recorded for shrubs supporting a nest as for those within quadrats.

After the nesting season, we estimated canopy coverage and dispersion of sagebrush in the vicinity of each nest by line intercept. A tape was extended from the nest 5 m in the four cardinal directions. We also recorded the height and crown girth of each shrub intercepted by the tape. In 1981, Daubenmire's (1959) technique was employed to estimate coverage of herbaceous vegetation 2.5 and 5 m from each active nest in the four cardinal directions.

Student's t -test was used for statistical analysis. Significant, between-year differences in the data were rare; accordingly, and unless stated otherwise, we pooled the data from both years. Statistical significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Nongame Bird Community

Although nongame birds were relatively abundant, the avian community had few species (Table 1). Sage sparrows and Brewer's sparrows accounted for more than 85% of the total density in both years. Population densities of all species increased slightly from 1980 to 1981, and, aside from the addition in 1981 of one common nighthawk (Chordeilis minor) whose territory was partially encompassed by the study area, bird community composition did not change.

Breeding Ecology of Sage Sparrows, Brewer's Sparrows, and Sage Thrashers

Territory Establishment and Maintenance

Although male sage sparrows selected a particular area soon after arrival, territory boundaries were not defined for 3-4 weeks. Singing and territory boundary disputes gradually increased in frequency and intensity, and by late April, territories were well delineated. Of 14 resident males marked in 1980, 11 returned in 1981 and established territories on the same or nearly the same sites they occupied in 1980. An additional 27 males and 24 females were marked in 1981.

Table 1. Population densities (males/40 ha) of nongame bird species breeding on the study area.

Species	1980	1981
Sage Sparrow	46.4	51.2
Brewer's Sparrow	32.0	33.6
Sage Thrasher	8.0	9.6
Western Meadowlark	1.6	2.4
Common Nighthawk	0	0.8
Total	86.4	97.6

Sage sparrow territories were contiguous and were vigorously defended until nesting was completed. Mean size of 43 territories mapped in 1981 was 0.75 ± 0.24 (SD) ha, similar to the value reported by Reynolds (1981) but much less than those documented by Rich (1980b), Tuckfield (1979), and Green (1981). With the exception of two males that, with their mates, disappeared during the 1981 breeding season, all males maintained territories of relatively constant size and shape throughout the breeding season. By contrast, Rich (1980b), Reynolds (1981), and Green (1981) reported considerable fluctuations in size and shape of sage sparrow territories within a season. Sage sparrows sang markedly less in early July, and, after completion of nesting (late July), territory boundaries were not well defined.

Soon after arrival, Brewer's sparrows and sage thrashers sang frequently and established territories. Six male Brewer's sparrows were marked in 1980; two returned in 1981, both to the same locations they had used previously. Fourteen additional males and 16 females were marked in 1981.

Brewer's sparrows were strongly territorial only until they acquired a mate. Thereafter, song frequency and intensity declined dramatically, and aggressive interaction between neighboring males was uncommon. Moreover, the areas used by pairs overlapped and were considerably larger than those originally defended by the males before pairing. Three males that failed to acquire mates in 1981 left the area within 2-3 weeks after their arrival. Male Brewer's sparrows did not initially utilize all available habitat; but established territories within relatively tall, dense patches of sagebrush. Fifteen territories mapped in 1981 averaged 0.51 ± 0.27 ha, nearly identical to the value reported by Reynolds (1981), but less than that documented by Tuckfield (1979).

Mating Success

In 1980 and 1981, most male sage sparrows, Brewer's sparrows, and sage thrashers succeeded in acquiring mates. Only 9 (11%) of 83 male sage sparrows, 6 (11%) of 57 male Brewer's sparrows, and 1 (7%) of 15 male sage thrashers failed to mate. Reynolds (1981) documented a similar pairing success rate for thrashers, but much lower rates for the two sparrow species.

Nesting and Productivity

Sage sparrows, Brewer's sparrows, and sage thrashers most often laid clutches of three or four eggs. Sparrow eggs evidently were incubated by females (see also Green, 1981) until at least one or two of the eggs hatched; thereafter, males also spent time on the nest. Nestling periods for the three species (Table 2) were somewhat shorter than those reported by Reynolds (1981). Both sexes of all three species fed their nestlings.

Table 2. Nesting data for the 1980 and 1981 breeding seasons.

	Sage Sparrow	Brewer's Sparrow	Sage Thrasher
Clutch size ^a	3.3+0.6 (72) 2-5	3.6+0.6 (45) 3-4	3.8+0.6 (10) 3-5
Incubation period (days) ^a	13.5+0.5 (13) 13-14	11.0+0.0 (2) 11	No data
Hatching rate (%) ^b	72 (231)	90 (158)	76 (38)
Nestling period (days) ^a	9.7+1.1 (19) 8-12	8.1+0.8 (27) 7-10	10.8+1.2 (5) 9-12
Fledging rate (%) ^c	72 (152)	74 (127)	60 (25)
Successful nest (%) ^d	58 (81)	75 (48)	54 (11)

^aMean + S.D.; (n); range.

^bPercent of eggs hatching. Includes only nests with full clutches; total number of eggs in parentheses.

^cPercent of nestlings fledging; total number of nestlings in parentheses, excluding broods in which there was observer-induced mortality.

^dPercent of nests fledging at least one young; total number of nests for which outcome was determined is in parentheses.

Brewer's sparrows experienced substantially higher nesting success than either sage sparrows or sage thrashers (Table 2). Reynolds (1981) reported a higher success rate for thrashers but a much lower rate for Brewer's sparrows. Potential predators inhabiting the study area include the Townsend's ground squirrel (*Spermophilus townsendii*), least chipmunk (*Eutamias minimus*), short-tailed weasel (*Mustela erminea*), gopher snake (*Pituophis melanoleucus*), and western rattlesnake (*Crotalus viridis*). Ground squirrels and chipmunks were abundant and may have accounted for many of the nest losses. Avian predation probably was rare; loggerhead shrikes (*Lanius ludovicianus*), known to prey on nestlings of all three species

(Reynolds, 1979; 1981), were seen on only two occasions and did not nest on the study area. Two brown-headed cowbirds (Molothrus ater) were observed in the 2 years, and one sage sparrow nest was parasitized. Fly larvae (Sarcophagidae) killed some nestlings, and one nest failed as a result. Several individual egg and nestling losses were attributable to severe weather, and at least three nests were deserted as a result of rain or snow.

Sparrow Nest-Site Selection

All nests were situated in big sagebrush plants. Mean heights of 104 sage sparrow and 48 Brewer's sparrow nest shrubs were 66 ± 12 (SD) and 68 ± 14 cm, respectively. Both means were significantly different from the average height of a random sample of shrubs (44 ± 18 cm), but not from each other. Neither sparrow species used dead shrubs for nest sites. Neither species used shrubs less than 30 cm or greater than 110 cm in height for nest sites, although shrubs in those size ranges were available. Both used shrubs 50-100 cm tall in higher proportion than their availabilities.

Although some partly dead shrubs were used, nests never were placed in the dead part of the shrub. Best (1972) also found most Brewer's sparrow nests in live shrubs.

Mean canopy coverage of sagebrush was significantly greater around Brewer's sparrow nests than around sage sparrow nests or on the study area in general (Table 3); the latter two were not significantly different. Feist (1968) and Best (1970) reported mean sagebrush coverages for Brewer's sparrow nest vicinities similar to ours.

Shrub dispersion near sage sparrow nests differed significantly from randomly sampled areas; shrubs around nests tended to be more clumped (Table 3). Shrub dispersion around Brewer's sparrow nests did not differ significantly from that on the study area in general. Although mean height of shrubs around sage sparrow nests was significantly greater than that of the random sample, the difference was relatively small; mean shrub volume did not differ significantly. Thus, coverage and structural features of sagebrush seemed to be most important in the vicinity of Brewer's sparrow nests, whereas spatial distribution of shrubs seemed most important around sage sparrow nests.

Mean herbaceous vegetation coverage was significantly less around Brewer's sparrow nests than on the study area in general (Table 3). Herbaceous plant coverage in the vicinity of sage sparrow nests did not differ significantly from that on the study area in general or in the vicinity of Brewer's sparrow nests (Table 3).

Nestling Biology and Adult Food Habits

Growth data were collected for 166 sage sparrow, 145 Brewer's sparrow, and 29 sage thrasher young; 143, 136, and 29 nestling food samples were collected from the respective species. The nestling diet of all species was entirely Arthropodan and was dominated by : Araneae, Hemiptera, Homoptera,

Table 3. Vegetative characteristics of the vicinities of sage sparrow and Brewer's sparrow nests and of the study area in general.
(Mean±S.D.)

Variable	Sage Sparrow	Brewer's Sparrow	Study Area
Sagebrush coverage (%)	24±9 A ^a (104) ^b	29±9 B (48)	25±10 A (200)
Shrub dispersion ^c	83±20 A (104)	78±16 A,B (48)	77±19 B (200)
Shrub height (cm)	47±20 A (2094)	54±21 B (1034)	44±18 C (2285)
Shrub volume (dm ³)	102±160 A (2094)	143±176 B (1034)	97±141 A (2285)
Herbaceous plant coverage (%)	9±12 A,B (376)	8±9 A (192)	10±12 B ^d (1936)

^aMeans in the same row followed by different letters are significantly different (t-test)

^bSample sizes are in parentheses

^cCoefficient of variation of intershrub distances

^d1981 data only

Lepidoptera, Orthoptera, Diptera, Hymenoptera, and Coleoptera. Forty-three adult sage sparrows and 31 adult Brewer's sparrows were collected for diet analysis.

CONCLUSIONS

To the extent that sagebrush is removed, we expect densities of sage and Brewer's sparrows and sage thrashers to decrease in response to fire, whereas densities of species more common to grasslands (e.g., horned larks, *Eremophila alpestris*; western meadowlarks, *Sturnella neglecta*) probably will increase (McGee, 1976; Rotenberry and Wiens, 1978; Castrale, 1981). Given the abundance of sagebrush and the similarities in nest shrubs of the two sparrow species, it seems unlikely that suitable nesting areas and substrates were limiting resources. Prescribed burning may reduce the sagebrush coverage such that relatively few sparrows and thrashers will locate suitable nest sites. Although herbaceous vegetation did not seem to greatly influence nest-site selection by sage sparrows, it could become important compensatory cover when shrubs of preferred size and density are eliminated (Best, 1972; Olson, 1974).

No studies have assessed the influence of habitat alterations on productivity of sage sparrows, Brewer's sparrows, and sage thrashers. Thus, it is difficult to predict the impact of prescribed burning on nesting success. If these species occupy burned sites at all, available nesting and foraging sites may be suboptimal at best, resulting in an overall decline in reproductive success.

LITERATURE CITED

- Beaver, D. L. 1976. Avian populations in herbicide treated brush fields. *Auk* 93:543-553.
- Best, L. B. 1970. Effects of ecological changes induced by various sagebrush control techniques on non-game birds. M.S. Thesis, Montana State Univ., Bozeman. 74 p.
- . 1972. First-year effects of sagebrush control on two sparrows. *J. Wildl. Manage.* 36:534-544.
- Braun, C. E., M. F. Baker, R. L. Eng. J. S. Gashwiler, and M. H. Schroeder. 1976. Conservation committee report on effects of alterations of sagebrush communities on the associated avifauna. *Wilson Bull.* 88:165-171.
- Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. *J. Forestry* 39:388-394.
- Castrale, J. S. 1981. Use of managed sagebrush grasslands by bird populations. Ph.D. Diss., Brigham Young Univ., Provo, Utah. 79 p.
- Daubenmire, R. F. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.* 33:43-64.
- Feist, F. G. 1968. Breeding bird populations in relation to proposed sagebrush control in central Montana. M.S. Thesis, Montana State Univ., Bozeman. 41 p.
- Green, B. H. 1981. Habitat selection and utilization by sage sparrows (*Amphispiza belli*) in a cold desert mixed shrub community. M.S. Thesis, Brigham Young Univ., Provo, Utah. 24 p.
- Hill, H. O. 1980. Breeding birds in a desert scrub community in southern Nevada. *Southwestern Nat.* 25:173-180.
- Johnson, E. J., L. B. Best, and P. A. Heagy. 1980. Food sampling biases associated with the "ligature method." *Condor* 82:186-192.
- McGee, J. M. 1976. Some effects of fire suppression and prescribed burning on birds and small mammals in sagebrush. Ph.D. Diss., Univ. of Wyoming, Laramie. 145 p.

- Olson, R. A. 1974. Bird populations in relation to changes in land use in Curlew Valley, Idaho and Utah. M.S. Thesis, Idaho State Univ., Pocatello, 40 p.
- Pyrah, D. B., and H. E. Jorgensen. 1974. Effects of ecological changes induced by sagebrush control techniques on nongame birds. p. 35-42, In Montana Fish and Game Dept., Job Prog. Report W-7.2. Nov., 1974.
- Reynolds, T. D. 1978. the response of native vertebrate populations to different land management practices on the Idaho National Engineering Laboratory site. Ph.D. Diss., Idaho State Univ., Pocatello. 117 p.
- _____. 1979. The impact of loggerhead shrikes on nesting birds in a sagebrush environment. Auk 96:798-800.
- _____. 1981. Nesting of the sage thrasher, sage sparrow, and Brewer's sparrow in southeastern Idaho. Condor 83:61-64.
- Rich, T.D.G. 1980a. Nest placement in sage thrashers, sage sparrows, and Brewer's sparrows. Wilson Bull. 92:362-368.
- _____. 1980b. Territorial behavior of the sage sparrow: spatial and random aspects. Wilson Bull. 92:425-438.
- Robbins, C. S. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723-726.
- Rotenberry, J. T., and J. A. Wiens. 1978. Nongame bird communities in northwestern rangelands. P. 32-46 In R. M. DeGraaf, ed. Workshop on nongame bird habitat management in the coniferous forests of the western U.S. U.S. For. Serv. Gen. Tech. Rep. PNW-64.
- Schroeder, M. H., and D. L. Sturges. 1975. The effect on the Brewer's sparrow of spraying big sagebrush. J. Range Manage. 28:294-297.
- Selby, S. M. (ed.). 1967. Handbook of tables for mathematics. 3rd ed. The Chemical Rubber Co., Cleveland, Ohio. 1050 p.
- Tuckfield, R. C. 1979. Optimal territory size: a model and test. M.S. Thesis, Brigham Young Univ., Provo, Utah. 41 p.
- Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithol. Monogr. 8. 93 p.

EFFECTS OF A CONTROLLED FIRE ON SMALL RODENT POPULATIONS IN A SAGEBRUSH COMMUNITY

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ABSTRACT

An investigation of species composition, food habits, and movement patterns of rodent populations on a prescribed burn area was initiated at the Idaho National Engineering Laboratory in June, 1981. Live- and snap-trap data collected prior to the burn indicated that the small mammal community was composed of deer mice (Peromyscus maniculatus), least chipmunks (Eutamias minimus), Townsend's ground squirrels (Spermophilus townsendii), Great Basin pocket mice (Perognathus parvus), Northern grasshopper mice (Onychomys leucogaster), Ord's kangaroo rats (Dipodomys ordii), and montane voles (Microtus montanus) in decreasing order of abundance. Changes in food habits, as assessed from stomach contents of snap-trapped individuals, and the movement-colonization pattern as it relates to feeding strategies of rodents will be compared for both pre- and post-burn residents occurring in control and experimental areas.

INTRODUCTION

Numerous studies have been conducted to assess the effect of fire on small mammal populations (cf. Bendell, 1974; Roppe and Hein, 1975; Lyon et al., 1978; Crowner and Barrett, 1979). Most of these studies have monitored abundance and composition of small mammal communities in experimental (fire) and control areas following a burn. Only a few investigators have intensively monitored demographic characteristics of populations on both areas (Christian, 1977; Crowner and Barrett, 1979; Gaines et al., 1979). Quantitative analyses of changes in food and cover have rarely been related to population responses (Bock and Bock, 1978; Crowner and Barrett, 1979).

Several studies have been reported for rodent communities on burned habitat in semi-arid areas (Halford, 1981; Hedlund and Rickard, 1981; Gano and Rickard, 1982; McGee, 1982). However, these studies have not considered food habits of resident communities of rodents before and after the burn, and changes in food habits have not been related to movement patterns for surviving or colonizing species found on the burn area. Further, no data are available on the amount of mortality to rodent communities during a prescribed burn of sagebrush habitat, although fire commonly is used as a management technique to eliminate xerophytic shrubs in desert areas.

A unique opportunity existed to study food habits, mortality and colonizing patterns of rodents at a prescribed burn for a 405 ha mature stand of big sagebrush (Artemisia tridentata) on the Idaho National Engineering Laboratory. Further, information on the insect fauna (Stafford and Barr, this volume) and vegetation (Floyd and Anderson, this volume) were being documented prior to the proposed burn. Thus, assessment of responses of small mammals to changes in insect food supply and vegetative cover, and potential differences

in the survival strategy and physical dimensions of the spacial areas used by individual species before and after habitat alteration by fire could be considered.

The objectives of the present study are to: 1) estimate changes in rodent species composition on burn and control areas before and after a prescribed burn, 2) determine whether individual rodents survive a burn and move to immediately adjacent, unburned habitat, 3) determine whether diets in the most common rodent species change significantly following a burn, 4) determine post-burn foraging ranges of rodents, and 5) determine whether unburned islands remaining in the experimental area can serve as optimal habitat for permanent colonization by rodents and, if possible, the size of areas required for permanent occupancy.

METHODS

Twenty-six snap-trap stations spaced at 10 m intervals were established along three vegetative macro-transects (Fig. 1) sampled by Floyd and Anderson, (this volume). In September, 1980 and May 1981, these transects were sampled with two Museum Special and one McGill rat trap at each station for 3 days following a 2-day prebait period as recommended by Johnson and Keller (1983). In September 1981, three Museum Special traps per station were used on the same lines. However, stations 1-10 on transects 3 and 5 were not trapped in order to preserve animals that were marked on adjacent control grids. Food habit analysis will be restricted to several species collected during fall and spring periods in snap traps before and after the burn. Food composition will be assessed from stomach samples of identifiable food fragments, as quantified by the method described by Sparks and Malechek (1968).

Eighteen study areas were selected for intensive live trapping prior to the burn. Hexagon grid systems (Keller, unpublished), each containing Longworth live traps spaced at 10 m intervals, were superimposed upon 10 vegetative sampling plots (Fig. 1). Six of the hexagons were located in control (non-burn) habitat whereas 12 were located in the burn area (Fig. 1). Thus, the trapping effort was twice as intensive (228 sites) in the burn area as the control area (114 sites).

During mid-summer 1981, live traps were set during early evening and examined for captures the following morning for three consecutive days. Owing to wide separation between sampling sites, we were able to live trap only six hexagons weekly. Traps were left locked open on each grid following enumeration of animals and areas were then selectively retrapped for 1 to 3 days to collect individuals for telemetry evaluations and to validate the number of living individuals just prior to the prescribed burn date. Since a complete burn was not obtained as anticipated, this procedure will be repeated during the summer of 1982 to mark as many individuals as possible.

All individuals captured were marked with individually numbered ear tags or numbered Essex leg bands and were released at the site of capture. Station of capture, weight, and reproductive condition were recorded for each individual to allow evaluation of movement and composition of rodent communities among hexagons.

Figure 1. Sampling configuration for small rodent studies on a proposed burn and control area, Idaho National Engineering Laboratory. Snap-trapping transects (STT) traverse both control and experimental habitat on the study area along macro-transects 3 to 5, whereas live-trap hexagons (above) are located along micro-transects where vegetation has been sampled (see text).

During the latter portion of July 1981, 16 previously tagged adult rodents were fitted with SM-1 transmitters attached to "R" -- adjustable loop collars (AVM Instrument Company, Dublin, CA). Minimum acrylic potting was used in the construction of each unit such that the finished weight averaged 2.2 g for units placed on deer mice (*Peromyscus maniculatus*) and least chipmunks (*Eutamias minimus*) and 3.7 g for the unit placed on one Ord's kangaroo rat (*Dipodomys ordii*). Three least chipmunks and 1 deer mouse were fitted with radio packages on control hexagons whereas four least chipmunks, seven deer mice, and one Ord's kangaroo rat were fitted with packages on the experimental area. Individuals were monitored with a scanning Dav-Tron receiver and a hand-held yagi antenna until the anticipated burn date. During the summer 1982, this procedure will be repeated to obtain information on movement and survival patterns during the scheduled burn.

RESULTS

Samples obtained during 1926 snap-trap nights completed during two fall and one spring period yielded 403 specimens of five species of small mammals (Table 1). The pooled snap-trap data suggest that deer mice, least chipmunks,

Table 1. Number of small mammals collected during three nights of snap-trapping line transects on the Idaho National Engineering Laboratory Burn Site.

<u>Date</u>	<u>Trap Nights</u>	<u>Location</u>	<u>Species</u>				
			<u>Peromyscus maniculatus</u>	<u>Perognathus parvus</u>	<u>Spermophilus townsendii</u>	<u>Onychomys leucogaster</u>	<u>Eutamias minimus</u>
September, 1980	234	Line 1	43	1	0	0	19
	234	Line 2	35	4	0	0	22
	234	Line 3	<u>36</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>23</u>
		Subtotal	114	6	0	0	64
May, 1980	234	Line 1	35	3	20	1	10
	234	Line 2	19	0	5	0	2
	234	Line 3	<u>40</u>	<u>0</u>	<u>4</u>	<u>2</u>	<u>6</u>
		Subtotal	94	3	29	3	18
September, 1981	144	Line 1	11	0	0	0	3
	234	Line 2	16	0	0	2	11
	144	Line 3	<u>21</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>8</u>
		Subtotal	48	0	0	2	22

and Townsend's ground squirrels were most abundant on the pre-burn area and that Great Basin pocket mice (*Perognathus parvus*) and Northern grasshopper mice (*Onychomys leucogaster*) were uncommon. The relative abundance of rodents appeared to be declining, a condition also noted at other sampling sites on the INEL (Keller, this volume).

During 1368 live-trap nights, 320 small mammals were individually marked on 18 hexagon grids (Table 2). Density of small mammals appeared to decrease at the upper end of the burn site (hexagons 4H, 2J, and 2K). The percentage of new deer mice marked during each sampling period was high, suggesting that extensive recruitment or movement was occurring among the hexagon matrices. Seventeen deer mice were caught on two different hexagons, often over intervals of 24 h and over distances exceeding 0.16 km. Recapture rates varied, but the number of new animals marked steadily decreased during live trapping.

Point relocations were not sought for individual radio-collared animals, as we only intended to attempt to relocate individuals immediately following the burn. However, radio-collared least chipmunks were noted to move distances greater than 100 m beyond the point of capture and release. Four hexagons in the experimental area were retrapped 1 day following release of transmittered animals. All radio-collared individuals were recaptured in live traps and all three species were recaptured. Two individuals were known to have died prior to battery failure of radio packages. Thirteen of the remaining radio packages failed shortly after the anticipated burn date, presumably due to battery failure. Radio packages functioned well for several weeks.

DISCUSSION

The effects of fire on small mammals have been studied in a variety of habitats ranging from grasslands to forests, although the majority of studies have taken place in forests. Few studies have been undertaken in sagebrush communities (McGee, 1982). From these studies, however, several generalizations can be made concerning the effect of fire on rodents. First, fire produces a shift in the species composition of small mammals that several authors have attributed to changes in vegetation (e.g., Ahlgren, 1966; Beck and Vogl, 1972), or food utilization (McGee, 1982). Secondly, both increases and decreases in abundance of small mammals have been reported following a fire. For example, Cook (1959), studying rodents in brush and grass areas near Berkeley, California, concluded that fire removed all species of small mammals either directly or indirectly by loss of food and cover. In contrast, some authors have noted that small mammals were more numerous on burn sites (cf. Gashwiler, 1959), and several studies have indicated that deer mouse populations increase following fires. Thirdly, recovery of small mammals following a fire has been attributed to immigration and increased reproduction, although there is contradictory evidence for the latter point.

The INEL prescribed burn study should provide data on mortality and dispersion of desert rodent populations subjected to fire. If a complete burn is obtained, we anticipate total destruction of the small mammal community, either directly by fire or indirectly through exposure of survivors to a high risk of predation. Thus, no marked or transmittered individuals should be collected along interface areas. Early colonization of burned habitat by granivores residing along the interface likely will be rapid if fire reduces competition for and cryptic exposure of unsprouted seed reserves.

Table 2. Number and species composition of small mammals live-trapped from June 30 to July 31, 1981 on 18 hexagon grids, Idaho National Engineering Laboratory Burn Site.

Week (trap) Nights	Hexagon	Traps set	Total recaptures	Total new animals	Species				
					<u>Peromyscus</u> <u>maniculatus</u>	<u>Eutamias</u> <u>minimus</u>	<u>Perognathus</u> <u>parvus</u>	<u>Dipodomys</u> <u>ordii</u>	<u>Microtus</u> <u>montanus</u>
1 (3)	1A	57	14	17	13	1	3		
	3A	"	21	20	19				1
	2B	"	28	22	20		1	1	
	4B	"	23	23	19	3	1		
	1C	"	17	18	12	5	1		
	3C	"	22	19	17	2			
	Total	342	125	119	100	11	6	1	1
2 (3)	2D	57	25	16	12	4			
	4D	"	19	14	8	6			
	1E	"	13	18	13	5			
	3E	"	21	18	16	2			
	2F	"	18	19	14	5			
	4F	"	15	15	11	4			
	Total	342	111	100	74	26			
3 (3)	1G	57	13	16	10	6			
	3G	"	16	12	7	4	1		
	2H	"	14	15	12	3			
	4H	"	8	8	7	1			
	2J	"	9	7	5	1	1		
	2K	"	4	7	5	2			
	Total	342	64	65	46	17	2		
4 (2)	2B	38	25	5	3	2			
	3C	"	14	6	5	1			
	2D	"	16	2	2				
	2F	"	11	4	4				
	Total	152	66	17	14	3			

Table 2. Continued

Week (trap) Nights	Hexagon	Traps set	Total recaptures	Total new animals	Species				
					<u>Peromyscus maniculatus</u>	<u>Eutamias minimus</u>	<u>Perognathus parvus</u>	<u>Dipodomys ordii</u>	<u>Microtus montanus</u>
5 (1)	3A	19	8	1	1				
	4B	"	9	0					
	1C	"	6	6	6				
	3C	"	8	0					
	4D	"	9	0					
	3E	"	10	5	5				
	4F	"	10	1	1				
	1G	"	9	3	2	1			
	3G	"	4	2	1		1		
	2H	"	7	1		1			
	Total	190	80	19	16	2	1		

LITERATURE CITED

- Ahlgren, C. E. 1966. Small mammals and reforestation following prescribed burning. *J. Forest.* 64:614-618.
- Beck, A. M. and R. J. Vogl. 1972. The effects of spring burning on rodent populations in a brush prairie savanna. *J. Mammal.* 53:337-345.
- Bendell, J. F. 1974. Effects of fire on birds and mammals. p. 73-138 In *Fire and Ecosystems*, T. T. Kosłowski and C. E. Ahlgren, eds. Academic Press, New York.
- Bock, C. E. and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. *J. Range Manage.* 31:296-300.
- Christian, D. P. 1977. Effects of fire on small mammal populations in a desert grassland. *J. Mammal.* 58:324-427.
- Cook, S. F., Jr. 1959. The effects of fire on a population of small rodents. *Ecology* 40:102-108.
- Crowner, A. W. and G. W. Barrett. 1979. Effects of fire on the small mammal component of an experimental grassland community. *J. Mammal.* 60:803-813.
- Gaines, M. S., A. M. Vivas, and C. L. Baker. 1979. An experimental analysis of dispersal in fluctuating vole populations: demographic parameters. *Ecology* 60:814-828.
- Gano, K. A. and W. H. Rickard. 1982. Small mammals of a bitterbrush-cheatgrass community. *Northwest Sci.* 56:1-7.
- Gashwiler, J. S. 1959. Small mammal study in west-central Oregon. *J. Mammal.* 40:128-139.
- Halford, D. K. 1981. Repopulation and food habits of Peromyscus maniculatus on a burned sagebrush desert in southeastern Idaho. *Northwest Sci.* 55:44-49.
- Hedlung, J. D. and W. H. Rickard. 1981. Wildfire and the short-term response of small mammals inhabiting a sagebrush-bunchgrass community. *Murrelet* 62:10-14.
- Johnson, W. C. and B. L. Keller. 1983. An examination of snap-trapping techniques for estimating rodent density in high desert. *Northwest Sci.* (in press).
- Lidicker, W. Z., Jr. 1975. The role of dispersal in the demography of small mammals. p. 103-128. In F. B. Golley, K. Petrusewicz, and L. Ryskowski, eds. *Small mammals: their productivity and population dynamics*. International Biological Programme, Volume 5. Cambridge University Press, Cambridge.

- Lyon, L. J., H. S. Crawford, E. Czuhai, R. L. Fredricksen, R. F. Harlow, L. J. Metz, and H. A. Person. 1978. Effects of fire on fauna. USDA Forest Service General Technical Report WO-6. U.S. Government Printing Office, Washington, D.C., 001-001-0482-1. 22pp.
- McGee, J. R. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. J. Range Manage. 35:177-179.
- Roppe, J. A. and D. Hein. 1975. Effects of fire on wildlife in the Rocky Mountains: a review. USDA Forest Service, Rocky Mt. Forest and Range Experiment Station, RM- 00- 74. 43pp.
- Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage dry weight in diets using microscopic technique. J. Range Manage. 21:264-265.
- Sullivan, T. P. 1979. Demography of populations of deer mice in coastal and clear-cut (logged) habitats. Can. J. Zool. 56: 1636-1648.

SAGE GROUSE, PRONGHORN, AND LAGOMORPH USE OF A
SAGEBRUSH-GRASSLAND BURN SITE ON THE
IDAHO NATIONAL ENGINEERING LABORATORY

Robert J. Gates and Robert L. Eng

ABSTRACT

A study was begun in May 1980 to determine the abundance, distribution, and food habits of sage grouse (Centrocercus urophasianus), pronghorn (Antilocapra americana), and lagomorphs on a sagebrush (Artemisia tridentata) grassland burn site on the Idaho National Engineering Laboratory (INEL). The burn site was treated in August and October 1981 and in September 1982. Post burn data were collected after treatment to document short term effects of fire on sage grouse and lagomorphs. Jack rabbit (Lepus californicus) density in the burn area was 0.4, 2.9, and 1.5 rabbits/ha in 1980, 1981, and 1982, respectively. Sage grouse and pronghorn used a 300 km² area which included the burn site primarily from November through June in 1981 and 1982. Sage grouse moved to areas where free water was available during the summer. Grouse used the study area as winter, breeding, nesting, and early brood rearing habitat. Sagebrush comprised > 90% of the pronghorn diet during the fall, winter, and spring and 87% of the April and May sage grouse diet. Summer diets of grouse and pronghorn were dominated by forbs. Pygmy rabbits (Brachylagus idahoensis) consumed 90% sagebrush during the winter and switched to a diet of primarily rabbitbrush (Chrysothamnus spp.) and grass in July and August. Winterfat (Ceratoides lanata) comprised 41% of the yearly jack rabbit diet. Jack rabbits consumed 14% grasses primarily from March through August. Dispersal from burned areas was documented for eight of 14 radio-collared pygmy rabbits during a 1 month period following the August 1981 burn. Eight rabbits, including three dispersers, died within a 2 month period after the burn. No mortality or dispersal of radio-collared rabbits was observed prior to the burn. Sage grouse responded to the burn by establishing a new lek on a burned area. Preliminary conclusions regarding the impact of fire on the above species were made based on the data presented.

INTRODUCTION

Research was initiated in May 1980 to evaluate the impact of a prescribed burn of a sagebrush-grassland on sage grouse, pronghorn, and lagomorphs. Many post-fire studies of vertebrate populations have been conducted without prior knowledge of the abundance, distribution, and ecology of the species present on areas impacted by unplanned fires (Riggs and Peek, 1980; Halford, 1981). Such studies necessarily rely only on comparisons of burned and unburned areas. A prescribed burn provides an opportunity to compare the distribution, abundance, and ecology of the above species before and after fire as well as on burned and unburned areas. Fire is an important source of disturbance in sagebrush-grassland communities (Wright et al., 1979), however, little is known about the effects of fire on sage grouse, pronghorn, and lagomorphs in sagebrush habitats.

Three lagomorph species occur on the burn site: pygmy rabbits, Nuttall's cottontails (Sylvilagus nuttalli), and black-tailed jack rabbits. Pygmy rabbits rely on sagebrush for food and cover throughout the year (Green and Flinders, 1980). Sage grouse depend primarily on sagebrush for food during the fall, winter, and spring as do pronghorn which inhabit shrub-dominated ranges. Both species switch to a diet dominated by forbs during the summer. (Patterson, 1952; Beal and Smith, 1970). Sagebrush also provides winter habitat for pronghorn and winter and nesting habitat for sage grouse (Bayless, 1969; Eng and Schladweiler, 1972; Wallestad and Pyrah, 1974). Black-tailed jack rabbit diets have been found to consist of over 65% grasses. Sagebrush is a relatively unimportant forage (Johnson, 1979; Johnson, 1982) although it may become important at certain times of the year (Currie and Goodwin, 1966; Fagerstone et al., 1980). Black-tailed jack rabbit densities are positively related to the relative abundance of grass cover (MacCracken and Hansen, 1982) probably because jack rabbits prefer to feed in open grassy habitats at night. During the day they use tall shrub cover for protection from weather and predators.

The purpose of this study was to provide indices to the abundance of the above species on the burn area prior to treatment. To help explain changes in grouse, pronghorn, and lagomorph abundance on the burn site after treatment, research was conducted to define some of the habitat requirements of these species. Since quantity and quality of food are important factors influencing the distribution and abundance of birds and mammals (Watson and Moss, 1970), research was conducted to determine the food habits of grouse, pronghorn, and lagomorphs in the burn area. Sage grouse and pronghorn on the INEL occupy seasonal ranges and make extensive movements between these ranges (Connelly, 1982; Hoskinson and Tester, 1980). Consequently, this study documented the seasonal importance of the burn site to these two species.

The specific objectives of this study were to: 1) provide indices to the abundance of grouse, pronghorn, and lagomorphs on the burn site and on a control area for comparison with the results of post-burn studies; 2) determine the food habits of grouse, pronghorn, black-tailed jack rabbits, and pygmy rabbits in unburned habitat; 3) document seasonal distribution and movements of sage grouse in relation to the burn site; 4) evaluate fire related mortality and dispersal of pygmy and cottontail rabbits.

STUDY AREA

The burn site is a 405 ha area located on the west-central boundary of the INEL, 10 km south of Howe, Butte County, Idaho. Floyd (1982) described the vegetation of the burn site prior to treatment. Dominant shrubs on the burn site were Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis) and green rabbitbrush (Chrysothamnus viscidiflorus). The dominant grasses were bluebunch wheatgrass (Agropyron spicatum), Indian ricegrass (Oryzopsis hymenoides), and bottlebrush squirreltail (Sitanion hystrix). Floyd (1982) identified 50 species of forbs in the burn area. Many of the forbs are important to the diets of sage grouse and pronghorn (Wallestad et al., 1975; Klebenow and Gray, 1968; Beale and Smith, 1970). Approximately 20% of the burn site was burned in August 1981, October 1981, and September 1982. Scattered patches of sagebrush were burned on the west half of the burn site; larger, continuous areas were burned on the east half.

The study area includes a 300 km² area surrounding the burn site (Fig. 1). This area is predominantly a sagebrush-grassland. There is an abrupt change to irrigated cropland 6.4 km north of the burn site. Alfalfa and barley are the principle crops. The mesic environment created by irrigation attracts large numbers of sage grouse and pronghorn during the summer. Elevation of the study area ranges from 1463 m to 1646 m. The climate is characterized by hot summers and cold winters with low precipitation. Average annual temperature is 5.6 C and annual precipitation averages 20.6 cm. More than one-third of the annual precipitation occurs during the spring (Atwood, 1970; Harniss and West, 1973).

METHODS

Fecal pellet counts (Neff, 1968) were used to obtain indices to the abundance of grouse, pronghorn, jack rabbits, and pygmy rabbits on the burn site and on a control area. Four pellet grids were located on the west half of the burn site. Four control grids were located immediately south of the burn site (Fig. 1). Each grid consists of 25 plots located at 50 m intervals in a 5 x 5 arrangement. Three concentric circular subplots were centered at each plot. Single sage grouse fecal pellets and roost droppings (groups of 10 or more pellets) were counted on 40 m² plots. Pronghorn pellet groups (15 or more pellets) were counted on 10 m² plots. Lagomorph pellets were counted on 1 m² plots. No distinction was made between jack rabbit and cottontail pellets, however, pygmy rabbit pellets were differentiated by size and morphology. All plots were examined twice and cleared of pellets as they were counted. Four pellet counts were conducted during the study. The first count was made as the plots were cleared for the first time in late September and early October 1980. The second count was completed in June 1981, the third in August 1981 (burn) and October 1981 (control), and the fourth count was completed in September 1982. The number of pellets recorded for each species (except pygmy rabbit) on all plots was divided by the number of months since the plot was last counted to adjust for varying time intervals between counts. An arbitrary value of 12.0 months was used for the first count.

Microhistological analysis of fecal contents (Sparks and Malachuk, 1968) was used to determine the food habits of grouse, pronghorn, jack rabbits, and pygmy rabbits. Jack rabbit and pronghorn fecal samples were collected monthly from December 1980 to November 1981. Eight to 10 samples were composited each month from jack rabbit feces collected on and near the burn site. Ten pronghorn pellet groups were collected monthly from herd locations and along unimproved roads within the study area. Twenty-six pygmy rabbit fecal samples collected from July to December 1981 were analyzed for plant composition. Pygmy rabbit feces were obtained from active burrows on and near the burn site and from rabbits live-trapped on the burn site. Thirty-nine grouse fecal samples collected from April to June 1981 on pellet grids, leks, and from flush and capture sites within the study area were analyzed for plant and insect composition. All fecal analyses were performed by the Composition Analysis Laboratory at Colorado State University.

Sage grouse leks were located by ground surveys and from an airplane during the springs 1981-82. Grouse were captured by night-lighting (Giesen et al., 1982) and mist-netting on five leks within 6.5 km of the burn site.

Figure 1. Study area showing locations of burn site, agricultural area, and sage grouse leks within the 300 km² study area. Insert shows detail of burn site with pellet count grids and three leks.

Captured grouse were marked with numbered patagial tags (males), poncho tags (females; Pyrah, 1970), or with radio-collars (males and females; Amstrup, 1980) to provide data on seasonal distribution and movements. Three leks were censused (Jenni and Hartzler, 1978) during the springs 1981-82. Two additional leks were discovered on the burn site and censused in spring 1982.

During the summers 1980-82 a 12 km sage grouse observation route was driven along the sagebrush-agriculture interface 6.4 km north of the burn site. The route was driven one to two times per week during mornings and evenings from June through September in 1980 and 1981. The route was driven once every 1-2 weeks from mid-June through August in 1982. Observations of males, broods, and females without broods were recorded separately. Grouse were captured with a net gun (Mechlin and Schaiffer, 1980), mist nets, and by nightlighting in alfalfa fields and adjacent sagebrush. Captured grouse were color-tagged or fitted with radio-collars to determine fall movements away from the agricultural area.

Radiotelemetry was used to investigate movements, mortality, and dispersal of pygmy and cottontail rabbits before and after the August 1981 burn. Four cottontail and 32 pygmy rabbits were captured with live traps set at active burrows along the south end of the burn site from July 1981 through August 1982. Captured rabbits were radio-collared or marked with number ear tags. Sex, species, weight, body length, ear lengths, hind foot lengths, and trap location were recorded for each capture. Radio-collared rabbits were located by triangulation two to five times per week from 13 July to 17 September, 1981 and in July and August 1982. Additional locations were determined by flushing radio-collared rabbits and from trap recaptures. Dispersing rabbits were located by airplane. Locations and the fate of dispersers were confirmed by observations at ground locations.

RESULTS

Pellet Counts

Pellet counts were used to estimate the density of jack rabbits on the pellet grids. Assuming that jack rabbits excrete 545 pellets/day (Arnold and Reynolds, 1943); the density ($\bar{x} \pm SD$) of jack rabbits on the pellet grids was 0.4 ± 0.2 in 1980, 2.9 ± 0.5 in 1981, and 1.5 ± 0.5 in 1982. Jack rabbit pellet densities were similar on the burn and control areas in the first and third counts but were higher on the burn area in the second and fourth counts ($P < 0.01$, Kruskal-Wallis test). Complete counts of pygmy rabbit pellets were not made, however, the number of pellets on each plot were assigned to one of four density classes (0, 1-25, 26-50, >50 pellets/plot). Pygmy rabbit pellet densities were not different on the burn and control areas except in the third count. Pellet densities were higher ($P < 0.05$, Chi-square test) on the control area probably as a result of the shorter time interval sampled by the third burn count. Pronghorn pellet densities were higher on the control area in the second and fourth counts ($P < 0.05$, Kruskal-Wallis test) but did not differ between the burn and control areas in the first and third counts. Sage grouse pellet densities were not different on the burn and control areas in the first three counts but were higher on the burn area in the fourth count ($P < 0.01$, Kruskal-Wallis test).

The second and third pellet counts were used to compare pronghorn and sage grouse use of the burn and control areas on a seasonal basis. Fall, winter, and spring use of the burn and control areas was sampled by the second count and summer use was sampled by the third count. The results of these counts were adjusted for the number of months which each count covered. Monthly pellet deposition rates were higher during the fall, winter, and spring period than during the summer for both species on the burn and control areas ($P < 0.01$, Kruskal-Wallis test).

Food Habits

Shrubs accounted for 76.2% of the yearly pronghorn diet. Sagebrush was the major shrub consumed by pronghorn throughout the year ranging from 11.9% of the diet in August to 96.4% of the October diet ($\bar{x} = 70.7\%$). Forbs were utilized primarily during June, July, and August when they comprised 57.5 - 61.0% of the diet. The most important forb species during these months were Sphaeralcea spp. (21.6%), Descurainia spp. (17.1%), and Balsamorhiza spp. (5.3%). Forbs accounted for 22.9% of the yearly diet and grasses contributed only 0.9% (Fig. 2).

Jack rabbits consumed 67.0% shrubs, 19.4% forbs, and 13.6% grass. Major shrubs in the yearly jack rabbit diet were Ceratoides lanata (41.4%), Chrysothamnus nauseosus (15.3%) and Artemisia spp. (8.3%). Ceratoides lanata was utilized primarily during the winter, spring, and summer, Chrysothamnus nauseosus was used mostly during the summer and fall, and Artemisia spp. was used primarily during the winter. Grasses were consumed by jack rabbits primarily from March through August when they comprised 15.9 - 25.5% of the total diet. The January diet consisted of 16.8% grass, most of which was a seedling not yet mature enough to have identifiable characteristics (Foppe, T., pers. comm.). The most abundant grasses in the jack rabbit diet from March through August were Oryzopsis hymenoides (8.9%), Stipa spp. (4.2%), and Poa spp. (3.0%). Forb use was sporadic throughout the year with peaks in consumption occurring in December (24.7% of the diet), March (33.5%), June (18.6%), and October (80.9%). Phlox spp. accounted for 80.7% of the forbs consumed and was primarily responsible for the pronounced monthly peaks in forb use (Fig. 3).

Shrubs contributed 85.2% (unweighted mean) of the pygmy rabbit diet from July to December 1981. Shrub use was lowest in August (73.1%) and highest in December (97.9%). Sagebrush was the most important shrub in the diet (54.2%) followed by Chrysothamnus nauseosus (25.8%), and Ceratoides lanata (4.6%). Grasses comprised 10.0% of the July to December diet and were consumed mostly during July and August. Oryzopsis hymenoides and Stipa spp. were the most important grasses consumed. Forbs contributed 4.9% of the July to December diet (Table 1).

Sage grouse diets were 77.7% sagebrush from April to June 1981. Grouse of different sex and reproductive classes did not appear to consume equal proportions of sagebrush ($P < 0.01$, 1-way ANOV). Breeding males consumed the greatest proportion of sagebrush (98.9%). Sage grouse diets did not differ significantly within the sexes; however, the proportion of sagebrush in the

Figure 2 Monthly pronghorn diet in unburned habitat surrounding the burn site, December 1980 - November 1981.

Figure 3. Monthly jack rabbit diet in unburned habitat on and near the burn site, December 1980 - November 1981.

Table 1. Pygmy rabbit diets (% dry weight), July-December 1981.

	July N = 4	August N = 8	September N = 8	November N = 3	December N = 3
Sagebrush	30.1 + 30.2 ^a	8.7 + 3.4	51.7 + 29.4	89.3 + 7.0	91.3 + 1.0
Rabbitbrush	35.3 + 23.7	60.0 + 18.6	24.7 + 24.1	4.9 + 4.3	3.9 + 3.5
Winterfat	13.8 + 13.2	3.3 + 4.0	3.2 + 2.6	1.1 + 2.0	1.6 + 1.6
Horsebrush (<i>Tetradymia</i> <i>canescens</i>)	0.7 + 1.5	0.3 + 0.8	0.0 + 0.0	0.0 + 0.0	1.1 + 1.9
Total Shrub	79.9 + 10.7	72.3 + 17.3	79.6 + 16.1	95.3 + 5.3	97.9 + 1.0
Grass	18.6 + 9.6	21.9 + 15.9	7.9 + 10.0	1.0 + 1.6	0.5 + 0.9
Forbs	1.5 + 1.8	5.8 + 6.6	12.5 + 8.0	3.7 + 3.6	1.6 + 1.6

^aMean + SD

Table 2. Sage grouse diets (% dry weight), April-June 1981.

	Nesting Hens N = 7	Brooding Hen N = 6	Broodless Hens N = 9	Males (Leks) N = 6	Males (Flush) N = 11
Sagebrush	79.9 + 19.0 ^a AB ^b	54.7 + 24.8 B	66.7 + 30.9 AB	98.9 + 1.4 C	86.2 + 16.7 AC
Rabbitbrush	0.0 + 0.0	0.0 + 0.0	0.0 + 0.0	0.2 + 0.5	<0.1
Forbs	19.9 + 19.1	44.3 + 24.7	33.0 + 30.9	0.7 + 0.9	13.4 + 16.9
Sedge	0.0 + 0.0	0.0 + 0.0	<0.1	0.0 + 0.0	0.0 + 0.0
Insects	0.2 + 0.4	1.0 + 1.3	0.2 + 0.3	0.2 + 0.5	0.3 + 0.7

^aMean + SD

^bPercentages of sagebrush with no letter in common were different at $P \leq 0.05$ (Duncan's new multiple range test).

diets of breeding males was significantly higher ($p < 0.05$) than that of all female groups. The proportion of sagebrush in feces collected at flush sites of males away from leks was significantly higher than only that of the brooding female (Table 2). Variation in the grouse diet was not explained completely by sex and reproductive class. The proportion of sagebrush in the grouse diet declined significantly ($P < 0.01$, $r^2 = 0.53$) through the sample period. Forbs and insects comprised most of the remainder of the sage grouse diet, averaging 21.9% and 0.3%, respectively.

Sage Grouse Distribution and Movements

Ten sage grouse leks occur within the 300 km² study area. Five of these leks were located within 6.5 km of the burn site (Fig. 1). One of the leks discovered on the burn site in Spring 1982 was a new lek which was established on an area partially cleared by the August 1981 burn. Lek counts indicated a reduced breeding population of male sage grouse in 1982. Maximum observed male attendance of the two largest leks declined an average of 47% from 1981 (Table 3). No males were observed in 1982 on a third lek which peaked at 18 males in 1981. Ninety-four grouse were captured and marked on or near five leks during the springs 1981-82 (Table 3). Six males and 15 females were radio-collared.

Transmitter failures limited the data collected on seasonal movements and distribution of sage grouse. The data collected to date are preliminary, however, they depict some consistent patterns of sage grouse seasonal distribution and movements. Male grouse distribution during the breeding season (late March to mid May) was closely associated with leks. All locations recorded for radio-collared male grouse during April and May were within 3 km of the lek which each bird attended. Spring movements from leks to summer habitat were documented for one radio-collared and eight color-marked males captured on three leks in the springs 1981-82. All nine birds moved to the agricultural area north of the burn site. The radio-collared male was last seen on the lek where it was captured on 2 May, 1981 and was first located in cropland on 29 May, 1981.

Nine of 11 females radio-collared on or near four leks in the spring of 1982 were followed to nest sites. Most of these grouse nested within 5 km of the lek on which they were captured. Five of the nine nesting hens hatched broods during the first week of June. Four of these hens moved their broods to the agricultural area north of the burn site by the second and third weeks of July. A fifth brood hen moved to near the Naval Reactors Facility (NRF) southeast of the burn site by the first week of August.

Hens without broods did not show a strong tendency to move to cropland north of the burn site. Six broodless hens radio-collared on four leks in 1981 and 1982 were followed for as long as their radio-collars operated. Four of these birds were not followed to summer ranges, however, only one hen showed any indication of movement toward cropland north of the burn site by mid-June. One hen moved in August to a second agricultural area southwest of the burn site. Another hen moved to sagebrush habitat near a natural spring located in the foothills of the Lost River Range by the first week of August.

Table 3. Male grouse attendance and capture summary for five leks closest to the burn site during the springs 1981-82.

Location (Relative to Burn Site)		1981		1982	
		Attendance ^a	Captures (M,F)	Attendance ^a	Captures (M,F)
8-mile Canyon #1	0.1 km North	41(45)	9,1	23(25)	10,6
8-mile Canyon #2	Burn Site	No Count	0,0	10(12)	5,1
Sinks #1	6.4 km East	38(39)	27,3	16 ^b (20)	19,4
Howe Peak	3.5 km Southeast	16(18)	4,0	0(0)	0,0
Knob Butte ^c	Burn Site	No Count	0,0	3(4)	2,3

^aAverage of three highest counts, maximum counts in parentheses.

^bAverage of two counts.

^cNew lek established on burn area in April 1982.

Ninety-seven grouse were captured and marked in cropland north of the burn site during the summers 1980-81. Three males and 13 hens were radio-collared. Fall movements away from the agricultural area were documented for six radio-collared and six color-marked grouse. Fall movements to wintering and breeding areas were all in a southerly direction from the agricultural area. Most of these movements occurred in late October and early November.

Grouse were first observed on the observation route in the agricultural area during the first, second, and fourth weeks of June in 1980, 1981, and 1982, respectively. Only males and broodless hens were observed during the first 2 weeks of June in 1980 and 1981. Broods were not observed in 1982 until the second week of July. Observations of grouse on the route peaked in mid-July in 1980 and 1981. The number of grouse/km observed on the route during June, July, and August was ($\bar{x}$ + SD) 3.4 ± 2.7 in 1980 and 3.1 ± 3.1 in 1981. The maximum number of grouse/km was 8.7 in 1980 and 13.1 in 1981. No grouse were observed on the route after the first week of October in 1980 and after the last week of September in 1981. Radio-collared grouse remained in the agricultural area before and after grouse were first and last observed on the observation route in 1981. Therefore, the actual length of time that grouse used the agricultural area was longer than the observation route results indicated.

Mortality and Dispersal of Lagomorphs

Two cottontail and 12 pygmy rabbits were radio-collared on the burn site prior to the August 1981 burn. Twelve rabbits were located 141 times from 13 July to 18 August 1981. Two pygmy rabbits were never located after being radio-collared. Two more pygmy rabbits were radio-collared on the burn site in mid-September 1981. Fourteen rabbits were located 136 times after the burn on 18 August, 1981. These data will be used to estimate home range sizes for two cottontail and nine pygmy rabbits. The amount of each rabbit's home range which was burned in 1981 will be determined.

No mortality or dispersal of radio-collared rabbits occurred prior to or during the August 1981 burn. Two months after the burn only three of 11 pygmy rabbits whose fates could be determined were still alive. Predation appeared to be the cause of death for seven of eight pygmy rabbits. Three pygmy rabbits and one cottontail were alive when their transmitters ceased functioning in November. Not all of these rabbits remained on the burn site. Rabbit dispersal occurred during a 1 month period following the August 1981 burn. Eight rabbits, including both cottontails, abandoned their home ranges. Seven of these rabbits were relocated off the burn site. Five of the dispersing rabbits were apparently predated; one cottontail and two pygmy rabbits established new home ranges off the burn site. The fate of one dispersing cottontail could not be determined. Six pygmy rabbits remained on the burn site near their capture sites. Only one of these rabbits survived through winter and was recaptured in March 1982 less than 40 m from where it was originally captured. Radio-collared pygmy rabbits were classed as immature or adult on the basis of weights and body measurements (Wilde, 1978). Dispersing pygmy rabbits included adults (>1 year) as well as immatures (<1 year).

Pygmy rabbit mortality did occur as a direct result of the burn in an area where the fire advanced rapidly and was more extensive. No rabbits were radio-collared in this area, however, several burned or asphyxiated rabbits were discovered.

DISCUSSION

Use of the burn site was documented for sage grouse, pronghorn, and three species of lagomorphs. Pygmy rabbits and black-tailed jack rabbits occur on the burn site throughout the year. Pellet counts indicated that the density of jack rabbits was highest during 1981. Jack rabbits tended to be more abundant on the burn area than on the control area. Pygmy rabbit abundance was similar on the burn and control areas. The status of cottontail rabbits on the burn site is unknown. Cottontails may not be very abundant on the burn site since only four of 31 rabbits captured were cottontails. Most of the cottontails on the burn site may be associated with lava ridges and outcrops (MacCracken and Hansen, 1982) where no rabbit trapping was done.

Pellet counts showed that sage grouse and pronghorn used the burn site primarily during the fall, winter, and spring. Sage grouse used the burn area as winter, breeding, nesting, and early brood rearing habitat. The lack of succulent vegetation during the summer precluded use of the burn area as summer habitat. All sage grouse for which movements to summering areas were determined moved during June and July to habitat where a source of free water was available. Hens with broods and males showed a strong tendency to move to agricultural land north of the burn site. Hens without broods showed spring movements in more random directions.

The reduced breeding population of sage grouse observed in spring 1982 may be explained by poor production of young due to abnormally wet weather during the springs 1980-81. April and May precipitation at the Central Facilities Area (CFA), 16.4 km southeast of the burn site, during April and May (nesting and hatching period) was 6.9 and 9.2 cm in 1980 and 1981, respectively. April and May precipitation during the previous 30 years averaged 4.8 cm. The ratio of juvenile grouse to adult hens observed in the agricultural area during June and July was 43:100 in 1980 and 96:100 in 1981. A mean of 293 juveniles/100 adult hens was observed from 1977-79 on various brood-rearing areas on or adjacent to the INEL site (Connelly, J., pers. comm.).

Grouse, pronghorn, and pygmy rabbits relied heavily on shrubs, particularly sagebrush, for food. Sagebrush was particularly important to these species during the winter. Winterfat was the most abundant forage in the jack rabbit diet, although sagebrush was the most important forage plant in the February diet. Pronghorn and sage grouse switched to a diet dominated by forbs during the summer. Pygmy and jack rabbits showed increased use of grasses and Chrysothamnus nauseosus during the summer.

The August 1981 burn may have indirectly caused the observed mortality of radio-collared pygmy and cottontail rabbits. No mortality of radio-collared rabbits occurred as a direct result of fire, however, the loss of sagebrush cover from the home ranges of rabbits may have increased

their vulnerability to predators. Pygmy rabbits rely on tall dense sagebrush cover for escape from predators (Wilde, 1978). Dispersing rabbits were also vulnerable to predators, five of six dispersing pygmy rabbits were apparently predated. The cause of dispersal of radio-collared rabbits is unknown. Increased interspecific competition for food and cover after the burn may have prompted some rabbits to leave partially burned areas, however, more research is necessary to prove or disprove this hypothesis. Several rabbits were found burned or asphyxiated in an area where the burn advanced rapidly and was extensive. Although pygmy rabbits use burrows (Green and Flinders, 1980) the burrows evidently do not always provide them with effective protection from fire.

CONCLUSION

A few tentative conclusions regarding the impact of the burn on sage grouse, pronghorn, and lagomorphs may be made based on the information presented here. Sage grouse depend on sagebrush for food and cover during the winter (Eng and Schladweiler, 1972) and for nesting cover in the spring (Klebenow, 1969). Elimination of sagebrush from the burn area should destroy winter and nesting habitat for grouse. Wallestad and Pyrah (1974) recommended that sagebrush not be eradicated within 3.2 km of a sage grouse lek in order to protect nesting habitat. However, the size of the burn is small in relation to the area used by nesting hens in this study. Sagebrush is the dominant cover type throughout nearly all of the 300 km² study area. The availability of nesting and wintering habitat is likely not limiting the sage grouse population. Sage grouse used a portion of the burn site as a lek during the first spring after the burn in a year when the breeding population was reduced. Suitable areas for leks may be limited in the vicinity of the burn site. Use of recently disturbed areas for breeding by sage grouse has been observed elsewhere on the INEL (Connelly et al., 1981). The patchy burn which occurred could enhance early brood rearing habitat. If the availability of forbs and insects is enhanced on burned areas, then an abundant food supply would be available for broods in close proximity to escape cover.

Similarly, pronghorn will lose winter food and cover as a result of the burn; however, the burn is small in relation to the size of the wintering area on which it occurs. Pronghorn could be benefited during the spring by an increased abundance of succulent forbs and grasses. Given the dependence of pygmy rabbits on sagebrush for food and/or cover throughout the year, the burn will likely have a negative impact on this species. A mitigating factor might be the soil erosion which occurred after the burn. Windblown soil has accumulated in sagebrush stands on the lee sides of burned areas. Once this soil has stabilized, suitable burrow sites may become available where there is adequate sagebrush cover for pygmy rabbits but soils are too shallow for burrowing. Jack rabbits could benefit from the burn by increased production of grasses and forbs adjacent to sagebrush cover after the burn.

There is evidence in the literature that sagebrush burning does increase the production of grasses and forbs. Blaisdell (1953) found that 1 year after burning, perennial grasses and forbs showed increased vigor later

in the growing season and remained green about 2 weeks longer on burned than on unburned areas of sagebrush-grassland on the upper Snake River Plains. Rhizomatous plants were able to produce an increased amount of herbage by the end of the first year. Total herbage of grasses and forbs peaked after about the third year. Sagebrush was completely killed when burned and was very slow to recover. Blaisdell's study areas were 300 m higher in elevation and received 7-20 cm more precipitation annually than the burn site. Consequently, his results may not be entirely applicable to this study area. Generally, decreased competition from sagebrush and enhanced nutrient availability following fire improves the growth of fire-resistant grasses and forbs (Humphrey, 1974). Harniss and Murray (1973) working on one of Blaisdell's study areas found that 30 years after burning sagebrush production had increased while the production of other shrubs, forbs, and grasses had decreased. Thus periodic fires may be an important tool for managing wildlife habitat in the sagebrush-grassland. However, before fire can be properly applied, research must be conducted to determine the short- and long-term responses of wildlife to prescribe burning of sagebrush-grasslands.

LITERATURE CITED

- Amstrup, S. C. 1980. A radio-collar for game birds. *J. Wildl. Manage.* 44:214-217.
- Arnold, J. F., and H. G. Reynolds. 1943. Droppings of the Arizona and antelope jack rabbits and the "pellet census." *J. Wildl. Manage.* 7:322-327.
- Atwood, N. D. 1970. Flora of the National Reactor Testing Station.. Brigham Young Univ. Sci. Bull., Biol. Series. Vol. 11, No. 4. 46 p.
- Bayless, S. R. 1969. Winter food habits, range use, and home range of antelope in Montana. *J. Wildl. Manage.* 33:538-551.
- Beale, D. M., and A. D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. *J. Wildl. Manage.* 34:570-585.
- Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. U.S. Dept. Agr. Tech. Bull. 1075. 39 p.
- Connelly, J. W., W. J. Arthur, and O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. *J. Range Manage.* 34:153-154.
- Connelly, J. W. 1982. An ecological study of sage grouse in southeastern Idaho. Unpubl. Ph.D. Diss., Washington State Univ., Pullman. 84 p.
- Currie, P.O., and D. J. Goodwin. 1966. Consumption of forage by black-tailed jackrabbits on salt-desert ranges of Utah. *J. Wildl. Manage.* 30:304-311 .

- Eng, R. L., and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. *J. Wildl. Manage.* 36:141-146.
- Fagerstone, K. A., G. K. LaVoie, and R. E. Griffith, Jr. 1980. Black-tailed jackrabbit diet and density on rangeland and near agricultural crops. *J. Range Manage.* 33:229-233.
- Floyd, D. A. 1982. A comparison of three methods for estimating vegetal cover in sagebrush steppe communities. Unpubl. M.S. Diss., Idaho State Univ., Pocatello. 178 p.
- Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage grouse in Colorado. *Wildl. Soc. Bull.* 10:224-231.
- Green, J. S., and J. T. Flinders. 1980. Habitat and dietary relationships of the pygmy rabbit. *J. Range Manage.* 33:136-142.
- Halford, D. K. 1981. Repopulation and food habits of Peromyscus maniculatus on a burned sagebrush desert in southeastern Idaho. *Northwest Sci.* 55:44-49.
- Harniss, R. O., and R. B. Murray. 1973. 30 years of vegetal change following burning of sagebrush-grass range. *J. Range Manage.* 26:322-325.
- _____, and N. E. West. 1973. Vegetation patterns of the National Reactor Testing Station, southeastern Idaho. *Northwest Sci.* 47:30-43.
- Hoskinson, R. L., and J. R. Tester. 1980. Migration behavior of pronghorn in southeastern Idaho. *J. Wildl. Manage.* 44:132-144.
- Humphrey, R. R. 1974. Fire in the deserts and desert grasslands of North America, p. 365-400. In: Kozlowski, T. T., and C. E. Ahlgren (eds.) *Fire and Ecosystems*. Academic Press, New York. 542 p.
- Jenni, D. A., and J. E. Hartzler. 1978. Attendance at a sage grouse lek; implications for spring censuses. *J. Wildl. Manage.* 42:46-52.
- Johnson M. K. 1979. Foods of primary consumers on cold desert shrub-steppe of southcentral Idaho. *J. Range Manage.* 32(6):365-368.
- Johnson, R. D. 1982. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. Unpubl. M.S. Diss., Idaho State Univ., Pocatello. 86 p.
- Klebenow, D. A., and G. M. Gray. 1968. Food habits of juvenile sage grouse. *J. Range Manage.* 21:80-83.
- Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. *J. Wildl. Manage.* 33:649-661.
- MacCracken, J. G., and R. M. Hansen. 1982. Herbaceous vegetation of habitat used by blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. *Am. Midl. Nat.* 107:180-184.

- Mechlin, L. M., and C. W. Schaiffer. 1980. Net-firing gun for capturing breeding waterfowl. *J. Wildl. Manage.* 44:895-896.
- Neff, N. J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. *J. Wildl. Manage.* 32:597-614.
- Patterson, R. L. 1952. *The sage grouse in Wyoming.* Sage Books, Denver. 341 p.
- Pyrah, D. B. 1970. Poncho markers for game birds. *J. Wildl. Manage.* 34:466-467.
- Riggs, R. A., and J. M. Peek.. 1980. Mountain sheep habitat-use patterns related to post-fire succession. *J. Wildl. Manage.* 44:933-938.
- Sparks, D. R., and J. C. Malachuk. 1968. Estimating percentage dry weights in diets using a microscopic technique. *J. Range Manage.* 21:264-265.
- Wallestad, R. O., and D. B. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. *J. Wildl. Manage.* 38:630-633.
- _____, J. G. Peterson, and R. L. Eng. 1975. Foods of adult sage grouse in central Montana. *J. Wildl. Manage.* 39:628-630.
- Watson, A., and R. Moss. 1970. Dominance, spacing behavior, and aggression in relation to population limitation in vertebrates, p 167-220. In: Watson, A. (ed.) *Animal Populations in Relation to Their Food Resources.* Blackwell Sci. Publications, Oxford. 477 p.
- Wilde, D. B. 1978. A population analysis of the pygmy rabbit on the INEL site. Unpubl. Ph.D. Diss., Idaho State Univ., Pocatello. 172 p.
- Wright, H. A., L. F. Neuenschwander, and C. M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities, a state-of-the-art review. U.S.D.A. Forest Service, General Technical Report INT-58. 48 p.

INSECTS ASSOCIATED WITH SAGEBRUSH COMMUNITIES
AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Michael P. Stafford and William F. Barr

ABSTRACT

A study was initiated in May 1981 on a proposed burn site near Howe, Idaho to document the taxonomic composition of the insect community and determine the ecological role and seasonal occurrence of insects associated with Artemisia tridentata communities. Collection methods included windowpane traps, Malaise traps, pitfall traps, black light traps, Berlese funnels and sweepnetting vegetation and resulted in 229 collections comprising nearly 40,000 specimens. Results from 1981 are incomplete but preliminary counts show that approximately 150 families representing 14 orders were collected on the study area.

INTRODUCTION

Insects are a dynamic component of rangeland ecosystems, and play vital roles in the decomposition of plant and animal matter, pollination of many plants, and in the aeration and turnover of soils. Insect predation and parasitism are major regulating mechanisms of insect populations. Other insects also may affect other animal species. Furthermore, the importance of insects as a food source for the vertebrate fauna of rangelands cannot be overlooked. Most important, however, is the profound effects that they have on rangeland vegetation due to defoliation, boring, mining, etc. of plant parts. For example, Gates (1964) reported that over 12 million acres of sagebrush in Oregon was defoliated by the sagebrush moth (Aroga websteri Clarke) during the course of 3 years.

There is a special need for study of the insects associated with the sagebrush communities on the INEL. Ecological studies on the Site have shown insects to be a major food item for many of the vertebrates associated with these communities (Gleason, 1979; Halford, 1981; K. Peterson, personal communication). Because of their overall importance, it is imperative that intensive studies be initiated that involve indepth evaluations of rangeland insects at the community level and on an individual species basis. Therefore, an insect study was initiated in May 1981. Originally the intent of this study was to document the insects associated with the sagebrush communities and determine the initial and long-term effects of a controlled sagebrush burn on the insects, especially to ascertain changes in insect species composition in relationship to vegetational successional changes. However, failure to achieve a complete burn of plants in the late summer of 1981 necessitated a postponement of that part of the study. Therefore, the objectives of this study were: 1) to determine the taxonomic composition of the insects associated with the sagebrush community and 2) establish the seasonal occurrence and ecological role of insects associated with (Artemisia tridentata). This study should provide baseline data that will be useful in future investigations involving ecology of insects associated with sagebrush rangelands in other areas of the west.

MATERIALS AND METHODS

Eight permanent sampling transects were established in March 1981 on the ca. 600 ha Howe burn site and immediately adjacent areas (Fig. 1). Because the study was initially designed to examine the effects of a controlled sagebrush burn on insects, each of the eight transects consisted of two parts. One part, designated "A" was inside the proposed burn perimeter and the other, a control designated "B", was outside. Vegetation along each transect was consistent in species composition.

Transects 1, 2, 5 and 6 were established in a habitat dominated by healthy big sagebrush and the perennial grasses *Agropyron spicatum* and *Oryzopsis hymenoides*. Other shrubs including gray horsebrush (*Tetradymia canescens*) and green rabbitbrush (*Chrysothamnus viscidifloris*) also were present. Transects 3 and 8 were located in old, decadent stands of *A. tridentata* without an evident grass understory. Transect 4 was established in a large, shallow depression dominated by giant wild rye grass (*Elymus cinereus*) and sparsely intermixed with *A. tridentata*. Transect 7 was located in a stand of green rabbitbrush (*C. viscidifloris*) intermixed with *A. tridentata*. The variety of plants at these transects afforded the opportunity of investigating host plant-insect relationships as well as making comparisons of insect kinds and numbers between the plant communities.

A variety of collecting methods were necessary for this study. The following were used throughout the summer on a regular or limited basis in each plant habitat: flight traps including the windowpane and Malaise traps, pitfall traps, black light traps, Berlese funnels, and sweeping or beating of vegetation.

Figure 1. Location of insect sampling transects at the Howe burn site on the Idaho National Engineering Laboratory.

Four windowpane traps (Stafford, 1982) were set up on a permanent basis on transects 1A, 3A, 6B, and 7A to capture diurnal and nocturnal flying insects. Twenty-four and 48-hour collections were made from these traps during each week of the summer.

A modified Malaise trap (Matthews and Matthews, 1971) was periodically used approximately every 2 weeks, during the summer at transects 4B, 5A, 7B and 8A to capture diurnal and nocturnal flying insects, especially species that were not taken at the windowpane traps. It was set up for 5-7 days at each transect.

Pitfall traps similar to that designated by Pausch et al., (1979) were set up permanently at each transect to collect terrestrial insects. Sixteen traps were used with one located within and outside the burn perimeter on each transect. These traps consisted of 100 cm long section of 12.7 cm metal rain gutter buried flush with the soil surface. One to 2.5 cm of a mixture of ethylene glycol and water in the trap served as a killing agent and a temporary preservative. Twenty-four or 48-hour collections were made from these traps during each week of the summer.

Four, battery operated portable, black light traps were used biweekly to collect nocturnal flying insects. At least one such collection was made at each transect during the summer. A standard 25.4 cm (10 inch) diameter Berlese funnel was used to collect litter and bunchgrass inhabiting insects.

Insects associated with A. tridentata, C. viscidifloris, E. cinereus, O. hymenoides, and Agropyron spp. were collected by sweeping or beating each plant species with a heavy duty sweep net. Twenty-five or 50 sweep collections were made weekly. During the course of the summer, at least one collection was made from each of the plant species at each transect.

All insects collected were preserved dry or stored in 70% ethanol and transported to the University of Idaho Entomological Museum for curation and identification.

RESULTS

During the 1981 field season, 229 collections were made which resulted in nearly 40,000 specimens. Because of the large number of insects collected and the difficulty associated with identification, specific results are incomplete. Therefore, the specific associations of insect species with the different plant species are unknown at this time. However, preliminary counts show that approximately 150 families representing 14 orders were collected.

Some collecting methods were more effective than others. The windowpane and Malaise traps appear to have accounted for the greatest number of insect species and the black light traps the greatest number of individual insects. From the standpoint of insect orders, Coleoptera, Diptera and Hymenoptera predominated at the windowpane traps; Diptera and Homoptera at the Malaise traps; Collembola, Thysanura and Coleoptera at the pitfall traps; and Hemiptera and Homoptera by sweepnetting vegetation. Collecting by means of the Berlese funnels was unsatisfactory, with only a few Coleoptera and Collembola taken.

The intensive collecting effort of the 1981 field season should provide us with the necessary information to document the taxonomic composition of the insect community. Therefore, the emphasis of the 1982 field season will be to determine the ecological role and seasonal occurrence of insects specifically associated with A. tridentata. Collecting is scheduled to begin in May and conclude in late August. Data collected from this study will also be used to help quantify the effects of fire on insects in Artemisia dominated communities. The data will help interpret pre- and post-burn data on birds (Peterson and Best, this volume; Winter and Best, this volume), small mammals (Keller et al., this volume) and sage grouse (Gates and Eng, this volume).

LITERATURE CITED

- Gates, D. H. 1964. Sagebrush infested by leaf defoliating moth. J. Range Manage. 17:209-210
- Gleason, R. S. 1978. Ecology of burrowing owls on the Idaho National Engineering Laboratory Site. In 1978 Progress Report Idaho National Engineering Laboratory Site Radioecology-Ecology Programs. IDO-12087. Nat. Tech. Inf. Ser., Springfield, VA.
- Halford, D. K. 1981. Repopulation and food habits of Peromyscus maniculatus on a burned sagebrush desert in southeastern Idaho. Northwest Sci. 55:44-49.
- Matthews, R. W. and J. R. Matthews 1971. The Malaise trap: its utility and potential for sampling insect populations. Michigan Entomol. 4:117-122.
- Pausch, R. D., S. J. Roberts, R. J. Barney, and E. J. Armbrust. 1979. Linear pitfall traps, a modification of an established trapping method. Great Lakes Entomol. 12:149-151.
- Stafford, M. P. 1982. A windowpane trap. Idaho Entomol. Group Newsletter 9(6):11-12.

PLANT AND SOIL WATER RELATIONS AT A PRESCRIBED BURN SITE
ON THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

Water potential of dominant shrubs and perennial grasses and soil moisture content on the Idaho National Engineering Laboratory prescribed burn study area were measured during the summer of 1981. Plant and soil moisture estimates were comparable for control and potential burn plots. Soil moisture ranged from 12% to nearly 18% of dry soil weight in early June and from 7% to 11% by mid July. Data from replicate samples show that a sample size of approximately 25 is required to sample soil moisture to within 10% of the mean with 95% confidence.

Diurnal patterns of water potential for big sagebrush (Artemisia tridentata) and green rabbitbrush (Chrysothamnus viscidiflorus) were similar. Water potential decreased from predawn levels throughout the morning and early afternoon, reaching minimum values during mid afternoon. Midday and predawn water potentials became increasingly lower as the season progressed. Diurnal and seasonal patterns for big sagebrush and green rabbitbrush water potentials were generally consistent with those published for Great Basin shrubs. By mid July, midday water potential of giant wildrye (Elymus cinereus) was below -4.0 MPa. Diurnal fluctuations of water potential in giant wildrye were 2.3 MPa, which is greater than that of the shrubs or typical values found in the literature for grasses.

Because the area that burned most thoroughly under prescription in August 1981 was a stand of giant wildrye, studies during the summer of 1982 will focus on that species. Effects of fire on growth and development, water relations, and gaseous exchange will be examined.

INTRODUCTION

Fire has played an important role in the evolutionary and developmental history of sagebrush steppe ecosystems. Prior to the influence of white settlers, the average fire frequency in sagebrush-grass communities was probably between 20 or 25 years (Houston, 1973) and 50 years (Wright et al., 1979). Numerous studies of the impacts of fire on species and communities have been conducted (see reviews by Daubenmire, 1968; Humphrey, 1974; Vogl, 1974; Wright et al., 1979), often with conflicting results. Early studies typically were made in the context of classical succession under the assumption that fire was harmful (Daubenmire, 1968). Contemporary studies reflect more of an evolutionary perspective, recognizing that fire is an important natural selective factor and that most species in sagebrush-grass communities are well adapted to recurring fires (Mueggler, 1976; Vogl, 1974).

Few studies have investigated the effects of burning on plant-soil water relations (Redmann, 1976). Potentially, fire may affect soil water through various mechanisms, the most obvious of which is reduction of the transpiring surface, which would tend to improve soil water conditions. Increased production by herbaceous species in years following burning of an area is thought to be at least in part due to decreased competition from woody plants for soil moisture (Blaisdell, 1953). Daubenmire (1968) and Vogl (1974) both cited several studies that suggest that the tissue moisture content of new shoots on burned sites was higher than that on unburned areas. Blaisdell (1953) noted, "Perennial grasses and forbs on burns remain green about 2 weeks longer than on unburned areas."

Fire may also tend to decrease infiltration, increase runoff, and increase evaporation from the soil surface (Hanks and Anderson, 1957; McMurphy and Anderson, 1965; Daubenmire, 1968), all of which would decrease available soil water. Some studies have reported reduced soil moisture on burned sites (Hanks and Anderson, 1957; McMurphy and Anderson, 1965; Redmann, 1978).

During the summer of 1981, we collected baseline data on soil moisture and water status of the dominant shrubs and grasses on the control and burn plots at vegetation transects 1 through 8. See Floyd and Anderson (this volume) for a description of the burn site and its vegetation. These studies were conducted to: 1) determine whether there were differences in plant water potential prior to burning between plants on the control plots and those on the burn plots, 2) determine if there were differences in plant water potential along the elevational gradient from transects 1 to 8, and 3) determine what species would lend themselves well to a study of water potential and stomatal diffusion characteristics following the burn.

Because the major portion of the area that burned thoroughly in August 1981 was dominated by giant wildrye (*Elymus cinereus*), and because giant wildrye is only slightly damaged by fire (Wright et al., 1979) and thus can be expected to grow vigorously following the fire, we have elected to concentrate the post burn studies on that species.

Giant wildrye is a robust, cool season, perennial bunchgrass. It is found along streams and roadsides, in ravines, on moist or dry slopes, and on plains from British Columbia to California and east into Minnesota, Colorado, and New Mexico (Hitchcock and Cronquist, 1973; Perry and Chapman, 1975). Giant wildrye is highly valued because of its early growth and production of abundant forage; it was formerly very important as winter forage in the Great Basin, but overgrazing of new growth during spring months has reduced or eliminated many populations (Perry and Chapman, 1975). Despite its importance, there apparently have been no studies on the physiological ecology of the species.

On the Idaho National Engineering Laboratory, giant wildrye frequently forms dense stands in depressions or other low lying areas where deep soils accumulate. The area most successfully burned in August 1981 was in such a stand. The stand was dominated by giant

wildrye, but big sagebrush (*Artemisia tridentata*) and annual forbs were common. The fire was intense and completely removed most above ground plant parts. During the summer of 1982, the effects of the fire on growth and development, water relations, and gaseous exchange of giant wildrye will be examined. The purpose of the present study was to determine the soil moisture characteristics and the water potential of shrubs and grasses of the burn study area.

METHODS

Soil moisture was determined gravimetrically (Reynolds, 1970). Soil was removed with an auger from depths of 30 cm and 60 cm and immediately placed in airtight containers. After initial weights were taken, the samples were dried at 80°C for 24 h and then reweighed. Soil moisture was expressed as a percentage of the oven-dry weight. For comparisons of burned with non-burned plots during the summer of 1982, soil moisture will be measured gravimetrically and with thermocouple psychrometers (Brown, 1970; Moore and Caldwell, 1972).

Water potential of big sagebrush, green rabbitbrush (*Chrysothamnus viscidiflorus*), and the dominant grass at each transect was measured with a PMS Instrument Company (Corvallis, Oregon) pressure bomb (Waring and Cleary, 1967). Twigs or grass leaves were wrapped in plastic bags to preclude moisture loss after excision (Turner and Long, 1980) and were then excised and placed immediately into the pressure chamber.

During the summer of 1982, stomatal resistance, transpiration rate, leaf and air temperatures, and ambient humidity will be measured with an LI-1600 Steady State Porometer (LI-COR, Inc., Lincoln, Nebraska). Photosynthetically active radiation will be monitored with an LI-190S Quantum Sensor (LI-COR, Inc.). Demographic patterns of tiller production on randomly-selected giant wildrye on burned and unburned sites will be compared. Parameters measured will include number of tillers, above ground biomass per plant and per tiller, size and specific weight of leaves, seed head production, and seed viability.

RESULTS

Soil moisture ranged from 12% to nearly 18% in early June and from 7% to 11% by mid July (Fig. 1). Small samples (n=3) precluded any statistical analyses for the first three sampling dates, but the overall pattern suggested that transects 1 and 2 near the bottom of the alluvial fan had higher soil moisture than those along the slope. On July 15, the percentage of soil moisture was significantly higher on transects 1 and 2 than on 4, 5, 6, and 8 ($P < 0.05$; one-way ANOVA and Student-Newman-Kuels test). We found no evidence to suggest differences between control and potential burn sites, but sample sizes were generally too small for meaningful statistical comparisons. Data from replicate samples (n = 8 to 10) indicated that approximately 20 to 25 samples would be needed to sample soil moisture to within 10% of the mean with 95% confidence, and between 50 and 100 samples would be necessary to sample within 5% with 95% confidence. Increased sample sizes and two techniques will be used during the summer of 1982 to assess impacts of burning on soil moisture in the giant wildrye study area.

Figure 1. Soil water content, expressed as a percentage of dry soil weight, at transects 1 - 8 in June and July, 1981. Data points for the first three sampling dates are from individual samples. Vertical bars are 95% confidence intervals for the July 15 samples.

On four occasions, water potential of big sagebrush and green rabbitbrush were measured at 2 h intervals from sunrise to sunset at transects 2 and 7. Diurnal patterns of water potential of big sagebrush were generally similar at the two transects on a given date (Fig. 2). Water potential decreased from predawn levels throughout the morning and early afternoon, reaching minimum values during mid afternoon. As the growing season progressed, the plants were under greater and greater water stress during the day. Predawn water potential also became progressively lower, indicating that greater soil moisture stress precluded full elimination of plant water deficit at night (Fig. 2). Patterns were similar for plants on control and potential burn plots.

Diurnal patterns of water potential in green rabbitbrush were similar to those for big sagebrush (Fig. 3). Minimum values were observed during early to mid afternoon, and water stress became progressively more pronounced as the season advanced. Plants on control and potential burn plots were comparable.

Early in the summer, there seemed to be little difference in minimum plant water potential along the elevational gradient from transect 1 to 8 (Fig. 4). Data from mid July, however, suggested that the plots on both ends of the transect had greater available moisture (lower plant water stress) than did those in the center of the transect (Fig. 4). The midday potentials were quite similar for the two shrub species.

Figure 2. Water potential of big sagebrush at transects 2 and 7 in June and July, 1981. Each point is the mean of two or three samples.

Figure 3. Water potential of green rabbitbrush at transects 2 and 7 in June and July, 1981. Each point is the mean of two or three samples.

Figure 4. Water potential of big sagebrush and green rabbitbrush at transects 1 - 8 in June and July, 1981. Each point represents an individual sample.

Few data were taken during 1981 on giant wildrye, but by July 8, water potential was lower than -4 MPa by 10 a.m. and remained so until late afternoon (-4 MPa was the lowest potential that we could measure with the pressure bomb available at that time). Predawn values were about -1.7 MPa; thus, the diurnal fluctuation in water potential was large.

DISCUSSION

Diurnal patterns of water potential in big sagebrush and green rabbitbrush are quite typical of those published for other species (Waring and Cleary, 1967; DePuit and Caldwell, 1975; Redmann, 1976; Pavlik, 1980; Anderson, 1982); however, in contrast to reports in which the minimal water potentials were often observed around midday or early in the afternoon (Love and West, 1972; DePuit and Caldwell, 1975; Pavlik, 1980; Anderson, 1982), minimum values in big sagebrush typically occurred later in the afternoon (Fig. 2). Similar findings were reported for big sagebrush (Branson and Shown, 1975) and the perennial bunchgrass, *Swallenia alexandrae* (Pavlik, 1980). It seems probable that in xerophytic species that can extract soil water and continue to actively transpire and photosynthesize at low water potentials, stomatal conductance may remain relatively high and plant water deficit will

become progressively greater over the course of the day under limiting soil moisture conditions. For species that are less tolerant of low water potentials, minimum plant water potentials are encountered earlier in the day and stomatal closure (possibly in response to decreased relative humidity; Schulze et al., 1975; Anderson, 1982) tends to keep water deficit from increasing through the afternoon. DePuit and Caldwell (1975) present data that suggest that the stomatal mechanism of big sagebrush may not respond directly to atmospheric humidity; they observed no recovery of net photosynthetic rates late in the afternoon as is often observed, and the daily patterns of stomatal resistance that they observed are not what one would predict if the stomata were responding to increasing evaporative demand over the course of the day. Further studies are needed to verify this interpretation.

The pattern of increasing water stress in big sagebrush and green rabbitbrush over the course of the growing season (Fig. 2) reflects decreasing availability of soil moisture (Fig. 1) and is to be expected given precipitation and temperature patterns for the area (Anderson and Holte, 1981). Similar seasonal trends for big sagebrush in Utah were reported by DePuit and Caldwell (1973) and for other Great Basin shrubs by Love and West (1972) and Dina et al. (1973).

Branson and Shown (1975) found that water potential of big sagebrush was correlated with the highest soil water potential in the rooting zone; sagebrush water potential was consistently about 2 MPa lower than maximum soil water potential. They concluded that plant water status might provide a reliable estimate of soil water status. Thus, it seems possible that comparisons of water potential of plants surviving a fire, such as rabbitbrush or perennial grasses, with that of the same species on control sites might provide a rapid and sensitive means of assessing the impacts of fire on soil moisture. This, of course, assumes that the plant-soil water potential relationships remain constant on both areas. Given that plants on burn sites have been reported to be somewhat more succulent than those on unburned areas (Daubenmire, 1968; Vogl, 1974), this assumption must be tested. Data on soil water potential and water potential of giant wildrye from the summer of 1982 will address this question.

The magnitude of the diurnal fluctuation of water potential in giant wildrye, about 2.3 MPa, appears to be substantially greater than that typically reported for either shrubs or herbaceous plants. Maxwell and Redmann (1978) reported diurnal fluctuations from 0.13 to 1.44 MPa in June and from 0.54 to 2.61 MPa in August for thickspike wheatgrass (*Agropyron dasytachyum*), a xeric grass which is also found on the INEL. Similarly, Redmann (1976) reported diurnal fluctuations in thickspike wheatgrass of about 1.5 MPa, and the lowest water potential observed was -2.8 MPa. Diurnal fluctuations in another perennial bunchgrass, *Swallenia alexandrae*, were typically about 1.0 MPa; those for three herbaceous dicots were of similar magnitude (Pavlik, 1980). DePuit and Caldwell (1975) reported diurnal fluctuations of 1.0 to about 1.5 MPa in big sagebrush and broom snakeweed (*Xanthocephalum sarothrae*). From our data, the magnitude of the diurnal fluctuations in big sagebrush and green rabbitbrush was typically about 1.0 to 1.2 MPa.

Maxwell and Redmann (1978) stated that the amount of water that a leaf loses in relation to a corresponding reduction of leaf water potential is an indication of drought resistance. They reported that drought-resistant plants show smaller changes in water content for a given reduction in water potential than do less resistant plants. The large diurnal fluctuation in water potential in giant wildrye suggests that large changes in water potential may be manifest by relatively little change in leaf water content. This could be an important adaptation for extracting water from water deficient soils while maintaining a sufficient degree of hydration to maintain high assimilation rates.

LITERATURE CITED

- Anderson, J. E. 1982. Factors controlling transpiration and photosynthesis in Tamarix chinensis Lour. Ecology 63:48-56.
- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangelands in southeastern Idaho. J. Range Manage. 34:25-29.
- Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. USDA Tech. Bull. 1075. U.S. Government Printing Office. 39 p.
- Branson, F. A. and L. M. Shown. 1975. Soil-moisture stress as related to plant-moisture stress in big sagebrush. J. Range Manage. 28:212-215.
- Brown, R. W. 1970. Measurement of water potential with thermocouple psychrometers: construction and applications. USDA Forest Service Res. Pap. INT-80. 27 p.
- Daubenmire, R. 1968. Ecology of fire in grasslands. p. 209-266. In Advances in Ecological Research, v. 5, J. B. Cragg, ed. Academic Press, New York.
- DePuit, E. J. and M. M. Caldwell. 1973. Seasonal pattern of net photosynthesis of Artemisia tridentata. Amer. J. Bot. 60:426-435.
- DePuit, E. J. and M. M. Caldwell. 1975. Gas exchange of three cool semi-desert species in relation to temperature and water stress. J. Ecology 63:835-858.
- Dina, S. J., L. G. Klikoff and M. B. Keddington. 1973. Seasonal water potential patterns in the mountain brush zone, Utah. Amer. Midl. Natur. 89:234-239.
- Hanks, R. J. and K. L. Anderson. 1957. Pasture burning and moisture conservation. J. Soil and Water Conserv. 12:228-229.

- Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle. 730 p.
- Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology 54:1111-1117.
- Humphrey, R. R. 1974. Fire in the deserts and desert grassland of North America. p. 366-399. In Fire and Ecosystems, T. T. Kozłowski and C. E. Ahlgren, eds. Academic Press, New York.
- Love, L. D. and N. E. West. 1972. Plant moisture stress patterns in Eurotia lanata and Atriplex confertifolia. Northwest Sci. 46:44-51.
- Maxwell, J. O. and R. E. Redmann. 1978. Leaf water potential, component potentials and relative water content in a xeric grass, Agropyron dasytachyum (Hook.) Scribn. Oecologia 35:277-284.
- McMurphy, W. E. and K. L. Anderson. 1965. Burning Flint Hills range. J. Range Manage. 18:265-269.
- Moore, R. T. and M. M. Caldwell. 1972. The field use of thermocouple psychrometers in desert soils. p. 165-169. In Psychrometry in Water Relations Research, R. W. Brown and H. P. Van Haveren, eds. Utah Agri. Exp. Stat., Logan.
- Mueggler, W. F. 1976. Ecological role of fire in western woodland and range ecosystems. p. 1-9. In Use of Prescribed Burning in Western Woodland and Range Ecosystems, A Symposium. Utah State University, Logan.
- Pavlik, B. M. 1980. Patterns of water potential and photosynthesis of desert sand dune plants, Eureka Valley, California. Oecologia 46:147-154.
- Perry, L. J. Jr. and S. R. Chapman. 1975. Effects of clipping on dry matter yields of basin wildrye. J. Range Manage. 28:271-274.
- Redmann, R. E. 1978. Plant and soil water potentials following fire in a northern mixed grassland. J. Range Manage. 31:443-445.
- Reynolds, S. G. 1970. The gravimetric method of soil moisture determination. Part I. A study of equipment, and methodological problems. J. Hydrol. 11:258-273.
- Schulze, E. D., O. L. Lange, L. Kappen, M. Evenari and U. Buschbom. 1975. The role of air humidity and leaf temperature in controlling stomatal resistance of Prunus armeniaca L. under desert conditions. II. The significance of leaf water status and internal carbon dioxide concentration. Oecologia 18:219-233.
- Turner, N. C. and M. J. Long. 1980. Errors arising from rapid water loss in the measurement of leaf water potential by the pressure chamber technique. Aust. J. Plant Physiol. 7:527-537.

- Vogl, R. J. 1974. Effects of fire on grasslands. p. 139-194. In *Fire and Ecosystems*, T. T. Kozlowski and C. E. Ahlgren, eds. Academic Press, New York.
- Waring, R. H. and B. D. Cleary. 1967. Plant moisture stress: evaluation by pressure bomb. *Science* 155:1248-1254.
- Wright, H. A., L. F. Neuenschwander, and C. M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities, a state-of-the-art review. USDA Forest Service Gen. Tech. Rep. INT-58. 48 p.

RELATIONSHIPS OF BLACK-TAILED JACK RABBIT DIETS TO VEGETAL COMPOSITION OF HABITATS

Randal D. Johnson and Jay E. Anderson

ABSTRACT

Diets, densities, and habitats of black-tailed jack rabbits (Lepus californicus) were examined on the Idaho National Engineering Laboratory (INEL) during the summer of 1980. Spotlight censusing showed that jack rabbit densities were consistently higher in some habitats than others. From these data, 11 study sites were chosen, representing a range of rabbit densities and a variety of vegetation types. Sixty-six plant species were identified in the habitats, including 11 grasses, 7 shrubs, and 48 forbs.

Analysis of fecal pellets showed that black-tailed jack rabbits ate a wide variety of plants. Forty-three taxa of plants were identified, including 11 grasses, 7 shrubs, and 25 forbs. Grasses, including Agropyron spp., Elymus spp., Sitanion hystrix, Stipa comata, and Oryzopsis hymenoides, were the most preferred food, comprising over 65% of the diet in nine sites. At two sites, winterfat (Ceratoides lanata) comprised the largest proportion of the diet. There was significantly greater similarity among diets than among vegetal compositions of the sites, suggesting that jack rabbits feed selectively.

Jack rabbit densities were higher in areas having higher proportions of grass cover. Similarity between diet and habitat composition was positively correlated with jack rabbit density and with the amount of grass cover in the habitats. Jack rabbits tend to select grass-dominated areas for feeding at night; this provides easy access to preferred foods and may conserve energy.

INTRODUCTION

The black-tailed jack rabbit (Lepus californicus) is the most widely distributed jack rabbit species (Hall and Kelson, 1959); it has been described as flexible in geographical, ecological, altitudinal, and zonal habitat requirements (Vorhies and Taylor, 1933). Jack rabbits are thought to have rather well defined home ranges, ranging in size from about 16 (French et al., 1965) to 20 ha (Lechleitner, 1959). Local black-tailed jack rabbit populations are thought to fluctuate sharply in seven to 10 yr cycles (Wagner and Stoddart, 1972; Gross et al., 1974).

Researchers often have observed high densities of jack rabbits in some local areas but not others (Vorhies and Taylor, 1933; Phillips, 1936; Wagner and Stoddart, 1972); however, the basis for such distributions is not understood. Some authors have proposed that high densities may reflect responses to environmental disturbances such as overcrowding and food shortage (Woodbury, 1955), presence of succulent vegetation (Nagy et al., 1976) or cultivated crops (Fagerstone et al., 1980), a consequence of a drought year (Bronson and Tiemeier, 1959), or large amounts of sagebrush cover (Adams and Adams, 1959; French et al., 1965).

Because black-tailed jack rabbits use a wide variety of habitats, the diets reported are extremely variable. The rabbits are generalist herbivores (Westoby, 1974; Milton, 1979); however, their diets show seasonal trends that are influenced by forage maturity and availability (Vorhies and Taylor, 1933; Hansen et al., 1969; Fagerstone et al., 1980). Grasses dominate the diet in spring and early summer, forbs may become more important in late summer and early fall, and shrubs are selected in late fall and winter. Black-tailed jack rabbits appear to prefer young succulent plants that are in the early stages of development (Lechleitner, 1958; Fagerstone et al., 1980).

Despite such patterns in diet selection, recent studies on black-tailed jack rabbit diets in cold desert shrub-steppe habitats (Westoby, 1973; Uresk, 1978; Johnson, 1979) have yielded somewhat dissimilar results. Johnson (1979) found that wheatgrasses (Agropyron spp.), bluegrasses (Poa spp.), winterfat (Ceratoides lanata), globemallow (Sphaeralcea munroana), Indian ricegrass (Oryzopsis hymenoides), and cheatgrass (Bromus tectorum) comprised the largest proportions of jack rabbit diets on the INEL. These results conflict with Uresk's (1978) study on the Department of Energy's Hanford Reservation in southcentral Washington; he found that needle-and-thread grass (Stipa comata) was the most preferred food item, whereas cheatgrass, though abundant, was actively selected against. These results also conflict with Westoby's (1973) report from northern Utah that Halogeton was the most important food item in jack rabbit diets. No reasons are apparent that would explain these differences. However, Johnson (1979) decided that, because jack rabbits were so mobile, it was not reasonable to describe the vegetal composition of habitats where pellets were collected. Failure to consider the vegetal components of local habitats might explain, in part, why diet studies have yielded dissimilar results.

Therefore, studies were initiated to study the effects of black-tailed jack rabbit herbivory on populations of shrubs and major perennial grasses on the Idaho National Engineering Laboratory (INEL) (Anderson and Johnson, this volume). The objectives of this study were (1) to compare vegetal species composition between areas having high and low jack rabbit densities, and (2) to compare jack rabbit diets from low and high density areas to vegetal composition in these areas. We hypothesized that there were quantifiable vegetal and diet differences between areas supporting high and low densities of black-tailed jack rabbits.

METHODS

Study Sites

Three methods were used to collect data on black-tailed jack rabbit density - paved road spotlighting, backroads spotlighting, and established pellet plots (Anderson and Johnson, this volume; Johnson, 1982). Based on the density data (Anderson and Johnson, this volume), 11 study sites (S1-S11) were chosen in June 1980 (Fig. 1). Sites S1, S2, S9 and S11 were located adjacent to road T-9, which traverses the northeast part of the INEL. The study sites were 12.1, 11.5, 7.9 and 4.0 km, respectively, east of Idaho 33 (Lincoln Blvd.). Site S10 was the Tractor Flats Enclosure Site; its location is described in Anderson and Johnson (this volume). The S3 study site was 3.0 km

Figure 1. Map of the Idaho National Engineering Laboratory (INEL) in Southeastern Idaho showing the paved road and back roads spotlight routes used to estimate jack rabbit density.

south of Idaho 33 on road T-20; S7 was 2.3 km east of Idaho 22, 33 on the first transect road south of Howe (approximately 6.4 km south) in the west central part of the INEL. Study site S6 was 5.7 km east of Lincoln Blvd. on ARVFS or Seven Mile Road; sites S4, S5 and S8 were approximately 2.7, 2.65 and 2.6 km, respectively, south of the intersection of ARVFS road and road S-6 in the central portion of the INEL. These areas represented a variety of jack rabbit densities and diversity of vegetation types (Johnson, 1982). Study sites S1-S8 were 50-m x 100-m in size, S9 was 30-m x 40-m (on top of a sand dune), whereas S10-S11 were two exclosure study areas from which vegetal data were taken in 1979 (Anderson and Johnson this volume). At sites S1-S8, 10 sample lines, each 50-m long and oriented perpendicular to a 100-m baseline, were used to sample plant cover and to establish locations of pellet plots. At S9, only six 30-m sample lines were used.

Diet-Vegetation Analyses

Plant cover was estimated by point interception (Floyd and Anderson, this volume). Data were collected from 100 placements of a 0.5-m x 1.0-m point frame within sites S1-S8. Forty-two point frames were read in S9 (the small sand dune site). Percent cover for each plant species within a study area was calculated by dividing the number of points falling on a species by the total number of points sampled.

Fecal pellets used in diet analysis were collected from 20 1-m² pellet plots. All fecal plots were cleared in June 1980. Fresh pellets were collected in July 1980, and three replicate samples, consisting of 30 large pellets chosen randomly from each study site's pooled sample, were submitted to the Composition Analysis Laboratory, Colorado State University. The microscope technique (Sparks and Malechek, 1968) was used to identify plant taxa. Five microscope slides were prepared per sample; 20 microscope fields were systematically located and examined at 100 power magnification. The slides were examined twice by the Composition Analysis Laboratory to resolve questions concerning the percent occurrence of certain grass species (Johnson, 1982).

Data Analyses

Statistical tests followed Zar (1974) with $\alpha = 0.05$. Arcsin transformations were performed on the diet and vegetal cover data for correlation analyses. Diet and habitat vegetal composition were analyzed for similarity with Kulczynski's coefficient of similarity (Oosting, 1956). Preference indices for plant groups and for various plant species were calculated according to Krueger (1972). The relative density of a plant species (or group) in the diet was divided by the relative cover of that species (group) in the habitat. A preference value greater than one indicates selection for that food, whereas a value less than one indicates selection against it. Reciprocal averaging ordinations (Gauch, 1977) of the vegetal and diet data were used to obtain rankings of study sites based on total floristic composition. Vegetal data were log transformed and ordered using an 11 site by 64 species matrix. Diet data were ordinated using an 11 site by 43 species matrix. Ordinations were conducted on Idaho State University's IBM 370/125 computer using ORDIFLEX (Gauch, 1977). Spearman's rank correlation coefficient was used to test for a relationship between study site rankings of vegetal composition and diet composition.

RESULTS

Vegetal Composition of Study Sites

The vegetal composition of study sites varied markedly between areas (Table 1). Sixty-six plant species including 11 grasses, 7 shrubs, and 48 forbs were identified on the 11 study sites. Species richness varied from 14 to 34 across the 11 sites; no consistent patterns in numbers of grasses, shrubs, or forbs across the habitats were evident.

Table 1. Relative cover (%) of grasses, forbs, and shrubs from each study site. (Total plant cover = 100%)

STUDY SITE	GRASSES	FORBS	SHRUBS
S1	58.9	10.0	31.1
S2	44.0	5.7	50.3
S3	28.4	15.5	56.1
S4	18.4	73.8	7.8
S5	12.2	85.7	2.1
S6	7.2	56.4	36.4
S7	17.9	28.8	53.3
S8	12.8	30.3	56.9
S9	4.5	3.6	91.9
S10	60.0	1.8	38.2
S11	28.3	4.2	67.5

On six of the 11 study sites, more than 50% of the vegetal cover was from shrubs (Table 1). The shrubs present varied between sites; only big sagebrush (*Artemisia tridentata*) was recorded on all study areas. Green rabbitbrush (*Chrysothamnus viscidiflorus*) was found in seven sites, saltsage (*Atriplex nuttallii*) in six, and winterfat in three sites.

Relative cover of grasses among sites ranged from 4.5% to 60%, whereas the relative cover of forbs ranged from 1.7% to 86% (Table 1). Grasses that were found in a majority of the sites included wheatgrasses, Indian ricegrass, bottlebrush squirreltail (*Sitanion hystrix*), and needle-and-thread grass. Ryegrasses (*Elymus* spp.) were found on five sites. Forbs occurring on most study sites included the legumes (*Astragalus* spp.), borages (*Boraginaceae*), tansymustard (*Descurainia* spp.), little blazing-star (*Mentzelia albicaulis*), and Russian thistle (*Salsola kali*).

Diet Composition

Analysis of fecal pellets showed that black-tailed jack rabbits ate a wide variety of plants. Forty-three taxa of plants including 11 grasses, 7 shrubs, and 25 forbs were identified (Johnson, 1982). Across study sites, grasses comprised the majority of the diet, whereas shrubs and forbs, even though recorded in diets from all study sites, comprised a much smaller proportion (Table 2). Only on sites S7 and S11, were grasses only a small proportion of the diet. At these sites, winterfat was the major diet component (Table 3); these were the only areas where winterfat was abundant.

Table 2. Relative densities (%) of grasses, forbs, and shrubs in fecal pellets from each study site. (Total diet composition = 100%)

STUDY SITE	GRASSES	FORBS	SHRUBS
S1	94.5	4.0	1.5
S2	86.3	8.4	5.3

Table 2. (Cont'd)

STUDY SITE	GRASSES	FORBS	SHRUBS
S3	71.8	6.7	21.5
S4	74.4	20.2	5.4
S5	79.6	11.3	9.1
S6	65.5	23.0	11.5
S7	24.2	6.8	69.0
S8	79.6	10.3	10.1
S9	72.5	14.9	12.6
S10	89.2	9.3	1.5
S11	37.8	15.3	46.9

For all sites combined, winterfat and seven grass species (or groups) comprised about 80% of the jack rabbit diet (Table 3). Wheatgrasses occurred most frequently, averaging 21% of the diet, while bottlebrush squirreltail and Indian ricegrass averaged 14% and 12% of the diet, respectively. Proportions of cheatgrass and bluegrass in jack rabbit diets were among the lowest for grass genera, averaging 4% and 3% respectively.

Shrubs, other than winterfat, were not eaten in large amounts (Johnson, 1982). Prickly-pear cactus (*Opuntia polyacantha*) was consumed in all 11 study sites, but in seven of the 11 areas it comprised less than 2% of the diet.

Forbs comprised from 4% to 23% of the jack rabbit diet (Table 2). The highest values were from study sites (S4 and S6) which had more than 55% cover of forbs (Table 1). Only two forb groups, the Boraginaceae and the Leguminosae, were found in diets from all 11 study sites. Boraginaceae composition ranged from 1% to 12%, whereas Leguminosae composition ranged from 0.2% to 6%. Numerous other forbs were detected in the diets, but they contributed little to the overall diet composition.

Relationships Among Diet, Density, and Habitat

Ordination of the vegetal data showed that study sites with higher jack rabbit densities tended to be on one end of the ordination axis; sites with relatively lower densities tended to be on the opposite end (Johnson, 1982). Ordination suggested that different vegetal characteristics characterized high density areas and low density areas. The study site ranks from the ordinations of diet and vegetal data were not significantly correlated (Spearman's $r = 0.68$, $P > 0.05$). This was also true when the two sites having an abundance of winterfat, S7 and S11, were deleted and the data were reordered (Spearman's $r = 0.12$, $P > 0.05$). Thus, jack rabbit diets were not a reflection of plant abundance.

Table 3. Relative densities (%) of eight dominant plant species in the jack rabbit diets.

PLANT SPECIES	STUDY SITES											MEAN
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	
<u>Agropyron sp.</u>	76	22	36	16	15	16	1	11	26	5	9	21
<u>Bromus tectorum</u>	1	3	3	2	7	5	1	7	3	6	2	4
<u>Elymus sp.</u>	11	6	5	5	8	9	1	8	13	4	7	7
<u>Poa sp.</u>	0	2	1	2	5	9	1	12	2	2	0	3
<u>Sitanion hystrix</u>	4	19	6	26	17	19	7	14	17	21	4	14
<u>Stipa comata</u>	1	10	2	11	17	4	6	6	2	19	4	8
<u>Oryzopsis hymenoides</u>	2	23	18	9	4	6	8	9	10	32	12	12
<u>Ceratoides lanata</u>	0	1	13	1	1	0	67	1	4	1	42	12
Total	95	86	84	72	74	63	92	68	77	90	80	80

Similarity indices based on diet data were significantly ($P < 0.05$; $U = 5.18$; Mann Whitney test) higher than those based on cover data across study sites (Johnson, 1982). Thus, there was greater similarity among the diets from the sites than there was among the vegetation found at the sites.

The mean food preference value for grasses (4.8) was significantly different from that of forbs (1.5) or shrubs (0.8) ($H = 13.5$, $P < 0.05$ by Kruskal Wallis test). No differences in food preference were found between high and low jack rabbit density sites.

When sufficient data were available, preference indices were calculated for individual plant species (Table 4). For most study sites, the grass species present were preferred foods. In contrast, shrub species were not preferred, with the exception of winterfat. Prickly-pear cactus was preferred at most sites. The only forbs preferred at a majority of sites were members of the Boraginaceae and the Leguminosae.

Jack rabbit density was positively correlated with total grass cover (Fig. 2), but not with forb or shrub cover. There were no significant correlations between rabbit density and the relative proportion of any individual plant species in either the vegetal cover or diet. Grass cover was positively correlated with the amount of grass in the diet ($r = 0.85$, $P < 0.05$) when study sites S7 and S11 were deleted from the analysis. No such relationships were found for shrubs or forbs.

Black-tailed jack rabbit diets became significantly more similar to the vegetal composition in habitats with high densities of rabbits than in areas with low densities (Fig. 3). Jack rabbit diets also became more similar to the vegetal composition of the habitat as grass cover increased on the study sites ($r = 0.83$, $P < 0.05$). No relationships between the similarity indices and shrub or forb cover of the habitat were found.

DISCUSSION

The distribution of black-tailed jack rabbits on the INEL in the summer of 1980 appeared to be related to the relative cover of grasses. Data from the study sites (Fig. 2) as well as repeated observations along all of the backroads spotlight routes showed clearly that the highest numbers of rabbits were associated with areas having higher proportions of grass cover. These data support MacCracken and Hansen's (1982) report that black-tailed jack rabbits were found in higher densities in areas that had large amounts of grass biomass. In contrast, French et al. (1965) reported that high densities of jack rabbits were found on the INEL in areas supporting a vigorous growth of shrubs; however, their census observations were made during the daytime. Similarly, we seldom saw rabbits in grassy, open areas during the day. We conclude that the jack rabbits select open, grass-dominated habitats for feeding at night and then retreat to the shrubby habitats during the day. Similar findings were reported by Fautin (1946), Lechleitner (1959), and Haug (1969), who thought that the taller, denser canopies provided protection from the sun and from predators.

Table 4. Preference indices for plant species found in a majority of study sites.

PLANT SPECIES	STUDY SITES										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
<u>Agropyrons & Elymus^a</u>	1.7	1.0	NA ^b	14.7	3.7	12.4	0.4	1.9	NA	2.2	0.7
<u>Bromus & Sitanion^a</u>	0.9	9.0	0.5	1.7	1.2	5.9	1.4	16.2	NA	8.4	1.5
<u>Oryzopsis hymenoides</u>	1.7	3.0	1.5	93.1	11.7	6.5	1.8	7.1	4.8	0.9	5.9
<u>Stipa comata</u>	0.9	2.2	NA	NA	NA	NA	2.9	NA	1.3	1.1	NA
<u>Artemisia tridentata</u>	0.0 ^c	0.02	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<u>Ceratoides lanata</u>	NA	NA	34.4	NA	NA	NA	5.0	NA	NA	NA	1.5
<u>Chrysothamnus viscidiflorus</u>	NA	0.0	NA	NA	0.0	NA	0.0	0.0	0.1	0.0	0.0
<u>Opuntia polyacantha</u>	NA	0.1	NA	2.1	NA	1.9	2.8	1.2	0.1	3.8	3.5
<u>Atriplex-Chenopodium</u>	2.9	2.5	0.1	NA	NA	NA	4.1	0.2	NA	NA	0.7
<u>Boraginaceae</u>	2.1	7.7	0.3	6.2	0.7	0.7	1.8	1.8	4.3	NA	NA
<u>Descurainia pinnata</u>	NA	0.0	NA	0.1	0.0	0.1	0.0	0.1	0.0	NA	NA
<u>Lappula redowskii</u>	NA	0.0	NA	0.01	0.02	0.0	0.0	0.0	NA	NA	NA
<u>Leguminosae</u>	NA	0.7	NA	NA	NA	1.9	8.0	0.3	1.1	1.0	NA
<u>Mentzelia albicaulis</u>	0.1	0.1	0.2	0.03	0.1	0.1	0.04	0.01	0.4	NA	NA
<u>Salsola kali</u>	0.1	2.3	0.0	0.2	0.01	NA	NA	NA	NA	NA	NA

^a Species grouped to minimize discrepancies in diet identification.

^b NA = Species recorded in habitat but not in diet data.

^c 0.0 = Species recorded in habitat but not in diet identification.

Figure 2. Relationship between black-tailed jack rabbit density and relative grass cover of the habitat. Density estimates for study sites are from pellet plot data.

Figure 3. Relationship between black-tailed jack rabbit density and the diet/habitat similarity index. Density estimates for study sites are from pellet plot data.

Although the rabbits on the INEL ate a large variety of plants, they nevertheless were selective and did not consume plants in proportion to their importance in the habitat. Our results support those of other investigators who have reported that grasses are the major component of diets when they are available in spring and summer (Currie and Goodwin, 1966; Hayden, 1966; Hansen et al., 1969; Fagerstone et al., 1980).

Jack rabbits do not appear to select habitats for specific grass species; rather, once in the "open" habitat, they tend to eat whatever grasses are found there, as shown by the positive correlation between the diet/habitat similarity index and the grass cover of the habitat. However, jack rabbits in high density areas foraged even more as generalist herbivores when compared to jack rabbits in low density areas (Fig. 3). Thus, there was a difference in diets between high and low density areas, but this difference was only apparent when the vegetal composition of the habitats was known.

We suggest that black-tailed jack rabbits in areas supporting high rabbit densities tend to be generalists in food selection, but specialists in habitat selection. By selecting grass-dominated habitats, the rabbits have easy access to their preferred foods; this may allow great dietary flexibility and conserve energy (Flinders and Hansen, 1972). Jack rabbits in areas having lower proportions of grass cover still select grasses as their major diet component. Such selective feeding may be less energy efficient in comparison to that of rabbits in the open habitats.

We found in Idaho, as Hayden (1966) did in Nevada, that Indian ricegrass and needle-and-thread grass were important components of the summer diet. Currie and Goodwin (1966) reported that bottlebrush squirreltail was also important in the diet in Utah jack rabbits. In contrast, our estimates of jack rabbit dietary components differ markedly from those of Johnson (1979), even though both studies were conducted on the INEL. We found that bottlebrush squirreltail and needle-and-thread grass were important diet components, whereas cheatgrass and the bluegrasses were relatively less important. In contrast, Johnson (1979) reported nearly opposite results. It seems unlikely that such a change in food preference would occur between his study and ours. Dissimilarities between our studies probably result from two factors - differences in sampling methods and areas, and inconsistencies in analysis of fecal pellets (Johnson, 1982). Unlike our study, Johnson (1979) "randomly" selected pellets that were to represent an annual diet from six areas on the INEL. The different diet estimates may result from vegetation differences between the habitats selected or from the fact that our samples were only representative of summer diets.

The low occurrence of shrubs in jack rabbit diets agrees with seasonal trends previously described. The strong selection for winterfat, however, conflicts with Currie and Goodwin (1966), Hayden (1966), and Westoby (1973) who reported that winterfat was not eaten by jack rabbits in summer. The differences between studies might result from vegetation differences in local areas from which diets were sampled. On the INEL, jack rabbit diets varied considerably based on particular food item availability. To accurately describe the diet for a large area, many small local habitats would have to be sampled.

The low importance of forbs in the diets, also conflicts with several earlier reports (Lechleitner, 1958; Sparks, 1968; Fagerstone et al., 1980). No reasons for these differences were apparent; however, native grasses may have been more available or more palatable than forbs in the areas we studied.

In conclusion, black-tailed jack rabbits are generalist herbivores, as evident in their use of a wide variety of food items and widespread overall range; however, black-tailed jack rabbits are also quite specialized in that they tend to use specific habitats for feeding. These tend to be grassy habitats in which the rabbits can feed as generalists on the foods they prefer - the grasses.

LITERATURE CITED

- Adams, H. B. and L. Adams. 1959. Black-tailed jackrabbit carcasses on the highways in Nevada, Idaho, and California. *Ecology* 40:718-720.
- Bronson, F. H. and O. W. Tiemeier. 1959. The relationship of precipitation and black-tailed jack rabbit populations in Kansas. *Ecology* 40:194-198.
- Currie, P. O. and D. L. Goodwin. 1966. Consumption of forage by black-tailed jack rabbits on salt-desert ranges of Utah. *J. Wildl. Manage.* 30:304-311.
- Fagerstone, K. A., G. K. Lavoie, and R. E. Griffith, Jr. 1980. Black-tailed jack rabbit diet and density on rangeland and near agricultural crops. *J. Range Manage.* 33:229-233.
- Fautin, R. W. 1946. Biotic communities of the northern desert shrub biome in western Utah. *Ecol. Monographs* 16:251-310.
- Flinders, J. T. and R. M. Hansen. 1972. Diets and habitats of jack rabbits in northeastern Colorado. *Range Sci. Dep. Sci. Ser. No. 12.* Colorado State Univ., Fort Collins. 29 p.
- French, N. R., R. McBride, and J. Detmer. 1965. Fertility and population density of the black-tailed jack rabbit. *J. Wildl. Manage.* 29:14-26.
- Gauch, Jr., H. G. 1977. *Ordiflex. Ecology and Systematics.* Cornell Univ., Ithaca, New York. 185 p.
- Gross, J. E., L. C. Stoddart, and F. H. Wagner. 1974. Demographic analysis of a northern Utah jackrabbit population. *Wildl. Monographs.* 40:63 p.
- Hall, E. R. and K. R. Kelson. 1959. *The mammals of North America.* Ronald Press Co. New York. 283 p.
- Hansen, R. M. and J. T. Flinders. 1969. Food habits of North American hares. *Range Sci. Dep. Sci. Ser. No. 1.* Colorado State Univ., Fort Collins. 17 p.

- _____, N. E. Green, and D. R. Sparks. 1969. Black-tailed jack rabbits on sandhill rangeland. Colorado State Univ. Exp. Sta. Progress Report, Fort Collins, CO. 2 p.
- Haug, J. C. 1969. Activity and reproduction of the black-tailed jack rabbit in the coastal cordgrass prairie of Texas. M.S. thesis. Texas A & M Univ., College Station. 116 p.
- Hayden, P. 1966. Food habits of black-tailed jack rabbits in southern Nevada. J. Mammal. 47:42-46.
- Johnson, M. K. 1979. Foods of primary consumers on cold desert shrub-steppe of southcentral Idaho. J. Range Manage. 32:365-368.
- Johnson, R. D. 1982. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. M.S. thesis. Idaho State Univ., Pocatello. 90 p.
- Krueger, W. C. 1972. Evaluating animal forage preference. J. Range Manage. 25:471-475.
- Lechleitner, R. R. 1958. Certain aspects of behavior of the black-tailed jack rabbit. Amer. Midl. Nat. 60:145-155.
- _____. 1959. Movements, density, and mortality in a black-tailed jack rabbit population. J. Wildl. Manage. 22:371-384.
- MacCracken, J. G. and R. M. Hansen. 1982. Herbaceous vegetation of habitat used by blacktail jackrabbits and Nuttall cottontails in southeastern Idaho. Amer. Midl. Nat. 107:180-184.
- Milton, K. 1979. Factors influencing leaf choices by howler monkeys: a test of some hypotheses of food selection by generalist herbivores. Amer. Nat. 114:362-378.
- Nagy, K. A., V. H. Shoemaker, and W. R. Costa. 1976. Water, electrolyte, and nitrogen budgets of jack rabbits (Lepus californicus) in the Mojave Desert. Physiol. Zool. 49:351-363.
- Oosting, H. J. 1956. The study of plant communities. 2nd ed. W. H. Freeman and Co., San Francisco, CA. 440 p.
- Phillips, P. 1936. The distribution of rodents in overgrazed and normal grasslands of Oklahoma. Ecology 17:673-679.
- Sparks, D. R. 1968. Diet of black-tailed jackrabbits on sandhill rangeland in Colorado. J. Range Manage. 21:203-208.
- _____ and J.C. Malechek. 1968. Estimating percentage dry weight in diets using a microscope technique. J. Range Manage. 21:264-265.

- Uresk, D. W. 1978. Diets of the black-tailed hare in steppe vegetation. J. Range Manage. 31:439-442.
- Vorhies, C. T. and W. P. Taylor. 1933. The life histories and ecology of jack rabbits, Lepus alleni and Lepus californicus spp., in relation to grazing in Arizona. Univ. Arizona Agr. Exp. Sta. Tech. Bull. 49:471-587.
- Wagner, F. H. and L. C. Stoddart. 1972. Influence of coyote predation on black-tailed jack rabbit populations in Utah. J. Wildl. Manage. 36:329-342.
- Westoby, M. 1973. Impact of black-tailed jack rabbits (Lepus californicus) on vegetation in Curlew Valley, northern Utah. Ph.D. thesis, Utah State Univ., Logan.
- _____. 1974. An analysis of diet selection by large generalist herbivores. Amer. Nat. 108:290-304.
- Woodbury, A. M. 1955. Ecology of the Great Salt Lake Desert. I. An annual cycle of the desert jack rabbit. Ecology 36:353-356.
- Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 620 p.

COYOTE-LEPORID RELATIONS ON THE
IDAHO NATIONAL ENGINEERING LABORATORY

James G. MacCracken and Richard M. Hansen

ABSTRACT

This study follows previous studies that have examined coyote (Canis latrans) food habits and abundance in relation to leporid populations on the Idaho National Engineering Laboratory (INEL). Results of data collected during September 1981 indicate that coyotes have increased consumption of blacktail jack rabbits (Lepus californicus) in response to the recent increase in blacktail jack rabbit populations on the INEL. These results support some predictions of optimal foraging theory concerning coyote food selection in relation to leporid abundance.

INTRODUCTION

This present study was initiated during September 1981 and is a continuation of those reported by Johnson (1978) and MacCracken (1980). Johnson (1978) examined seasonal food selection by coyotes (Canis latrans) from July 1975 through July 1977 on the Idaho National Engineering Laboratory (INEL). He reported that cottontail rabbits (Sylvilagus spp.) and montane voles (Microtus montanus) were the two most abundant prey types in coyote feces. Johnson (1978) also reported no seasonal differences ($P > 0.05$) in the major foods and suggested that coyotes were not opportunistic feeders on the INEL.

During Johnson's (1978) study, blacktail jack rabbits (Lepus californicus) populations were low compared to a peak that occurred between 1969 and 1972. Anticipating an increase in blacktail jack rabbit populations on the INEL, MacCracken (1980) initiated a study in October 1977 monitoring coyote foods, abundance, and distribution, and leporid abundance and distribution on the INEL. He observed a three-fold increase in blacktail jack rabbit density (0.18/ha) from October 1977 through July 1979 accompanied by a slight increase (6%) in jack rabbit remains in coyote feces and a slight increase in coyote abundance.

Following termination of MacCracken's (1980) study, blacktail jack rabbit populations increased dramatically in southeastern Idaho including the INEL (Johnson and Anderson, This volume; Knowlton et al., this volume). Because of the increase in jack rabbit populations on the INEL, we initiated the present study to examine coyote response to the jack rabbit increase. The purpose of this study is to determine (1) the effects of fluctuations in leporid populations on coyote food selection, abundance, and distribution, and (2) leporid food habits on the INEL. We hope to determine the accuracy of assumptions and predictions of optimal foraging theory (MacArthur and Pianka, 1966 Charnov, 1976) and Lotka-Volterra models (Wagner and Stoddard, 1972) which have not yet been tested for the coyote and jack rabbit relationship in the western United States.

METHODS

The methods and procedures will remain the same as previously reported (Hansen and MacCracken, 1978; MacCracken, 1980). Coyote feces will be collected seasonally from 25 permanent transects (700x5m) on the INEL. Ten transects each are located in both central (ungrazed by livestock) and peripheral (grazed) areas. Five transects are located in a transitional area along the border of the livestock allotments and the central portion of the INEL. Coyote feces will be examined to determine food habits (Johnson and Hansen, 1979a,b), and coyote fecal accumulation rates will be used as an index of coyote abundance. Leporid fecal pellets will be collected from 1m² plots (20 at each coyote transect), and pellet accumulation will provide an estimate of leporid abundance. Leporid feces may also be used to estimate food habits based on their botanical composition.

RESULTS

Initial sampling (September 1981) resulted in the collection of 119 coyote scats from 25 permanent transects. No significant difference ($P > 0.05$, ANOVA) was observed for the mean weight of coyote feces deposited per 28 day period on the three areas of the INEL with 2.2 ± 1.0 ($\bar{X} \pm SE$), 14.1 ± 5.8 , and 4.6 ± 2.7 gm/28 days on the central, transitional, and peripheral transects, respectively. The average weight of a coyote scat was 19.4 ± 7.3 grams.

Nuttall cottontails (Sylvilagus nuttalli) made up approximately 56% of the dry matter ingested (DMI) by coyotes over the entire INEL. Blacktail jack rabbits averaged 23% of DMI, northern pocket gophers (Thomomys talpoides) averaged 5% and montane voles 4% (Table 1). Although Leporid fecal accumulation plots were cleared, no estimate of leporid abundance or distribution was made.

DISCUSSION

Results to date indicate that coyotes have responded to the blacktail jack rabbit increase by increasing consumption of jack rabbits. Johnson (1978) reported that jack rabbits made up 16% of DMI by coyotes during July 1975. From October 1975 through April 1979, blacktail jack rabbits averaged $2.2 \pm 2.0\%$ of DMI by coyotes (MacCracken, 1980). The present study indicates an increase of 400% in blacktail jack rabbit remains in coyote feces over that collected 2 years previous.

The accumulated mass of coyote scats reported for the present sample is lower than previously reported (MacCracken, 1980). However, the time span between the present sampling and the previous sample collection confounds any definite statements about coyote abundance on the INEL due to weather degradation of scats and other factors previously discussed (MacCracken, 1980).

Theories of optimal foraging suggest that predators seek to maximize their net intake of nutrients while minimizing energy expenditure (MacArthur and Pianka, 1966; Emlen, 1966; Schoener 1971; Charnov, 1976; and others). MacArthur and Pianka's (1966) model dealt with resources that were

Table 1. Percent relative dry weight ($\bar{X} \pm SE$) of foods ingested by coyotes on the Idaho National Engineering Laboratory from July 1979 through September 1981.

Food Item ^a	Areas			
	Central	Transitional	Peripheral	Overall
<u>Sylvilagus nuttalli</u>	45 + 16	63 + 11	64 + 12	56 + 7
<u>Brachylagus idahoensis</u>	2 + 2	13 + 11	3 + 3	3 + 1
<u>Lepus californicus</u>	34 + 13	25 + 5	15 + 12	23 + 10
<u>L. townsendi</u>			4 + 4	1 + 1
<u>Microtus montanus</u>	7 + 5	5 + 4	b	4 + 2
<u>Spermophilus townsendi</u>	1 + 1	2 + 3	1 + 1	1 + 1
<u>Thomomys talpoides</u>	9 + 6	5 + 4	1 + 1	5 + 3
Cricetid mice	1 + 1	1 + 1		1 + 1
<u>Antilocapra americana</u>		1 + 1		b
<u>Perognathus</u> spp.			4 + 4	1 + 1
plant fragments	1 + 1	2 + 1	1 + 1	1 + 1

^a Other items recovered from scats in small amounts were Dipodomys ordii, Centrocerus urophasianus, Zenidura macroura, other Passerine birds, insects, seeds of grasses, wheat, and Opuntia polyacantha, grass leaves, and pieces of wood.

^b < 1%

non-random in distribution. Optimal foraging models predict that 1) predators are unselective when profitable prey is scarce 2) predators ignore low quality prey when profitable prey are abundant, and 3) predators selectivity is governed by fluctuations in abundance of profitable prey, regardless of alternate prey abundance (MacArthur, 1972).

For coyotes on the INEL, blacktail jack rabbits are presumably the most profitable prey type due to their large body size compared to other small mammals and their relative ease of capture, once detected, as compared to ungulates (MacCracken, 1980). If optimal foraging theory applies to coyotes, consumption of blacktail jack rabbits should increase as jack rabbit populations increase, and coyote diet diversity should decrease. Diet diversity (H' , Shannon-Weiner index, Pileou 1975) averaged 2.1 during 1975-1979 (MacCracken, 1980) as compared to 1.7 in the present study.

LITERATURE CITED

- Charnov, E.L. 1976 . Optimal foraging: attack strategy of a mantid. Am. Nat. 110:141-151.
- Emlen, J.M 1966. The role of time and energy in food preferences. Am. Nat. 100:611-617.

- Hansen, R.M. and J.G. MacCracken. 1978. Seasonal diets of coyotes on the INEL Site. p. 255-264 In O.D. Markham, ed. Ecological studies on the Idaho National Engineering Laboratory Site 1978 progress report IDO-12087. Nat. Tech. Inf. Serv. Springfield, VA.
- Johnson, M. K. 1978. Food habits of coyotes in southcentral Idaho. Ph.D Thesis. Colo.State Univ., Fort Collins, CO. 75 p.
- _____ and R.M. Hansen. 1979a. Coyote food habits on the Idaho National Engineering Laboratory. J. Wildl. Manage. 43:951-955.
- _____ and _____. 1979b. Estimating coyote food intake from undigested residues in scats. Am. Mid. Nat. 102:363-367.
- MacArthur, R.H. 1972. Geographical ecology. Harper and Row, New York, NY.
- _____ and E.R. Pianka. 1966. On the optimal use of a patchy environment. Am. Nat. 100:603-609.
- MacCracken, J.G. 1980. Feeding ecology of coyotes on the upper Snake River Plain, Idaho. M.S. Thesis, Colorado State Univ., Ft. Collins 85 p.
- _____ and R.M. Hansen. 1982. Herbaceous vegetation of habitat used by blacktail jack rabbits and nuttall cottontails in southeastern Idaho. Am. Mid. Nat. 107:180-184.
- Pileou, E.C. 1975. Ecological diversity. Wiley and Sons, New York, NY. 165 p.
- Schoener, T.W. 1971. Theory of feeding strategies. Ann. Rev. Ecol. Syst. 2:369-404.
- Wagner, F.H. and L.C. Stoddard. 1972. Influence of coyote predation on blacktailed jack rabbit populations in Utah. J. Wildl. Manage. 36: 329-342.

RELATIVE ABUNDANCE OF COYOTES, LAGOMORPHS, AND RODENTS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

L. Charles Stoddart

ABSTRACT

Starting in 1975, spring and fall density indices of coyotes (Canis latrans), black-tailed jack rabbits (Lepus californicus), two species of rabbits (Sylvilagus nutallii and S. idahoensis) and several species of rodents have been obtained for the eastern half of the INEL. The purpose has been to measure the pattern and interrelationships of density change among these predator and prey species. Relative abundance of coyotes, measured by a combination of three independent index procedures, (trap line, scat line, and scent station line) increased 3-fold from 1975 to 1981. Over the same period, jack rabbit density, estimated from flushing-transect counts, increased from 2 to 189 jack rabbits per km² in 1980 then declined 18% in 1981. Flushing-transect density estimates of the two Sylvilagus species combined increased from 27 rabbits per km² in 1979 to 45 rabbits per km² in 1981. 1975 to 1978 density indices of each of the five most commonly captured rodent species showed short term changes of about 3-fold. In 1980 and 1981 indices of the rodent species (with one exception) showed marked increases of about three times previous observed highs. During spring and fall 1981, 400 jack rabbits were collected on the INEL to provide jack rabbit demographic information. Breeding was synchronous with four littering periods. Average production of young per adult female surviving the breeding season was 11.5. Juveniles sustained a 92% mortality rate from birth to October. Over-summer adult jack rabbit mortality was 69%.

INTRODUCTION

Dynamics of coyote, black-tailed jack rabbit, and various rodent species populations in Curlew Valley, Utah, have been studied by Utah State University and the U.S. Fish and Wildlife Service since 1962. Models generated by these studies (Stoddart, 1978; Knowlton and Stoddart, 1982) suggest that coyotes and jack rabbits in Curlew Valley operate in a fashion similar to that described by the Lotka-Volterra predation equations (Wangersky, 1978). Because of lag in coyote response to changes in prey abundance, an intrinsic limit cycle (Tanner, 1975) is generated. To test the generality of the manner in which these various species fluctuate and the interrelationships of the fluctuations, the Predator Ecology and Behavior Project of the U.S. Fish and Wildlife Service expanded the studies to include the Idaho National Engineering Laboratory (INEL). In 1975, spring and fall indices of abundance for coyotes, jack rabbits, rabbits and major species of rodents were initiated on the INEL. In some instances these indices have been related to estimates of absolute density. In addition, in 1981 a schedule of jack rabbit collections was begun on the INEL to provide estimates of some jack rabbit demographic parameters.

Two contrasting features of the study areas will be helpful in broadening our understanding of coyotes and prey species dynamics. First, the coyote population in Curlew Valley is under extreme hunting and trapping pressure from sport hunters, fur trappers, the U.S. Fish and Wildlife Service Division of Animal Damage Control (ADC), and woolgrowers. On the INEL there is limited control by ADC on parts of the grazed portion of the site. Hunting and trapping by private interests are not allowed. Second, on the INEL jack rabbits are essentially nonexistent in the coyote diet during a jack rabbit low (Johnson, 1978) whereas they still constitute 60 to 70 percent of the coyote winter diet in Curlew Valley during a jack rabbit low (Hoffman, 1979). Apparently the difference in diet is due in part to the two rabbit species (Sylvilagus nutallii and S. idahoensis) which are numerous on the INEL and make up approximately 50 percent of the coyote winter diet during a jack rabbit low (Johnson, 1978). These species are relatively rare on the Curlew Valley site and are not important coyote food items (Hoffman, 1979). Whether or not differences in these two features are reflected by dissimilar population dynamics between the two areas will provide a measure of the propriety of our present models.

METHODS

Indices of animal abundance are provided for that portion of the INEL bounded on the north by Pole Line Road and State Highway 33, on the east by the INEL boundary, on the south by State Highway 20, and on the west by West Monument Road. (See Figure 1).

Three independent methods are employed to obtain indices of coyote abundance. Results of these procedures are made comparable by multiplying each index by a constant factor such that the means become equal. The indices are then averaged to provide a single, unitless coyote density index for each sampling period.

Forty-nine modified standard coyote scent-station lines (Roughton and Sweeny, 1982) were randomly selected and permanently located in the INEL study area. Each line is 4.3 km in length and composed of 10 scent stations operated for one night. A coyote scent station index, the fraction of operable stations visited by coyotes during the night of interest, is obtained for all lines in May and September of each year. The 49 index values are averaged for a single coyote scent station index value. A second coyote index is obtained using a trap line consisting of 200 steel traps equipped with tranquilizer tabs. Traps are set at about 1.6-km intervals along 320 km of road permanently identified on the INEL. The trap line is run every day for 30 days in September of each year. The number of coyotes captured per 1000 trap nights serves as an index of coyote abundance. Mean rate of scat deposition (scats/km/day) on 100 permanent, randomly selected, 1.6-km sections of road is used as a third index of coyote density in May and October. The road sections are first cleared of coyote scats, then, at the end of each of two 2-week intervals newly deposited scats are counted and picked up along each of the road sections.

Attempts are periodically made to relate indices of coyote abundance to absolute density estimates. Coyotes captured during fall 1981 were injected with a radioactive isotope, ^{54}Mn . Since part of the radioactive material is continually being passed in the feces of injected

Figure 1. Map of study area (shaded) within the Idaho National Engineering Laboratory.

coyotes, it is possible to identify scats deposited by these animals. Scats later collected on the scat collection lines are analyzed for presence of ^{54}Mn . The ratio of active to non-active scats serves as an estimate of the fraction of the coyote population injected. This ratio and a knowledge of the number of coyotes initially injected permits estimation of coyote density.

Lagomorph densities are obtained using 80 square, 1.6-km flushing transects randomly and permanently located adjacent to roads in the study area. The transects are walked each spring and fall and records kept of the numbers and right-angle flushing distances of jack rabbits and rabbits observed. Density estimates are computed from the distribution of right-angle flushing distances. If the assumption is made that all lagomorphs on and very near the transect line are flushed and observed, a curve fitted to the lateral distribution of observed lagomorphs will provide an estimate of absolute density near the transect line. This can be extrapolated to an estimate of mean absolute density for the study area as a whole (Gross et al., 1974).

Six permanent rodent transect lines have also been located within the study area. Each line is 23.7 km long and is comprised of 25 transects spaced at 1-km intervals along unimproved dirt roads. Each transect is perpendicular to the line and is composed of 10 trap stations spaced at 10-m intervals. An M-4 rat snap trap with an expanded treadle (Carley and Knowlton 1971) and baited with a standard mixture of peanut butter and rolled oats is set at each station and checked for three consecutive nights. Catch per unit of effort for each species trapped serves as an index to species abundance. Rodent transect lines were not operated in spring 1979 through spring 1980.

Jack rabbit demographic parameter estimates are made using samples of jack rabbits collected from the study area at night. Collections are made in February through June to get samples of pregnant females and in October to obtain an age ratio estimate. Pregnant females are necropsied to acquire estimates of litter size, fetus age, conception and parturition dates, and percentage of females breeding for each littering period. Ovaries are collected and sectioned to obtain corpora lutea counts to facilitate estimating prenatal mortality. Fall adult and juvenile indices of abundance are obtained using fall density indices and age ratio estimates. With the fall adult and spring population density indices, over-winter and over-summer adult mortality rates can be calculated. By assuming a constant over-summer mortality rate of adults, an adult female index of abundance can be determined for each of the four littering periods during the breeding season (Gross et al., 1974). Female jack rabbit indices and natality rate estimates for each littering period are then used to calculate an index to the total number of juveniles born during the breeding season. A birth to October estimate of juvenile mortality is calculated for each summer from the index of juveniles born and the index of fall juvenile abundances.

RESULTS

When the three coyote density indices (Fig. 2) are averaged, a 3-fold increase in fall coyote abundance on the INEL from 1975 to 1981 is indicated (Fig. 3). This increase is concomitant with a rather substantial increase in jack rabbit density over the same period. In September 1981, 65 coyotes were trapped on the INEL and injected with ^{54}Mn . In October and November approximately 1,200 scats were collected. These are presently being analyzed for radioactive manganese to obtain an estimate of absolute coyote density for September 1981.

Fall and spring jack rabbit densities on the INEL (Fig. 4) increased logarithmically from a low in spring 1975 when only one jackrabbit was observed on the 80 transects to a high in spring 1981 when 421 were observed. The fall 1981 density subsequently declined by 18% from fall 1980. Estimates of rabbit density (Fig. 5) show little change from fall 1979 to 1980 and then a relatively abrupt increase of 60% in fall 1981 to an observed high of 45 rabbits per km^2 .

Figure 2. Three indices of spring and fall coyote abundance on the INEL study area, 1975-1981.

Figure 3: Fall jack rabbit density (closed circles) and indices of coyote abundance (open circles) on the INEL study area, 1975-1981. During the period 1975 through 1978, jack rabbit density tended to decrease while coyote density tended to increase. During 1979 and 1980, jack rabbit density tended to increase while coyote density tended to decrease. The inset graph shows the same data for the period 1975-1981, with the left y-axis representing Fall jack rabbits/km² · INEL (0 to 150) and the right y-axis representing Fall coyote density index · INEL (0 to 150). The inset graph shows that jack rabbit density (closed circles) decreased from approximately 140 in 1975 to 100 in 1978, then increased to 125 in 1981. Coyote density index (open circles) increased from approximately 25 in 1975 to 125 in 1981. The inset graph also shows a dashed line for 'Rabbit density index · INEL' which increased from approximately 25 in 1975 to 125 in 1981.

Figure 4. Spring and fall jack rabbit density on the INEL study area, 1975-1981.

Figure 5. Spring and fall rabbit density on the INEL study area, 1979-1981.

Spring and fall indices of abundance for each of the five most commonly captured rodent species on the INEL indicate short-term changes of about 3-fold from 1975 through 1978 (Fig. 6). During this period the long-term density trend of deer mice *Peromyscus maniculatus* tended to increase while the other species tended to decline slightly. During 1980 and 1981 indices of all rodent species increased markedly except for Great Basin pocket mouse (*Perognathus parvus*). Whether these increases are causatively related to the concurrent increases in lagomorph and coyote densities is not presently known.

During spring 1981, 120 female jack rabbits were collected for reproductive information. Breeding in 1981 was synchronized and 100% of the females participated in three conception periods separated by 40-45 days. Seventeen percent of the females conceived a fourth time. Peak littering periods occurred March 12, April 24, June 6, and June 26. Mean litter sizes for the four litters were 1.5, 3.9, 5.4 and 4.0, respectively. Average production of fetuses per female surviving the breeding season was 11.5.

Fifty-eight percent of a sample of 200 jack rabbits taken in October 1981 were juveniles, and the fall juvenile density index was 60. The index of total juveniles produced during the breeding season was 746, indicating juveniles sustained a 92% mortality rate from birth to October. Prenatal mortality as measured by embryo resorption and lack of ova implantation was 11% over the breeding season. Over-summer adult jack rabbit mortality was 69%. Over the past 3 years the spring jack rabbit density index has exceeded the preceding fall index, indicating a net movement of jack rabbits into the INEL study area between fall and spring. This movement precludes estimating over-winter jack rabbit mortality using our present methods.

Figure 6. Spring and fall indices of the five most commonly captured rodent species on the INEL study area, 1975-1981.

DISCUSSION

Discussions of relationships between coyote and jack rabbit abundance on the INEL as well as comparisons with those in Curlew Valley are necessarily limited at this stage of our studies since our observations at INEL only include the incline phase of the cycle. Though other factors may be involved, the observed increase in coyote abundance on the INEL was apparently basically in response to a marked increase in jack rabbit numbers. Density increases of these two species on the INEL are in phase and nearly identical to patterns of increase in coyote and jack rabbit abundance in Curlew Valley. Though the patterns of increase are similar, a comparison of the indices between the two study areas indicates coyote densities are somewhat higher and jack rabbit densities in fall about 25% lower than in Curlew Valley.

Food supply, particularly in winter when supplies tend to be shortest, is one important factor determining coyote abundance (Weaver, 1979; Knowlton and Stoddart, 1982). Higher overall coyote densities on the INEL may reflect a more extensive winter food base, which includes

higher densities of Sylvilagus spp. and antelope (Antilocapra americana) than in Curlew Valley. Differential levels of exploitation may also affect to some degree the relative coyote densities on the two study areas.

In Curlew Valley, over-summer mortality of juvenile jack rabbits is apparently the most important factor determining changes in jack rabbit abundance and is positively correlated with coyote density. This relationship is essentially independent of the size of the prey base (Stoddart, 1978). Perhaps the lower fall jack rabbit density on the INEL as compared with Curlew Valley is a reflection of the generally higher coyote abundance there. During 1979-1981 spring jack rabbit densities on the INEL were higher than the preceding fall densities and in the past 2 years have been the same or greater than those observed in Curlew Valley. Over-winter increases in jack rabbit abundance on the INEL have also been observed by other investigators (Johnson and Anderson, this volume). Since there is no jack rabbit reproduction during the winter months and since fall populations normally sustain about a 50% over-winter mortality (Gross et al. 1974), we suspect that more than half the spring jack rabbit populations during 1979-1981 moved onto the INEL study area between November and March.

It is our present intention to continue monitoring coyote, lagomorph and rodent populations through the remainder of this coyote-jack rabbit cycle.

LITERATURE CITED

- Carley, C. J. and F. F. Knowlton. 1971. Trapping woodrats: effectiveness of several techniques and differential catch by sex and age. *Tex. J. Sci.* 22:248-251.
- Gross, J. E., L. C. Stoddart and F. H. Wagner. 1974. Demographic analysis of a northern Utah Jack rabbit population. *Wildl. Monogr.* 40:1-68.
- Hoffman, S. W. 1979. Coyote-prey relationships in Curlew Valley during a period of low jack rabbit density. M. S. Thesis. Utah State Univ., Logan. 139 p.
- Johnson, M. K. 1978. Food habits of coyotes in southcentral Idaho. Ph.D. dissertation. Colo. State Univ., Ft. Collins. 77p.
- Knowlton, F. F. and L. C. Stoddart. 1982. Coyote population mechanics: Another look. In *Symposium on Natural Regulation of Wildlife Populations*. Academic Press. (in press)
- Roughton, R. D., and M. W. Sweeny. 1982. Refinements in scent-station methodology for assessing trends in carnivore populations. *J. Wildl. Manage.* 46:217-229.

- Stoddart, L. C. 1978. Population dynamics, movement and home range of black-tailed jackrabbits (Lepus californicus) in Curlew Valley, northern Utah. Final Rep. U.S. Dept. Energy, Contract No. E(11-1)-1329. 46 pp.
- Tanner, J. T. 1975. The stability and the intrinsic growth rates of prey and predator populations. *Ecology* 56:855-867.
- Wangersky, P. J. 1978. Lotka-Volterra population models. *Ann. Rev. Ecol. Syst.* 9:189-218.
- Weaver, J. L. 1979. Influence of elk carrion upon coyote populations in Jackson Hole, Wyoming. In M. S. Boyce and L. C. Hayden-Wing, eds. North American Elk: Ecology, Behavior and Management. Univ. Wyo., Laramie. 294 p.

BLACK-TAILED JACK RABBIT MOVEMENTS AND HABITAT UTILIZATION
AT THE IDAHO NATIONAL ENGINEERING LABORATORY
RADIOACTIVE WASTE MANAGEMENT COMPLEX

John C. Grant

ABSTRACT

In June 1982, a study of black-tailed jack rabbit (Lepus californicus) ecology was initiated at the Idaho National Engineering Laboratory Radioactive Waste Management Complex (RWMC). This study will provide data necessary to evaluate the role of jack rabbits in radionuclide transport away from the Subsurface Disposal Area of the RWMC. Primary goals are to document radionuclide concentrations in jack rabbit tissues, and determine population size, movement patterns, habitat use, and food habits of jack rabbits inhabiting the RWMC area. Study design and preliminary results are discussed.

INTRODUCTION

The RWMC was established in 1952 on the Idaho National Engineering Laboratory (INEL) as a site for disposal and storage of fission, activation, and transuranic contaminated wastes. The Subsurface Disposal Area (SDA) was the original site for below-ground storage of radioactive wastes at RWMC, and is still in use although disposal practices have been modified (Arthur and Markham, 1978).

The SDA occupies a 36 ha area surrounded by a drainage channel and barbed wire fence. The primary vegetation within the SDA is seeded crested wheatgrass (Agropyron cristatum), with Russian thistle (Salsola kali) and squirreltail grass (Sitanion hystrix) growing on some recently disturbed and unseeded areas.

The surrounding vegetation is the big sagebrush-bluebunch wheatgrass-green rabbitbrush (Artemisia tridentata-Agropyron spicatum-Chrysothamnus viscidiflorus) vegetation type described by McBride et al. (1978). Crested wheatgrass seedings also occur within several hundred meters north and south of the SDA where surface soil was removed for use as a waste covering.

During nocturnal feeding periods, black-tailed jack rabbits (Lepus californicus) visit the crested wheatgrass seedings of RWMC, including the SDA. Because surface soils and vegetation within and near the SDA contain elevated levels of some radionuclides (Markham 1978, Markham et al., 1978; Arthur, 1982), jack rabbits may become contaminated from these sources.

Data from trapping studies suggest that normal activities of black-tailed jack rabbits are restricted to within 0.4 to 0.8 km (Lechleitner, 1958; French et al., 1965). French et al. (1965), however, reported a jack rabbit on the INEL Site moved 45 km, and although such an extensive movement is probably uncommon, it could result in long distance radionuclide transport if such a rabbit was contaminated.

Due to the use of the SDA by jack rabbits, and the potential for them to become contaminated and move considerable distances, this study was initiated in June 1982 to determine (1) the number of jack rabbits utilizing the SDA site on a seasonal basis, (2) daily and seasonal movement patterns of rabbits near the SDA, (3) effect of habitat characteristics on jack rabbit movements, (4) food habits and forage preferences of jack rabbits near the SDA, (5) the amount of SDA herbage consumed by jack rabbits, and (6) radionuclide concentrations in jack rabbits living near the SDA and jack rabbits living in an area with background radionuclide levels.

METHODS

Jack rabbit population density will be estimated using mark/resighting techniques, fecal pellet counts, and spotlight counts. Animals will be marked with colored ear discs, and a ratio of marked/unmarked rabbits observed will give an estimate of the number of rabbits in the area. Using previously estimated defecation rates (Arnold and Reynolds, 1943), an estimate of population density will be obtained from fecal pellet density and compared with the mark/resighting estimate. Spotlight counts will document relative density.

A 296-point grid system designed and established by Arthur and Markham (1978) will serve as a fecal pellet grid. At each grid point, a circular plot enclosing a 1-m² area was cleared of all pellets in July 1982. At three month intervals, pellets deposited on the plots by jack rabbits will be counted and removed. Density of pellets in the SDA and in surrounding crested wheatgrass seedings will be compared to document relative use.

Movement of individual jack rabbits will be determined using two methods. Rabbits, captured by trap or by nightlighting, will be fitted with a battery-powered radio transmitter or marked with color-coded discs attached to their ears. Numbered ear tags will aid in in-hand identification should a rabbit lose other markers and be subsequently recaptured. Marked rabbits will be released at point of capture.

Locations of radio-equipped jack rabbits will be determined periodically using a hand-held antenna and portable radio receiver. Visual observations will occasionally be made at these times to check condition of rabbits and transmitter attachments. In addition, 24-hour monitoring sessions will be conducted for transmitted rabbits using a truck-mounted stacked yagi antenna system. Triangulation will be used to map rabbit positions on aerial photographs. Distance moved and habitat utilization will be determined by this technique. Data from sightings of color-marked rabbits will supplement telemetry data.

Food habits of jack rabbits on the study area will be determined by microscopic analysis of fecal pellets (Sparks and Malechek, 1968). Fresh feces will be collected randomly throughout the study as they are encountered. Feces will also be taken from the intestinal tracts of rabbits killed near the study area.

A test for forage preference (Krueger, 1972; Johnson, 1982) will be utilized to determine whether jack rabbits select crested wheatgrass seedlings as feeding sites. Frequency of occurrence in the habitat will be determined from aerial photographs and from field measurements using a point interception method (Floyd and Anderson, 1981).

The amount of SDA forage consumed by jack rabbits will be estimated by comparing plant biomass on fenced versus unfenced 1-m² plots within the SDA using a paired plot sampling design. Plots will be established in November 1982 and clipped in April 1983 to determine forage consumption over winter. More plots will be established in April 1983 and clipped at the end of the growing season. Forage consumption estimated by fenced-plot methods will be compared to estimates based on individual daily consumption rates and estimated population using the area (Westoby and Wagner, 1973).

Jack rabbits were collected in August 1982 for analysis of radionuclides in tissues. Eleven from the SDA area and four from a control area were dissected to compare radionuclide concentrations in various body tissues. Hide, gastro-intestinal tract, and remaining carcass were oven dried at 60°C for 48 hours, weighed, and submitted for analysis of gamma-emitting and transuranic radionuclides.

PRELIMINARY RESULTS AND DISCUSSION

As of 1 October 1982, 39 jack rabbits were captured. Of these, 18 were equipped with radio transmitters, 11 were marked with colored ear tags, two were marked only with numbered ear tags, and eight were sacrificed for radionuclide analysis. An additional eight were collected by shooting for radionuclide analysis.

The most effective method of capture was spotlighting and netting. This method accounted for 33 captures. Four were captured in boxtraps and three (including one recapture) were caught in a walk-in funnel trap. Although spotlighting was the most productive technique, it required at least three people, with four or five being most effective.

A 71% mortality of radio-equipped rabbits has been observed in the initial 15 weeks of the telemetry study. Stoddart and Knowlton (1982) reported a 69% mortality of adult jack rabbits in summer and a 92% mortality of juvenile jack rabbits from birth to October on the INEL. The observed mortality rate in this study therefore does not seem unusual.

Approximately 300 radio locations (including eight 24-hour monitoring sessions) have been recorded. Rabbits appear not to move more than about 1 km, although more intensive tracking must be completed before firm conclusions can be drawn. The greatest linear movement noted to date was 1.6 km in one night. This rabbit was killed, apparently by a coyote (*Canis latrans*), before it was determined whether it typically moved this far. Another rabbit was monitored as it moved from the sagebrush approximately 1.0 km to spend 4 hours inside the SDA. This rabbit was tracked on another night when it moved to within 100 m of the SDA.

Tracking will continue through the summer of 1984 to determine movement patterns and habitat utilization near the SDA. Jack rabbit population size and food habits will be monitored throughout the study. When data from all phases of the study are collected and analyzed, the role of black-tailed jack rabbits in radionuclide transport away from the SDA will be evaluated.

LITERATURE CITED

- Arnold, J. F. and H. G. Reynolds. 1943. Droppings of Arizona and antelope jack rabbits and the "pellet census". J. Wildl. Manage. 7:322-327.
- Arthur, W. J., III. 1982. Radionuclide concentrations in vegetation at a solid radioactive waste-disposal area in southeastern Idaho. J. Environ. Qual. 11:394-399.
- Arthur, W. J. and O. D. Markham. 1978. Ecology studies at the Idaho National Engineering Laboratory Radioactive Waste Management Complex p. 74-92. In O. D. Markham (editor). Ecological Studies on the Idaho National Engineering Laboratory, 1978 Progress Report. IDO-12087. Nat. Tech. Inf. Serv., Springfield, VA.
- Floyd, D. A. and J. E. Anderson. 1981. Vegetation studies on the BLM/DOE prescribed burn study area. Progress report to Idaho Operations Office, Radiological and Environmental Sciences Laboratory, Idaho Falls, Idaho. 16 p.
- French, N. R., R. McBride and J. Detmer. 1965. Fertility and population density of the black-tailed jackrabbit. J. Wildl. Manage. 29:14-26.
- Johnson, R. D. 1982. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. M. S. Thesis. Idaho State Univ., Pocatello. 86 p.
- Krueger, W. C. 1972. Evaluating animal forage preference. J. Range Manage. 25:471-475.
- Lechleitner, R. R. 1958. Movements, density, and mortality in black-tailed jack rabbit populations. J. Wildl. Manage. 22:371-384.
- Markham, O. D. 1978. Activation and fission products in the environment near the Idaho National Engineering Laboratory Radioactive Waste Management Complex. Rep. No. IDO-12085. Nat. Tech. Info. Serv., Springfield, VA. 19 p.
- Markham, O. D., K. W. Puphal, and T. D. Filer. 1978. Plutonium and americium contamination near a transuranic storage area in southeastern Idaho. J. Environ. Qual. 7:422-428.

- McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. Rep. No. IDO-12084. Nat. Tech. Info. Serv., Springfield, VA. 28 p.
- Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage of dry weight in diets using a microscopic technique. J. Range Manage. 21:264-265.
- Stoddart, L. C. and F. F. Knowlton. 1982. Relative abundance of coyotes, lagomorphs, and rodents on the Idaho National Engineering Laboratory Site. In Idaho National Engineering Laboratory, Hanford Site, and Los Alamos National Laboratory Symposium on Radioecology and Ecology. Moran, WY. IDO-12095. Nat. Tech. Inf. Serv., Springfield, VA.
- Westoby, M. and F. H. Wagner. 1973. Use of a crested wheatgrass seeding by black-tailed jackrabbits. J. Range Manage. 26:349-352.

SEASONAL SOIL INGESTION RATES BY PRONGHORN AND BLACK-TAILED JACK RABBITS

W. John Arthur and Robert J. Gates

ABSTRACT

Research was initiated in November 1980 to determine the seasonal masses of soil ingested by pronghorn antelope (Antilocapra americana) and black-tailed jack rabbits (Lepus californicus) on the northwestern section of the Idaho National Engineering Laboratory (INEL). Since a portion of the study area is scheduled to have a controlled burn in summer 1982, information obtained from this study should be useful for comparing changes in soil intake rates during changes in vegetation patterns. By relating soil and forage intake rates to trace element (Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, K, Si, Sr, V and Zn) concentrations in these media, the relative importance of these two pathways can be evaluated in relationship to elemental intake. Similar applications of the data will be used to determine the role of soil versus vegetation intake and their relationship to radionuclide intake by pronghorn and jack rabbits on the INEL.

INTRODUCTION

Soil ingestion by wildlife and domestic animals can be an important source of trace elements (Healy, 1968; Healy et al., 1970; Mayland et al., 1975; Skipworth, 1974), as well as an uptake pathway for environmental pollutants (Mayland et al., 1977; Arthur and Alldredge, 1979). Few previous studies have dealt with the quantity of soil ingested by wildlife (Arthur and Alldredge, 1979); therefore, only minimal information exists on this pathway for intake of various elements and compounds.

Research was initiated in November 1980 in the northwest section of the 8300 km² Idaho National Engineering Laboratory in southeastern Idaho to determine the masses of soil ingested seasonally by pronghorn antelope and black-tailed jack rabbits. This particular area was selected because of a controlled burn scheduled for July 1982; therefore, trends in soil ingestion rates by these two herbivorous species could be documented during successional changes in vegetation. In conjunction with research on pronghorn and jack rabbit food habits at the study site (Gates and Eng, this volume), vegetation dietary components and soil samples were analyzed for trace elements. Based on the concentration of these elements in dietary components, comparisons will be made on the quantity of trace elements ingested due to soil versus vegetation intake. Results from this study will also be used to model radionuclide intake by pronghorn and jack rabbits near several nuclear related facilities on the INEL.

STUDY AREA

The study area encompassed approximately 300 km² and was located 10 km south of Howe, Idaho. Soils on the west section of the study area were alluvial loams deposited from the Lost River mountains with the majority of the area thin loess covered basalt plains and some areas of bare basalt. Elevation ranged from 1460 to 1520 m. Vegetation was dominated by big sagebrush (Artemisia tridentata), green rabbitbrush (Chrysothamnus viscidiflorus), and squirreltail grass (Sitanion hystrix) (McBride et al., 1978). Bluebunch wheatgrass (Agropyron spicatum) and giant wildrye (Elymus cinereus) also occurred frequently at the study area.

Throughout the study, black-tailed jack rabbit populations were at high densities. Pronghorn use of the area in summer and fall was fairly low; however, in winter and early spring a herd of 200 animals was commonly observed in the study area.

METHODS AND MATERIALS

Estimates of the quantity of soil ingested were made by determining titanium concentrations in soil, vegetation, animal tissues, and fecal material. The experimental approach has been previously described (Healy, 1968, Mayland et al., 1975) and is based on the premise that titanium is relatively abundant in soil (1000 to 3000 ppm) and is not metabolized by vegetation (usually <5 ppm). Since no titanium is retained by animal tissues (<1 ppm) most titanium detected in fecal material is due to soil intake (Mayland et al., 1975).

Twelve surface (0-5 cm) soil and 24 vegetation (big sagebrush leaves and grass composite) samples were collected in July 1980. Between November 1980 and December 1981, 15 pronghorn and 10 black-tailed jack rabbit fecal group samples (at least five pellets per group) were collected monthly from the study area. Care was taken to collect only recently deposited samples.

Ten jack rabbits were collected in November 1980 and April 1981 and metacarpal bone, muscle, liver, and kidney samples were obtained. Additionally the same tissues were collected from road killed pronghorn whenever possible.

All animal tissue, vegetation, and fecal samples were ultrasonically washed in demineralized water to remove surfically attached soil particles. Fecal samples were also hand scrubbed to facilitate soil removal. Samples were oven-dried for 72 hours at 70°C, screened through a 2-mm mesh screen and sent to a commercial laboratory where they were digested and analyzed for titanium by flame atomic absorption (S. Moore, personal communication). Twenty percent of the samples were analyzed in duplicate to assure consistency in spectrophotometer readings. National Bureau of Standards reference samples were analyzed for quality assurance.

Additionally, to obtain information on elemental concentrations in each media, all soil, vegetation, and animal tissue samples were analyzed for Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, K, Si, Sr, V, and Zn. These analyses were conducted by a conductively coupled argon plasma spectrograph.

Estimates of the quantity of soil ingested were made by the following equation.

$$S_{DAY} = \frac{(F_{Ti} \times F_{DAY}) - (V_{Ti} \times V_{DAY})}{S_{Ti}}$$

where:

S_{DAY}	=	soil mass (g) ingested per day
F_{Ti}	=	titanium concentration in ($\mu\text{g/g}$) feces
F_{DAY}	=	dry weight (g) feces defecated/day
V_{Ti}	=	titanium concentration in vegetation ($\mu\text{g/g}$)
V_{DAY}	=	dry weight (g) vegetation consumed/day
S_{Ti}	=	mean titanium concentration ($\mu\text{g/g}$) in surface soil

A mean daily forage intake rate (dry weight) of 680 g (spring-summer) and 980 g (fall-winter) for pronghorns (Severson et al., 1968) and 110 g (fall-winter) and 60 g (spring-summer) for blacktail jackrabbits (Currie and Goodwin, 1966) will be used to model soil ingestion.

Mean soil ingestion rates were calculated each month. One-way analysis of variance procedures were used to determine significant differences in soil intake rates among months. A significance level of $P = 0.05$ was used for rejection of the null hypothesis. Duncan's new multiple range test (Duncan, 1955) was used to separate statistically different means.

Mean concentrations of Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, K, Si, Sr, V, and Zn will be calculated for soil, vegetation, and animal tissue samples. These concentrations will be multiplied by daily soil and vegetation intake rates and each element compared for the percentage of its intake due to soil versus vegetation consumption.

RESULTS

As of this time, all field sampling and trace element analyses are complete. Results of this study will be submitted for publication in spring 1983.

LITERATURE CITED

Arthur, W. J. and A. W. Alldredge. 1979. Soil ingestion by mule deer in northcentral Colorado. *J. Range Manage.* 32: 67-71

- Currie, P. O. and D. L. Goodwin. 1966. Consumption of forage by black-tailed jack rabbits on salt-desert ranges in Utah. J. Wild. Manage. 30: 304-311.
- Duncan, D. B. 1955. Multiple range and multiple f tests. Biometrics 11:1-42.
- Healy, W. B. 1968. Ingestion of soil by dairy cows. New Zealand J. Agr. Res. 11:487-499.
- Healy, W. B., W. J. McCabe, and G. F. Wilson. 1970. Ingested soil as a source of microelements for grazing animals. New Zealand J. Agr. Res. 13:503-521.
- Mayland, H. F., A. R. Florence, R. C. Rosenau, V. A. Lazar, and H. A. Iurner. 1975. Soil ingestion by cattle on semiarid range as reflected by titanium analysis of feces. J. Range. Manage. 28:448-452.
- Mayland, H. F., G. E. Shewmaker, and R. C. Bull. 1977. Soil ingestion by cattle grazing crested wheatgrass J. Range. Manage. 30:264-265.
- McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site IDO-12084. Nat. Tech. Inf. Serv., Springfield, VA. 29 p.
- Severson, K., M. May, and W. Hepworth. 1968. Food preferences, carrying capacities and forage competition between antelope and domestic sheep in Wyomings's Red Desert. Science Monograph 10. Agricultural Experiment Station. University of Wyoming, Laramie. 51 p.
- Skipworth, J. P. 1974. Ingestion of grit by bighorn sheep. J. Wildl. Manage. 38:880-883.

IMPACTS OF JACK RABBIT HERBIVORY ON SAGEBRUSH STEPPE VEGETATION

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ABSTRACT

This report describes the vegetation studies that have been initiated on the Idaho National Engineering Laboratory (INEL) to assess the impacts of a peak in the black-tailed jack rabbit (Lepus californicus) population cycle on range vegetation. The results of censuses of the jack rabbit population from 1979 to present are also discussed. During the summer of 1979, two clusters of exclosure plots were established on the INEL. Each cluster consists of six exclosure plots paired with six plots that are open to jack rabbit herbivory. The clusters were located in two contrasting vegetation types, but both areas were chosen to assess the impacts of jack rabbits on preferred foods. In 1979, there was no significant difference in total vegetal cover or cover of dominant species between exclosed and open plots in either cluster. Vegetal data from these permanent plots will be collected again in 1982. Since January 1980, nighttime jack rabbit counts, made by spotlighting, were conducted quarterly along three paved highway routes and occasionally along backroads routes. Estimates of black-tailed jack rabbit densities from the backroads counts were usually much higher than those from paved road counts. The average density for a 45-km backroads route in May of 1981 was 2.6 jack rabbits/ha. The highest densities of jack rabbits were observed in grass-dominated habitats on the northern portion of the Site. The same general areas received heavy rabbit use from May, 1980, through May, 1981, but by September, 1981, the distribution of jack rabbits along the 45-km backroads route had changed markedly.

INTRODUCTION

The black-tailed jack rabbit (Lepus californicus) is an important herbivore on sagebrush steppe rangelands throughout most of the Intermountain West. In many areas including southern Idaho, populations of jack rabbits are cyclic reaching very high densities at approximately 10-year intervals (Wagner and Stoddart, 1972; Gross et al., 1974; U.S. Fish and Wildlife Service, unpublished data).

Numerous studies of food preferences and seasonal dietary trends for black-tailed jack rabbits have been conducted; these provide a reasonably complete picture of feeding behavior, although seemingly conflicting results have been reported (Johnson and Anderson, this volume). Over much of the species range, the diet in spring and early summer consists primarily of grasses; forbs may become more important in late summer and early fall, and the staple foods during winter are typically shrubs (Currie and Goodwin, 1966; Hayden, 1966; Hansen et al., 1969; Nagy et al., 1976; Fagerstone et al., 1980). Our studies on the Idaho National Engineering Laboratory (INEL) confirm the importance of perennial grasses in the early summer diet (Johnson and Anderson, this volume).

Despite plentiful data on food habits, little is known regarding the effects of black-tailed jack rabbit herbivory on native plant communities (Anderson et al., 1978). It is generally assumed that peak population densities will have severe impacts on range vegetation, but such impacts have been documented largely by casual observation. What effects, if any, that the jack rabbit cycles have on long term vegetation development are unknown.

This project was initiated to assess the impacts of a peak in the black-tailed jack rabbit cycle on range vegetation and to attempt to relate those impacts to long-term trends in vegetation development. Our intent was to document the immediate impacts of a peak in the cycle and then evaluate the effects of those impacts over a period of several years. This report includes a description of the vegetation studies that were initiated in 1979 and the results of our efforts to monitor trends in the jack rabbit population from 1979 to the present.

METHODS

Vegetation Studies

During the summer of 1979, two clusters of exclosure plots were established on the INEL. One cluster, designated RM, is located near the intersection of Road T-9 and East Monument Road (Section 35, T6N, R32E; Fig. 1). The second cluster (TF) is located along Road T-4 to the north of Tractor Flat (Sections 23 and 24, T4N, R33E; Fig. 2). Each cluster consists of six pairs of plots. We attempted to locate each cluster in an area supporting a relatively homogeneous stand of vegetation but having a reasonably high species richness and equitability.

Plots (5 x 5 m) in each pair were chosen subjectively to be as similar vegetatively as possible; the 5 x 5 m areas were then permanently staked with 0.9-m lengths of 1.3 cm steel reinforcing rod. One member of each pair was chosen by a coin toss to be fenced with a rabbit-proof exclosure. Each 15 x 15 m exclosure was centered on the vegetation plot. Exclosures were constructed from field fence (a loosely-woven wire fence) covered with chicken wire and supported by steel fence posts. The fences were buried in the soil to a depth of approximately 40 cm to preclude hares or rabbits from burrowing under them. Because the TF cluster is in an area that is open to sheep grazing, the open plots were fenced with field fence suspended about 30 cm above the ground to preclude access by livestock but not by jack rabbits.

Perennial vascular plant species in 15 1-m² quadrats were mapped for all plots. Layout and numbering of the 15 quadrats are shown in Fig. 1 and 2. Maps were drawn freehand using a sighting frame consisting of superimposed dm² string grids to facilitate vertical projection of the plants. Cover of each plant species was determined by weighing cutouts from photocopied duplicates of the completed maps and computing the area from a standard relationship of photocopy paper area to weight. The point interception technique (Floyd and Anderson, this volume) will be used for future data collection.

Figure 1. Plot layout for the RM enclosure site. Plots 1A, 2B, 3A, 4A, 5B, and 6A are fenced with rabbit-proof enclosures. Expanded plot shows numbering and layout of the 15 m² quadrats from which vegetation data were taken.

Figure 2. Plot layout for the TF enclosure site. Plots 1A, 2B, 3A, 4A, 5A, and 6B are fenced with rabbit-proof enclosures. Expanded plot shows numbering and layout of the 15 m² quadrats from which vegetation data were taken.

The overall sampling regime for each cluster was designed to take advantage of the power of pairing design statistical tests (paired sample t or Wilcoxon's signed-ranks test) to test for significant herbivore impacts on the open vs. exclosure plots.

To monitor rabbit use, all rabbit pellets were cleared from the 15 m² quadrats in each of the open plots in August and September of 1979. Pellets were counted and the plots re-cleared during the summers of 1980 and 1981.

Population Trend Studies

Idaho State University assumed responsibility for censusing jack rabbits along three paved highway routes in January, 1980 (see Fig. 1, Johnson and Anderson, this volume). These routes were originally established and monitored by R. M. Hansen of Colorado State University. One of the three routes was driven during each of three consecutive nights; the procedures are similar to those described by Flinders and Hansen (1973).

Jack rabbits were counted by spotlighting an area extending 50 m from the right-hand side of the road; a count was made for every other 1.6 km (1 mile) interval along each route. Data from these routes have been taken quarterly, in January, April, July, and October.

During the summer of 1980, we made nighttime counts using spotlights of jack rabbits along numerous backroads on the INEL. These data were used to establish study sites for an investigation of vegetation/diet relationships (Johnson and Anderson, this volume). Two of the backroads routes have been monitored periodically since that time. One 45-km route (Roads T-9 and T-4) was censused in May 1980, October 1980, May 1981, and September 1981. A 4-km backroads route (Road T-20) was observed in September and October 1980 and January, April, and October 1981. On the backroads routes, approximately 50 m on both sides of the vehicle were sampled. Jack rabbit densities were estimated according to Flinders and Hansen (1973). Error associated with the density estimations was estimated by treating each km segment of the 45-km backroads route as a sample unit. Assumptions and implications of this approach to estimating density are discussed under "Population Trends".

RESULTS AND DISCUSSION

Exclosure Plot Vegetation Studies

Previous studies have shown that several of the most important perennial grasses on the INEL are among the most preferred foods of the black-tailed jack rabbit. These include Indian ricegrass (Oryzopsis hymenoides), needle-and-thread grass (Stipa comata), and various wheatgrasses (Agropyron sp.) (Currie and Goodwin, 1966; Hayden, 1966; Uresk, 1978; Johnson, 1979). Winterfat (Ceratoides lanata) is also a common diet constituent (Currie and Goodwin, 1966; Hayden, 1966; Westoby, 1973). The locations of the two exclosure clusters were chosen primarily to attempt to assess the effects of jack rabbits on these species. Additionally, we chose areas that, based on the presence of abundant jack rabbit pellets, appeared to be receiving considerable rabbit use.

Table 1 presents the cover values by plot for the 20 perennial species that occurred on plots at the RM site. The species and plots are ordered according to their ranks on the first axis of a reciprocal averaging ordination (Gauch, 1977). Because the plot pairs were chosen on the basis of superficial similarity, one would expect the members of each pair to fall adjacent to one another on the ordination axis. Members of only one pair were adjacent (4a, 4b), but most of the other pairs tended to occur together. The matrix reflects the overall homogeneity of the study site. Eight species occurred on all 12 plots; they made up 98% of the total vegetal cover.

The TF site is in an old burn and is dominated by needle-and-thread grass and Indian ricegrass (Table 2). Bottlebrush squirreltail (Sitanion hystrix) is also common. Big sagebrush (Artemisia tridentata) is the dominant shrub, but green rabbitbrush (Chrysothamnus viscidiflorus) occurred on all but one plot.

The TF site is less homogeneous in vegetation than is the RM site; only four species were found on all 12 plots. Thickspike wheatgrass (Agropyron dasytachyum) was found only on plots on the north end of the study area, whereas Hood's phlox (Phlox hoodii) and prickley phlox (Leptodactylon pungens) occurred only on the southernmost plots. As a consequence, similarity between plots in pairs was higher than for the RM site. Plots of four of the six pairs were adjacent to each other on the first reciprocal averaging ordination axis (Table 2).

For the cluster plots to be used to assess the effects of jack rabbit herbivory, the plots must be comparable at the time of their establishment. Based on the 1979 data, there were no significant differences in total cover or cover of the dominant species between the exclosed and open plots in either cluster ($P > 0.05$; pairing design t test). Because the overall experimental design will enable us to not only compare open vs. exclosed plots, but also to compare data from each plot to its original data (1979), the exclosures should provide a reasonably sensitive assessment of jack rabbit impacts. Jack rabbit use on the exclosure areas was too low to warrant reading the plots in 1980 or 1981, but both areas have received considerable use over the past year, and vegetation data will be taken during June, 1982.

Population Trends

Census data from habitats along backroads showed wide variation in the numbers of jack rabbits observed from one local area to another. In May of 1980, the number of jack rabbits observed per km range from 0 to 39; in September 1980, the numbers ranged from 0 to 67 (Fig. 3), and in May 1981, from 3 to 87 jack rabbits were seen per km segment (Fig. 4). Similar variability in density was observed on all backroads routes.

In 1980, the highest densities of jack rabbits were found between kilometers 8 and 20 on the 45-km backroads route (Fig. 3). These high density areas were primarily in grass-dominated habitats along Road T-9, which crosses the northern portion of the INEL. This same section of the

Table 1. Species by plot matrix of cover (cm²) of perennial vascular plants for the RM enclosure site. Species and plots are ordered according to ranks on the first axis of a reciprocal averaging ordination.

SPECIES	PLOT											
	4A	4B	3B	1B	2A	1A	2B	3A	5B	6A	5A	6B
<u>Chaenactis douglasii</u>	10	-	-	-	-	-	-	-	-	-	-	-
<u>Eriogonum ovalifolium</u>	65	-	-	-	-	-	-	-	-	-	-	-
<u>Erigeron pumilus</u>	-	13	-	-	-	-	-	-	-	-	-	-
<u>Leptodactylon pungens</u>	453	272	345	33	10	-	-	-	30	-	-	-
<u>Arenaria sp.</u>	13	6	-	-	-	-	-	-	-	-	4	-
<u>Astragalus purshii</u>	-	-	-	-	45	-	8	-	-	-	-	-
<u>Phlox longifolia</u>	354	167	23	272	219	39	246	-	16	61	44	17
<u>Sitanion hystrix</u>	2323	2718	1125	1740	452	1627	589	169	706	95	428	53
<u>Opuntia polyacantha</u>	-	-	-	82	-	568	-	367	69	-	-	-
<u>Phlox hoodii</u>	1151	784	2563	908	1486	361	1273	461	1014	569	569	524
<u>Artemisia tridentata</u>	13517	12708	5675	5007	12039	4643	9721	377	4995	4822	9922	2619
<u>Agropyron dasytachyum</u>	4961	3921	1968	18417	5519	12478	2344	5396	7144	7710	5059	1713
<u>Ceratoides lanata</u>	10967	10033	1259	9128	5159	13646	7380	9050	4408	7256	7915	11658
<u>Oryzopsis hymenoides</u>	683	591	126	153	1669	386	204	108	406	706	1020	725
<u>Chrysothamnus viscidiflorus</u>	834	485	3420	1027	2673	171	2792	63	2380	2982	1209	2223
<u>Atriplex spinosa</u>	1383	1415	773	1633	1171	1195	689	1185	2025	3362	1347	3514
<u>Comandra umbellata</u>	-	-	-	-	-	-	-	-	112	-	-	-
<u>Tetradymia canescens</u>	-	-	-	-	-	-	-	-	-	-	617	-
<u>Eriogonum microthecum</u>	-	-	-	-	-	-	-	-	-	-	95	368
<u>Astragalus sp.</u>	-	-	-	-	-	-	-	-	-	-	-	101
Total cover	36714	33113	17277	38400	30442	35114	25246	17176	23305	27563	28229	23515

Table 2. Species by plot matrix of cover (cm²) of perennial vascular plants for the TF enclosure site. Species and plots are ordered according to ranks on the first axis of a reciprocal averaging ordination.

SPECIES	PLOT											
	4A	4B	3B	1B	2A	1A	2B	3A	5B	6A	5A	6B
<u>Agropyron dasytachyum</u>	3453	995	3528	44	71	-	-	-	-	-	-	-
<u>Astragalus ceramicus</u>	525	-	-	69	-	-	43	-	-	193	-	-
<u>Astragalus sp.</u>	195	-	-	-	-	-	13	-	13	-	7	-
<u>Unknown #3</u>	-	69	-	-	-	-	27	-	-	95	-	-
<u>Stipa comata</u>	2720	4519	1488	858	6422	5533	2353	183	2013	4343	2656	1542
<u>Oryzopsis hymenoides</u>	5941	8414	5316	5807	1802	3824	6030	8550	8800	5537	5784	7042
<u>Artemisia tridentata</u>	2759	881	1287	1712	301	345	2344	4244	2182	1066	1145	3526
<u>Sitanion hystrix</u>	79	335	476	189	398	908	283	496	642	469	1480	944
<u>Chrysothamnus viscidiflorus</u>	1313	-	3358	19454	1038	4067	4847	1874	1666	1523	6311	7833
<u>Phlox longifolia</u>	-	-	-	-	-	-	-	7	-	-	-	-
<u>Erigeron pumilus</u>	-	-	-	-	-	-	69	-	40	-	-	-
<u>Opuntia polyacantha</u>	-	-	43	-	-	-	-	-	-	-	-	270
<u>Zigadenus venenosus</u>	-	-	-	-	-	-	-	-	-	69	-	-
<u>Astragalus filipes</u>	-	-	-	-	-	-	26	-	-	-	-	-
<u>Poa nevadensis</u>	-	-	-	-	-	-	-	23	-	-	493	-
<u>Leptodactylon pungens</u>	-	-	-	-	-	-	-	-	822	471	820	711
<u>Phlox hoodii</u>	-	-	-	-	-	-	-	-	-	436	764	407
Total Cover	16985	15213	15496	28133	10032	14677	16035	15377	16178	14202	19460	22275

Figure 3. Number of black-tailed jack rabbits counted per 1-km segment of a 45-km backroads spotlight route. Symbols represent counts made in May 1980 (Δ) and September 1980 (○).

Figure 4. Number of black-tailed jack rabbits counted per 1-km segment of a 45-km backroads spotlight route. Symbols represent counts made in May 1981 (Δ) and September 1981 (○).

sample route supported large numbers of rabbits in the spring of 1981, but high densities were also observed in several additional sections (Fig. 4). By September of 1981, the distribution of jack rabbits along the 45-km route had changed markedly from the pattern observed 1 year earlier (cf. Fig. 3, 4). Relatively few rabbits were observed in the original high density areas, and more rabbits were observed in shrub-dominated sections of the route. High densities were observed in grass-dominated habitats at 18-20, 24-25, and 35-40 km; the latter section traverses a crested wheatgrass seeding, but we observed few jack rabbits in the crested wheatgrass area previously.

From May 1980 to May 1981, the total number of jack rabbits observed along the 45-km backroads route increased from 348 to 1193, indicating a 3.4-fold increase in the population over 1 year. The average density for the 45-km route was 0.8 ± 0.13 (S.E.) jack rabbits/ha in May 1980 and 2.6 ± 0.30 (S.E.) jack rabbits/ha in May 1981.

Estimating the absolute density of jack rabbits in an area from the spotlight counts requires a number of assumptions, including the following: 1) the route provides a representative, unbiased sample of habitats and rabbit distributions, 2) the roads do not influence rabbit distribution, 3) all rabbits within the spotlighted strip are counted, and 4) estimates of 50 m on each side of the vehicle are accurate. The extent to which these assumptions are violated determines the validity of the estimate. The jack rabbit distribution along the transect route is strongly clumped ($P < 0.001$; Poisson distribution test for randomness), but we have no way of knowing how representative of jack rabbit densities or habitat diversity the sample is. The clumping contributes to the variance and is thus reflected in our estimate of the standard error. The length of the transect and the fact that it crosses a variety of both shrub- and grass-dominated habitats suggests that the first assumption may not be unreasonable. The backroads have little disturbance associated with them; for the most part, they are simply two tracks through the adjacent vegetation. On the south end of the 45-km route where the road has been graded, no roadside seeding has been done. Traffic along the route is very light and infrequent. Thus, assumption two seems valid. The probability of sighting a rabbit is certainly less in shrub dominated habitats than in open, grassy areas; in the latter it approaches 1. The extent to which this error affects the estimate is unknown; it would make the overall density estimate low. It is not difficult to estimate the 50 m distance to within 5 m. Few rabbits are observed that fall within the questionable area; errors of omission and commission within this area are thought to be offsetting.

It seems reasonable to conclude that the density estimates are reasonably accurate for the general areas on the northern and eastern portions on the INEL that are traversed by the 45-km route. For the INEL as a whole, the density estimates are probably better treated as indices of population trends rather than estimates of absolute density.

Density estimates from the backroads spotlight counts were typically much higher than those from paved roads spotlight counts (Fig. 5). Only in July 1981 did the numbers observed along the paved road routes approximate those for the backroads routes. Why the paved roads estimate for this date was so much higher than the others is not clear, but it may reflect movement of

Figure 5. Average densities of black-tailed jack rabbits from periodic spotlight censusing on the paved road routes (□), a 45-km backroads route (○), and a 4-km backroads route (Δ).

rabbits from more to less desirable habitats. As noted above, there appeared to be a significant change in the distribution of jack rabbits on the Site between May and September, 1981.

One can only speculate on the reasons that the density estimates were usually higher for the backroads routes than for the paved road routes. It seems reasonable to assume that well-traveled paved roads would select strongly for road avoidance, but of course this assumption is dependent upon the presence of genetically controlled traits that manifest themselves in such behavior. We are aware of no evidence that would support such an assumption, but it cannot be ruled out. Another hypothesis, and perhaps a more plausible one, is that the paved road routes traverse less of the preferred feeding habitats than do the backroads routes. Our data (Johnson, 1982; Anderson and Johnson, this volume) indicate that jack rabbits on the INEL prefer grass-dominated habitats for feeding at night. Both the backroads and paved road routes intersect a variety of habitats, but grass-dominated habitats are somewhat more common on the backroads routes. It should be noted, however, that the paved route south of Howe crosses some 18 km of grass-dominated habitat; few rabbits have been observed in that area. Thus, this hypothesis is not entirely satisfactory either. Because the 45-km backroads route is isolated from human activity, and because it samples a variety of both shrub- and grass-dominated habitats, we think that it probably provides a better index of the overall density of black-tailed jack rabbits on the INEL.

LITERATURE CITED

- Anderson, J. E., R. J. Jeppson, R. J. Wilkosz, G. M. Marlette and K. E. Holte. 1978. Trends in vegetation development on the Idaho National Engineering Laboratory Site. p. 144-166. In Ecological Studies on the Idaho National Engineering Laboratory Site 1978 Progress Report. IDO-12087. Nat. Tech. Infor. Serv., Springfield, VA.
- Currie, P. O. and D. L. Goodwin. 1966. Consumption of forage by black-tailed jackrabbits on salt-desert ranges of Utah. J. Wildl. Manage. 30:304-311.
- Fagerstone, K. A., G. K. Lavoie and R. E. Griffith Jr. 1980. Black-tailed jackrabbit diet and density on rangeland and near agricultural crops. J. of Range Manage. 33:229-233.
- Flinders, J. T. and R. M. Hansen. 1972. Diets and habitats of jackrabbits in northeastern Colorado. Range Sci. Dep. Sci. Ser. No. 12, Colorado State Univ., Fort Collins. 29 p.
- Flinders, J. T. and R. M. Hansen. 1973. Abundance and dispersion of leporids within a shortgrass ecosystem. J. Mammal 54:287-291.
- Gauch, H. G. Jr. 1977. ORDIFLEX: a flexible computer program for four ordination techniques. Ecology and Systematics, Cornell Univ. Ithaca. 185 p.
- Gross, J. E., L. C. Stoddart and F. H. Wagner. 1974. Demographic analysis of a northern Utah jackrabbit population. Wildl. Monographs 40:68 p.
- Hansen, R. M., N. E. Green and D. R. Sparks. 1969. Black-tailed jackrabbits on sandhill rangeland. Colorado State Univ. Exp. Sta. Prog. Rep. Fort Collins. 2 p.
- Hayden, P. 1966. Food habits of black-tailed jack rabbits in southern Nevada. J. Mammal. 47:42-46.
- Johnson, M. K. 1979. Foods of primary consumers on cold desert shrub-steppe of southcentral Idaho. J. Range Manage. 32:365-368.
- Johnson, R. D. 1982. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. M.S. Thesis Idaho State Univ. Pocatello.
- Nagy, K. A., V. H. Shoemaker and W. R. Costa. 1976. Water, electrolyte, and nitrogen budgets of jack rabbits (Lepus californicus) in the Mojave Desert. Physiol. Zool. 49:351-363.
- Uresk, D. W. 1978. Diets of the black-tailed hare in steppe vegetation. J. Range Manage. 31:439-442.
- Wagner, F. H. and L. C. Stoddart. 1972. Influence of coyote predation on black-tailed jackrabbit populations in Utah. J. Wildl. Manage. 36:329-342.
- Westoby, M. 1973. Impact of black-tailed jack rabbits (Lepus californicus) on vegetation in Curlew Valley, northern Utah. Ph.D. Thesis. Utah State Univ. Logan.

LONG-TERM STUDIES OF RELATIVE DENSITY OF RODENTS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Barry L. Keller

ABSTRACT

A long-term study of the relative density of 5 rodent communities was initiated during fall and spring periods beginning September, 1980 at the Idaho National Engineering Laboratory. Mean rodent numbers, as determined by snap trapping, declined from 207.2 to 78.4 individuals per 1,000 trap nights on 4 of 5 independent study areas over a 2 1/2 year period. However, density appeared to be increasing on all 5 study areas based upon samples collected during September, 1982. Diversity varied among sampling sites but remained most extensive at a locality near the Radioactive Waste Management Complex on the Idaho National Engineering Laboratory.

INTRODUCTION

Allred (1973), Reynolds (1980), Johnson (1982), Groves and Keller (1983), and Johnson and Keller (1983) have documented densities of small mammals on several areas on the Idaho National Engineering Laboratory. However, a long-term commitment to develop information on annual variation in rodent abundance was not established by the Department of Energy until 1980. Spring-fall determinations of rodent density have been sought by the U.S. Fish and Wildlife Service from 6 transects located in the center of the INEL Site and sampled with M-4 rat traps with expanded treadles from 1975-1978 and 1980-1982 (F. Knowlton, personal communication).

During 1980, I selected 4 independent sample sites for temporal contrast of indices of rodent abundance. The objectives of this study are to: 1) develop fall and spring estimates of changes in relative densities and composition of rodent communities at fixed sites over a period of years, and 2) provide Idaho State University students field experience in methods used to sample small mammals at the Idaho National Engineering Laboratory National Environmental Research Park.

METHODS

Four permanently staked sites, dominated by big sagebrush (Artemisia tridentata), were sampled beginning September 1980. A fifth site, dominated by a seeded monoculture of crested wheatgrass (Agropyron cristatum), was sampled beginning May 1981. Three transect lines containing 26 sampling points spaced at 10 m intervals were established at 0.2 km (1/10 mi) intervals at each area (Fig. 1). Whereas the dominant vegetation on 4 areas is big sagebrush, the northernmost site, TAN, contains some sparse cover of winterfat (Ceratoides lanata), bluebunch

Figure 1. Locations of five sampling areas, each containing three transects with 26 snap-trap stations spaced at 10 m intervals, on the Idaho National Engineering Laboratory. The name of each location has been keyed to the written text and exact coordinates provided.

wheatgrass (Agropyron spicatum), and needle-and-thread grass (Stipa comata). Cover is greater on the BURN and RWMC areas, and several additional species of grasses, Nevada bluegrass (Poa nevadensis), Sandberg's bluegrass (Poa sandbergii) and Indian ricegrass (Oryzopsis hymenoides), are common on both areas. The ARGONNE site is dominated by big sagebrush and bluebunch wheatgrass. Transects at ARGONNE, TAN and the RWMC site were established within 15 m of paved roads and were oriented in a magnetic north direction. Transects at the WILSON site were established in the center of the stand. Transects at the BURN site were developed along vegetation transects already established by Floyd and Anderson (this volume). The latter transects are oriented NW approximately 16° from magnetic north on a dirt road into the area (see Fig. 1, Keller, et al., this volume).

Three days prior to initiating each mid-September or May census, two Museum Special and one McGill rat traps have been placed within 2 m of each station. All traps have been prebaited with a mixture of whole oats, peanut butter and bacon fat and have been left unset 2 days prior to being set to catch. Beginning September 1981, 3 Museum Special sets were used as a result of time limitations in resetting traps at 5 distant locations and to allow contrast with indicies currently being sought with rat traps by the Fish and Wildlife Service. Trapping has been conducted for 3 days during samplings. All animals caught have been immediately frozen and representative study skins prepared for deposit at the Radiological and Environmental Sciences Laboratory, INEL or the Idaho Museum of Natural History, Idaho State University.

RESULTS

In 16,423 snap-trap nights, 2,313 specimens of 11 species of rodent were collected (Table 1). The mean relative density of rodents per 1000 snap-trap nights obtained from samples for the first fall ($\bar{x} = 207.2 \pm 52.6$ (SD), $n=4$) was significantly higher ($p \leq 0.01$) than the last fall ($\bar{x} = 78.4 \pm 24.6$, $n=5$). The 5 samples representing 2 seasons show a consistent pattern of decline except at the TAN site, but not all individual species were subject to decline. The highest single relative density was observed on the TAN site, but the highest mean density of rodents ($\bar{x} = 155.5 \pm 78.8$, $n=5$) for a single area was noted on the BURN site where additional studies of rodents are in progress (Keller, et al., this volume). Species diversity has been greatest at the RWMC site, whereas it has been lowest at the TAN site (Table 1). The deer mouse (Peromyscus maniculatus) and least chipmunk (Eutamias minimus) consistently have been the most common mammals trapped in sagebrush habitat.

DISCUSSION

Transect sampling systems must remove a significant fraction of the total individuals residing in a given area. Additionally, samples removed along one transect should be independent and result in no immediate effect on samples from adjacent transects unless all of the data are to be pooled for a given area. Live-trapping estimates of movement on the BURN area (Keller, et al., this volume) suggest that some deer mice may travel distances greater than 160 m in 1 day. Thus, I have pooled data for individual transects until the extent of this movement and its effect on population estimates can be examined in greater detail.

Table 1. Number of individuals caught, number of snap-trap nights, and relative density per 1000 trap nights for fall and spring samples of 11 species of rodents sampled at 5 trapping areas, Idaho National Engineering Laboratory.

Area & Sample Period	<u>Dipodomys</u> <u>ordii</u>	<u>Eutamias</u> <u>minimus</u>	<u>Microtus</u> <u>montanus</u>	<u>Onychomys</u> <u>leucogaster</u>	<u>Perognathus</u> <u>parvus</u>	<u>Peromyscus</u> <u>maniculatus</u>	<u>Reithodontomys</u> <u>megalotis</u>	<u>Spermophilus</u> <u>townsendii</u>	<u>Taonomys</u> <u>talpoides</u>	<u>Mus</u> <u>musculus</u>	<u>Lagurus</u> <u>curtatus</u>	Row Total all species	Trap nights	Relative density per 1000 trap nights
ARGONNE														
Sept. 1980		6		1	3	147				1		158	702	225.0
May 1981					2	112	1	5	1		1	122	702	173.8
Sept. 1981		8			4	89						101	702	143.9
May 1982		2			12	12						26	702	37.0
Sept. 1982		5		1	4	42						52	702	74.1
BURN														
Sept. 1980		64			6	114						184	702	262.1
May 1981		18		3	3	94		29				147	702	209.4
Sept. 1981		22		2		48						72	522	137.9
May 1982	1	12		2	6	32		2				55	702	78.4
Sept. 1982		10		3	5	45						63	702	89.7
RWMC														
Sept. 1980	3	4		2	12	123						144	702	205.1
May 1981				4	17	107		6	1			135	697	193.7
Sept. 1981	5	10		1	3	96	3				1	119	702	169.5
May 1982	1	4		3	7	33						48	702	68.4
Sept. 1982	1			4	4	67						76	702	108.3

Table 1. (Continued)

TAN

Sept. 1980	6	1	89								96	702	136.8
May 1981	10	3	102	2	83						200	696	287.4
Sept. 1981	13	1	1	120							135	702	192.3
May 1982	5	2	16	21		5					49	702	69.8
Sept. 1982	3	3	2	47							55	702	78.4

WILSON

May 1981	3	7	14	111	18	1					154	702	219.4
Sept. 1981	1	1	4	2	61	13					82	702	116.8
May 1982				5	6						11	468	23.5
Sept. 1982			1	2	25	1					29	702	41.3

Totals	15	203	11	37	130	1743	38	131	2	1	2	2313	16423	140.8
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LITERATURE CITED

- Allred, D. M. 1973. Small mammals of the National Reactor Testing Station, Idaho. *Great Basin Nat.* 33:246-250.
- Groves, C. R. and B. L. Keller. 1983. Ecological characteristics of small mammals on a radioactive waste disposal area in southeastern Idaho. *Amer. Midl. Nat.* 109:253-265.
- Johnson, M. K. 1982. Response of small mammals to livestock grazing in southcentral Idaho. *J. Range. Manage.* 35:51-53.
- Johnson, W. C. and B. L. Keller. 1983. An examination of snap trapping techniques for estimating rodent density in high desert. *Northwest Sci.* (in press).
- Reynolds, T. C. 1980. Effects of some different land management practices on small mammal populations. *J. Mammal.* 61:558-561.

AN ECOLOGICAL STUDY OF THE AMERICAN ROUGH-LEGGED HAWK ON THE IDAHO NATIONAL ENGINEERING LABORATORY

James W. Watson and Robert L. Eng

ABSTRACT

A study was initiated in January 1982 on the Idaho National Engineering Laboratory Site to investigate the winter ecology of the American rough-legged hawk (Buteo lagopus). Seven hawks were trapped and wing-marked between the Central Facilities Area and the Test Area North along Lincoln Boulevard. One marked hawk occupied a 1.3 km² range for several weeks and exhibited conspecific territorial defense. Changes in rough-legged hawk density and food habits appeared related to snow cover. Future radio-tracking and data collection will continue through March, 1983.

INTRODUCTION

The American rough-legged hawk (Buteo lagopus) is the most common migrant and resident raptor wintering in southern Idaho, including the Idaho National Engineering Laboratory (INEL) Site (Craig, 1978; U.S.D.I., 1979; Thurow et. al., 1980). The importance of the INEL as a wintering area for rough-legged hawks and other raptors has been documented (Craig, 1979), yet the environmental parameters affecting this species' abundance and distribution on the site have not been investigated. Although all present evidence circumstantially links wintering raptor densities with prey densities, other factors may influence bird numbers (Newton, 1979). A better understanding of these factors and their influence on rough-legged hawk distributions on the INEL are important because this species could consume contaminated prey near nuclear facilities (Arthur, this volume; Halford, this volume) and thus become a mode of radionuclide transport on the site.

Published literature of this species' winter ecology is limited and is based largely on research from cultivated areas in the midwest (Craighead and Craighead, 1969; Weller, 1964; Schnell, 1967a, 1967b, 1968, 1969). The sagebrush habitat and relatively undisturbed area of the INEL provided a unique study site for an investigation of rough-legged hawk winter ecology that was initiated in January 1982. The objectives of this research are to: 1) determine the abundance and distribution of rough-legged hawks on the INEL in relation to food habits, prey base, and perch sites; 2) determine if temporal or spatial distributions exist and the winter range size for the species; and 3) assess the population status, behavior, movements, and food habits of rough-legged hawks near nuclear facilities including the Idaho Chemical Processing Plant (ICPP), the Test Reactor Area (TRA), and the Radioactive Waste Management Complex (RWMC).

METHODS

Study objectives will be met by monitoring the movements of wing-marked and radio-tagged hawks. Several trapping techniques have been tested in this study, including noose carpets (Berger and Hamerstrom, 1962), wired around black-tailed jack rabbit (Lepus californicus) carcasses, bal-chatris (Berger and Mueller, 1959), modified bal-chatris (Ward and Martin, 1968)

baited with deer mice (Peromyscus maniculatus), and padded leg-hold traps. Moose carpets and bal-chattris were dropped from a moving vehicle under a perched hawk; leg-hold traps were placed on fenceposts or the ground and baited with rabbit carcasses or mice.

All captured rough-legged hawks were wing-marked with numbered, orange-vinyl patagial markers (Kochert, 1972). Hawks were aged and sexed (Cade, 1955; Hamerstrom and Weaver, 1968), weighed, and leg-banded. Culmen length, tarsus length and tarsus width were recorded.

Records were kept of marked bird sightings. Estimates of range size of marked birds were computed by the minimum area method (Mohr, 1947). Posters requesting information on marked birds have been distributed to INEL facilities and to Government agencies in surrounding states and Canada. Rough-legged hawk feeding behavior was also recorded by prey type, and bird/bird interactions were recorded according to whether or not prey defense occurred.

A 32.6 km car survey encompassing the ICPP, TRA, and RWMC was conducted approximately every 6 days (Fig 1). Each survey was driven at about 32 KPH between 1100 and 1300 h. No surveys were conducted during inclement weather. Bird species, location, and activity were recorded.

Rough-legged hawk castings have been collected under perch sites near nuclear facilities and at an offsite area near Howe. Castings were collected carefully to minimize soil contamination, and were oven-dried. These will be analyzed to document food habits and the presence of gamma-emitting radionuclides.

RESULTS AND DISCUSSION

Seven rough-legged hawks were trapped by moose carpets between 12 January and 2 February (Table 1). Four different marked hawks have been resighted since their capture (Table 2). One daily range for adult female F04 was 1.2 km² (n=20 observations). The area occupied by this bird for several weeks, defined as the weekly range (Craighead and Craighead, 1969), was 1.3 km² (n=11 observations).

Census data for 10 surveys are summarized in Table 3. Rough-legged hawks were most abundant in section 1 averaging .44 hawks/km near nuclear facilities TRA and ICPP. Changes in rough-legged hawk numbers and feeding behavior appeared related to snow cover. From January to 14 February snow covered hunting areas and hawks declined. A rapid decline in rough-legged hawks in Illinois was attributed to the passage of a month-long cold front which left snow on hunting areas (Schnell, 1967a). Feeding behavior on the INEL during this period indicated the heavy use of rabbit/carrion as a food source. Forty-three incidents of rough-legged hawks feeding on road-killed rabbits and seven attempted small rodent kills were observed. No hawks were seen on rabbit carcasses but five attempted rodent kills were observed after the ground was exposed beginning 15 February. The increase in hawks observed 21 March after snow 17 March was probably due to the tendency of raptors to concentrate on roadways and forage for carrion when hunting areas are snow covered (Klein and Mason, 1981).

Figure 1. Rough-legged hawk survey routes on the Idaho National Engineering Laboratory.

TABLE 1. Rough-legged hawks trapped on the Idaho National Engineering Laboratory during January and February 1982.

Date	Marker Number	Sex	Age ^a	Location ^b
1-12	F01	F	SY	5.6 km N ICPP
1-15	F02	F	ASY	Junction NRF
1-20	F03	M	SY	Junction Seven Mile Rd.
1-22	F04	F	ASY	Junction Seven Mile Rd.
2-1	F05	F	ASY	Junction ICPP
2-1	F06	M	ASY	Junction Seven Mile Rd.
2-2	F07	M	ASY	Junction ICPP

^aSY=second year ASY=after second year.

^bLocation on Lincoln Boulevard.

TABLE 2. Observations of marked rough-legged hawks on the Idaho National Engineering Laboratory during January and February 1982.

Bird	Maximum obs. diameter between capture and resighting (km)	Inclusive dates of resighting	No. observation
F01	2.4	1-12 1-24	1
F04	3.2	1-22 2-23	11
F05	1.6	2-1 2-2	1
F07	3.2	2-2 2-4	2

TABLE 3. Rough-legged hawks observed during 32.6 km car survey 1982.

Date	Section ^a					Total
	1	2	3	4	5	
1-31	6	2	1	0	2	11
2-6	2	0	2	0	2	6
2-12	4	0	1	0	0	5
2-18	2	0	0	0	0	2
2-24	1	0	0	0	0	1
3-3	0	0	0	1	0	1
3-8	1	0	0	0	0	1
3-13	0	1	0	0	0	1
3-21	4	0	0	0	2	6
3-27	1	0	0	0	1	2
Total	21	3	4	1	7	
Mean birds/km	.44	.05	.07	.01	.10	

^aSee Figure 1.

Twenty-five interactions between rough-legged hawks at perching sites were observed between 12 January and 8 March. Twenty of these interactions (80%) resulted in one hawk displacing another from a perch site or carcass. Of these successful displacements, 12 (60%) appeared to result from the defense of prey, and the remaining 8 (40%) involved no obvious relation to prey. Three interactions involved displacement of another hawk from perch sites by bird F04 and appeared to be "territorial defense." In every interaction F04 escorted the displaced hawk to a certain geographical boundary and returned to her original perching area. This possible defense of range is unusual particularly in a gregarious species like the rough-legged hawk (Brown and Amadon, 1968). Craighead and Craighead (1969) found territorial behavior among wintering raptors to be inconspicuous if present at all, although Sylven (1978) observed conspecific territorial behavior of the rough-legged hawk in Sweden.

Future research plans for this study include collecting radiotelemetry data from rough-legged hawks, as well as trapping small mammals in selected areas of high and low hawk density. These data will provide information on rough-legged hawk prey base, movements, food habits and home range. Data collection will continue through March, 1983.

LITERATURE CITED

- Berger, D. D. and F. Hamerstrom. 1962. Protecting a trapping station from raptor predation. *J. Wildl. Manage.* 26:203-206.
- _____, and H. C. Mueller. 1959. The bal-chatri: a trap for birds of prey. *Bird Banding* 30:18-26.
- Brown, L. and D. Amadon. 1968. *Eagles, hawks and falcons of the world.* Vol. 1. McGraw-Hill, NY.
- Cade, T. J. 1955. Variation of the common rough-legged hawk in North America. *Condor* 57:313-346.
- Craig, T. H. 1978. A car survey of raptors in southeastern Idaho 1974-1976. *Raptor Res.* 12:40-45.
- _____, 1979. The raptors of the Idaho National Engineering Laboratory Site, IDO-12089. *Nat. Tech. Inf. Serv.*, Springfield, VA.
- Craighead, J. J. and F.C. Craighead. 1969. *Hawks, owls and wildlife.* Stackpole Co. Harrisburg, PA. 443 p.
- Hamerstrom, F. and J. D. Weaver. 1968. Aging and sexing of rough-legged hawks in Wisconsin and Illinois. *Ontario Bird Banding* 4:133-138.
- Klein, R. J. and D. R. Mason. 1981. Changes in raptor hunting behavior following heavy snowfall. *Raptor Res.* 15:121.

- Kochert, M. N. 1972. Population status and chemical contamination in golden eagles in southwestern Idaho. M. S. Thesis, Univ. of Idaho, Moscow.
- Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Mid. Nat. 37:223-249.
- Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD. 399 p.
- Schnell, G. D. 1967a. Population fluctuations, spatial distributions, and food habits of rough-legged hawks in Illinois. Kansas Ornith. Soc Bull. 18:21-28.
- _____, 1967b. Environmental influence on the incidence of flight in the rough-legged hawk. Auk 84:173-182.
- _____, 1968. Differential habitat utilization by wintering rough-legged and red-tailed hawks. Condor 70:373-377.
- _____, 1969. Communal roosts of wintering rough-legged hawks (Buteo lagopus). Auk 86:682-690.
- Sylvén, M. 1978. Interspecific relations between sympatrically wintering common buzzards Buteo buteo and rough-legged buzzards Buteo lagopus. Ornis Scandinavia 9:197-206.
- Thurrow, T. L., C.M. White, R. P. Howard, and J. F. Sullivan. 1980. Raptor ecology of Raft River Valley, Idaho, EGG-2054. Idaho Falls, ID.
- United States Department of the Interior. 1979. Snake River birds of prey environmental statement. Bureau of Land Management, Boise District Office. Boise, ID.
- Ward, F. P. and D. P. Martin. 1968. An improved cage trap for birds of prey. Bird Banding 39:310-313.
- Weller, M. W. 1964. Habitat utilization of two species of Buteos wintering in central Iowa. Iowa Bird Life 34:58-62.

RAPTOR STUDIES ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Timothy H. Craig, Erica H. Craig and Leon R. Powers

ABSTRACT

A study of wintering and nesting raptors is being conducted on the Idaho National Engineering Laboratory (INEL) during 1981-1982 at a time when black-tailed jack rabbits (Lepus californicus) are numerous. Baseline data on raptors which inhabited the study area were collected in a previous study from 1974 through 1976 at a time when jack rabbits were scarce, and comparisons in raptor densities will be made between the two studies. In addition, information will also be collected on home range size of long-eared owls (Asio otus) in the vicinity of nuclear facilities. A nesting census, collection of productivity data on nesting raptors and the long-eared owl study will begin in spring 1982. Preliminary data from a car survey of non-breeding raptors in 1981-1982 indicate a much higher population of large raptors on the INEL than in 1974-1976 and suggest that the large black-tailed jack rabbit populations may be responsible.

INTRODUCTION

Craig and Trost (1976) pointed out that base-line studies of raptor populations on the INEL are important: 1) since raptors may be valuable indicators of environmental pollution; 2) for comparison of this unimpacted population of raptors to those inhabiting impacted environments; and 3) to alert scientists to significant changes in raptor populations over long periods of time. Craig (1977, 1979) conducted a raptor study on the Idaho National Engineering Laboratory (INEL) from 1974 through 1976. General base-line data were collected on raptor winter density, nesting density and radionuclide concentrations in nestling raptors near nuclear facilities. These studies occurred when black-tailed jack rabbit (Lepus californicus) numbers were low, a trend that is now reversed (Stoddard, this volume). Results suggested that the nesting density of large raptors on the INEL may be linked to jack rabbit numbers as has been indicated for other intermountain raptor populations (Thurow et al., 1980; Seibert et al., 1976; Woffinden, 1977). Craig (1979) reported the presence of numerous, unused large stick nests on the Site which appeared to be old ferruginous hawk (Buteo regalis) or golden eagle (Aquila chrysaetos) nests; an indication that these species were once more numerous than in the mid-1970's. A decline in nesting ferruginous hawks was documented from 1971, when jack rabbits were numerous, to 1975 when they were scarce for both the Little Lost River Valley and the adjacent INEL (Powers and Craig, 1976). However, the presence of numerous ground squirrels (Spermophilus richardsonii) in the Little Lost River Valley complicated the conclusion that prey numbers were the exclusive reason for the decline. The early studies also suggested that the winter density of large raptors on the INEL may be related to jack rabbit numbers because reports of large numbers of golden eagles on the INEL in 1971 were in contrast to data collected in the winters of 1974 through 1976. Results of another roadside raptor survey suggested that the number of large raptors in Utah declined in conjunction with the declining jack rabbit population (Woffinden and Murphy, 1977).

The objectives of the present study are to determine the relative density of wintering and nesting raptors on the INEL as related to prey densities and to determine the home range and food habits of long-eared owls.

METHODS

Winter-spring survey. The raptor survey began on the INEL on 30 November 1981 and will continue through April 1982. The methods and survey route are the same as employed by Craig (1977) and entail counting all raptors observed over a 187 km route every 2 weeks throughout the winter and spring (Fig. 1). One change from the earlier study is that two independent surveys are conducted simultaneously during this study (two different people in different vehicles but separated by approximately five min). This duplication may help estimate errors associated with this widely used technique.

Figure 1. Map of the Idaho National Engineering Laboratory Site showing prominent landmarks and the car survey route (numbered segments) used in 1974-1976 and 1981-1982.

Eagles were observed during February 1982 roosting overnight on powerlines on the INEL; consequently, in addition to our morning raptor censuses, eagle surveys were conducted at dusk along segments of the survey route where power poles were abundant. We inventoried roosting eagles along route 22 (segments 3 and 4 combined) and the major portion of segment 7 (Test Area North, TAN, to Central Facilities Area, CFA). We later inventoried these segments on one night and segment 1 and the major part of segment 8 on the following night, to estimate the number of roosting eagles on the major power lines on the INEL. Surveys of each segment were conducted simultaneously 45 min. before dark on calm evenings, and every eagle observed anywhere along the routes was recorded. We assumed that any eagles observed at that time would remain overnight since observations on moonlit nights revealed the presence of roosting birds on poles.

The potential for electrocutions of raptors including both bald (Haliaeetus leucocephalus) and golden eagles using powerlines for roosts or perches could be greater if populations increase with increasing jack rabbit numbers. Therefore, powerline corridors between TAN and CFA will be searched in spring 1982 to assess the impact of this powerline on wintering raptors.

Nesting survey. An inventory of all nesting raptors on and around the INEL will be initiated in mid-April 1982 using techniques described by Craig and Trost (1976) and Craig (1979). Historic nest sites will be inventoried first so that efforts in other areas can be maximized after these known sites are checked. Some large raptors forage far from their nest sites (Newton, 1979). Therefore, cliffs bordering the INEL to the north and west will be inventoried since raptors nesting there probably hunt on the INEL.

Nests will be visited one or two times after young have hatched since some raptors are sensitive to human disturbance during the early nesting period (Fyfe and Olendorff, 1976), and information will be obtained on brood size, fledging success and food habits. Nestling raptors will be banded with USF&WS bands during the late brood-rearing period.

Long-eared owl home range. In 1976 long-eared owls were one of the more numerous nesting raptors near Test Reactor Area (TRA), Idaho Chemical Processing Plant (ICPP) and along the Big Lost River adjacent to the Radioactive Waste Management Complex (RWMC) (Craig, 1977). In April and May nesting locations of long-eared owls will be identified. During late incubation, or the early nesting period, an attempt to trap both adult birds from each of three nests will be made. Alternate nests may be selected if some adults prove difficult to trap. A variety of trapping techniques may be attempted including the use of mist nets and balchatrix (Harris, 1980). Adults will be banded and equipped with back-pack radio transmitters (Dunstan, 1972). Both birds at each nest will be monitored at least once every 10 min. throughout the night by taking simultaneous radio fixes from two tracking stations (vehicles or semi-permanent blinds). Two to six all-night tracking periods will be expended on each owl as long as they remain at the nest site. Radionuclide concentrations in prey remains found at the nest sites where the adults are radio-tracked will be documented during the summer of 1982 (Craig et al., 1979). This information will be related to the foraging activities of long-eared owls as determined by radiotelemetry.

RESULTS

Winter-spring survey. Raptor surveys through early March (Table 1) have indicated an increase in the number of wintering raptors on the INEL compared to 1974-1976 (Craig, 1977). The greatest increases were in large raptors which feed on hares and rabbits in the west (Sherrod, 1978; Watson, this volume). In the first six surveys of 1981-1982, golden eagles, bald eagles, American rough-legged hawks (Buteo lagopus), ferruginous hawks, and northern harriers (Circus cyaneus) all increased significantly over the highest number seen during either survey in the mid-1970's (Mann Whitley U Test $P < 0.05$).

The total number of raptors observed per survey day was also much larger than observed in the mid-1970's, with 16 times the total number of raptors in 1981 in the mid-December survey than the number seen during the same time on either of the two surveys conducted in 1974-1976. In contrast to the 1974-1976 surveys, bald eagles, an endangered species, and the largest North American broad-winged hawk, the ferruginous hawk, were consistently present on the Site throughout the winter of 1981-1982. In contrast one bald eagle was observed during the 1974-1976 surveys and ferruginous hawks migrated from the area in the winters of 1974-1976, but in 1981-1982 some birds remained throughout the winter and were often seen near the locations of nesting territories. More unidentified buteos and eagles were recorded during the surveys of 1981-1982 than were reported in the 1974-1976 surveys because the large number of birds sighted per survey did not allow time for difficult identifications.

An unusually large number (Table 2) of eagles roosted on about 20 km of powerline in segments 3 and 4 of the survey route. Nearly as many birds used the three major lines between TAN and CFA but over a much greater distance. Because of low light conditions, all eagles could not be identified to species, but we assume most were golden eagles since all of the birds positively identified were golden eagles, and most of the bald eagles which occurred on daytime surveys were around Howe, Idaho where a communal roost was discovered in a grove of trees. Thirteen bald eagles were observed in this roost on 12 February and 17 were counted during the mid-winter bald eagle count in January (John Arthur, pers. comm.).

To estimate the total number of golden eagles roosting on the INEL, we inventoried eagles along four different routes on two consecutive evenings in February 1982. A total of 208 eagles were observed on these surveys. On 8 February, 7 eagles were observed roosting on one pole, some nearly touching one another. This behavior may have resulted from the severe weather conditions during this month (-36°C overnight temperature) since the birds may have shared warmth by roosting close together.

The native vegetation of the INEL Site appears to be an important reservoir for prey species and the raptors which are dependent upon them. The relatively dense rabbit and hare populations during the winter of 1981-1982 probably attracted the large numbers of eagles and hawks to the area. These results emphasize the importance of collecting raptor/prey density information over a number of years and stress the inherent dangers of making conclusions about raptor densities from short-term studies.

Table 1. Raptors observed along a 187 km survey route on the Idaho National Engineering Laboratory, 1974-1976 (Craig, 1977) and 1981-1982.

Species	Survey No. 1 11/9/75			Survey No. 2 11/28/75			Survey No. 3 12/14/75			Survey No. 4 12/28/75		
	11/20/74 11/30/81			12/6/74 12/14/81			12/16/74 12/28/81			12/23/74 1/10/82		
Northern Harrier	0	0	6	0	2	3	0	0	8	0	0	2
American Rough-legged Hawk	8	15	81	6	19	64	11	10	119	5	12	97
Ferruginous Hawk ^a	--	--	6	--	--	7	--	--	6	--	--	6
Red-tailed Hawk ^a	--	--	0	--	--	0	--	--	0	--	--	2
Unidentified Buteo ^a	--	--	2	--	--	5	--	--	9	--	--	5
Golden Eagle	4	4	28	1	0	35	0	3	50	1	2	46
Bald Eagle ^a	--	--	3	--	--	14	--	--	6	--	--	14
Unidentified Eagle ^a	--	--	5	--	--	2	--	--	7	--	--	18
Prairie Falcon	2	3	1	0	1	3	0	0	2	0	0	2
American Kestrel	0	0	1	0	0	1	0	0	1	0	0	1
Total	14	22	133	7	22	134	11	13	208	6	14	193

Species	Survey No. 5 1/10/76			Survey No. 6 1/29/76			Survey No. 7 2/14/76			Survey No. 8 3/4/76			Total 75-76		
	1/17/75 1/26/82			2/2/75 2/8/82			2/17/75 2/23/82			3/2/75 3/8/82			74-75 81-82		
Northern Harrier	0	0	3	0	1	2	0	0	2	0	0	2	0	3	28
American Rough-legged Hawk	11	18	99	8	37	48	15	25	18	11	17	29	75	151	555
Ferruginous Hawk ^a	--	--	6	--	--	2	--	--	4	--	--	4	--	--	41
Red-tailed Hawk ^a	--	--	0	--	--	1	--	--	0	--	--	1	--	--	4
Unidentified Buteo ^a	--	--	3	--	--	4	--	--	1	--	--	0	--	--	29
Golden Eagle	8	5	68	0	1	59	5	4	18	1	0	33	2	19	337
Bald Eagle ^a	--	--	8	--	--	4	--	--	5	--	--	11	--	--	65
Unidentified Eagle ^a	--	--	12	--	--	11	--	--	0	--	--	6	--	--	61
Prairie Falcon	1	0	2	0	1	0	2	0	1	0	1	0	5	6	11
American Kestrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Total	20	23	201	8	40	131	22	29	49	12	18	86	100	181	1135

^aOccurrences of these raptors were so rare in the 1974-1976 surveys that they were considered incidental sightings (Craig, 1978).

Table 2. Eagles observed roosting on the Idaho National Engineering Laboratory, 1982.

Survey Segment	<u>Survey Date</u>						
	2/5/82	2/8/82	2/9/82	2/11/82	2/12/82	2/21/82	3/7/82
3/4	90	124	74	90	--	18	16
7 ^a	--	63	92	87	--	--	20
1	--	--	--	--	8	--	--
8 ^a	--	--	--	--	23	--	--
Total	90	187	166	177	31	18	36

^a41 km of segment 7 and 27 km of segment 8 were inventoried.

LITERATURE CITED

- Craig, T. H. 1977. Raptors of the Idaho National Engineering Laboratory Site. Master Thesis. Idaho State University, Pocatello. 102 p.
- Craig, T. H. 1978. A car survey of raptors in southeastern Idaho 1974-1976. Raptor Res. 12:40-45.
- Craig, T. H. 1979. The raptors of the Idaho National Engineering Laboratory Site. IDO-12089. USDOE Idaho Operations Office, Idaho Falls, ID. 27 p.
- Craig, T. H. and C. H. Trost. 1976. A study of the raptorial species on the INEL Site, p. 106-120. In 1975 Progress Report, Idaho National Engineering Laboratory Site Radioecology--Ecology Programs, IDO-12080. Nat. Tech. Inf. Ser., Springfield, VA.
- Craig, T. H., D. K. Halford and O. D. Markham. 1979. Radionuclide concentrations in nestling raptors near nuclear facilities. Wilson Bull. 91:72-77.
- Dunstan, T. C. 1972. A harness for radio-tagging raptorial birds. Inland Bird Banding News. 44:4-8.
- Fyfe, R. W. and R. R. Olendorff. 1976. Minimizing the danger of nesting studies to raptors and other sensitive species. Canadian Wildl. Ser. Occasional Paper No. 23, 17 p.
- Harris, P. A. 1980. A bibliography on the capturing, aging, sexing and banding of North American owls. Inland Bird Banding 52:49-55.
- Newton, I. 1979. Population ecology of raptors. Buteo Books. Vermillion, SD. 399 p.

Powers, L. R. and T. H. Craig. 1976. Notes on the status of nesting ferruginous hawks (Buteo regalis) in Little Lost River Valley and vicinity, southeastern Idaho. Murrelet 57:46.

Seibert, D. J., R. J. Oakleaf, J. M. Laughlin and J. L. Page. 1976.

Nesting

ecology of golden eagles in Elko County, Nevada. Tech. Note No. 281, U. S. Bureau of Land Management, Denver Service Center, Denver, CO. 17 p.

Sherrod, S. K. 1978. Diets of North American Falconiformes, Raptor Res. 12:49-121.

Thurrow, T. L., C. M. White, R. P. Howard and J. F. Sullivan. 1980. Raptor ecology of Raft River Valley, Idaho. EGG-2054. Nat. Tech. Inf. Ser., Springfield, VA. 45 p.

Woffinden, N. D. and J. R. Murphy. 1977. A roadside raptor census in the Eastern Great Basin 1973-1974. Raptor Res. 11:62-66.

RAPTOR ELECTROCUTIONS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

James W. Watson

ABSTRACT

Information on raptor electrocutions was collected on the Idaho National Engineering Laboratory (INEL) and in two areas adjacent to the site during winter 1982. Double-pole supported lines electrocuted no raptors while armless and crossarm poles electrocuted 54 raptors including 37 golden eagles (Aquila chrysaetos). Recommendations are made concerning the modification of hazardous poles.

INTRODUCTION

Raptors frequently use power poles along electric transmission lines for hunting and roosting perches. Unfortunately, raptors may be electrocuted when landing on or launching from poles. During winter 1982 information on raptor electrocutions was collected for all single pole lines and most double pole lines on the INEL. Chance locations of raptors electrocuted near Howe, Idaho and along "old" U.S. Highway 26 were also recorded.

METHODS

Data were compiled with previously recorded raptor electrocutions on the INEL. Approximate date of electrocution for all birds was based on the degree of carcass decomposition. Because necropsies were not performed on carcasses, electrocution was the assumed cause of mortality. Shooting mortality was probably insignificant because the site is regularly patrolled and public access prohibited. Mortality from collisions with transmission lines was regarded as insignificant (Kroodsma, 1978). Electrocution data of raptors may be underestimated due to removal of carcasses by humans and mammalian predators or the presence of undetected carcasses.

RESULTS AND DISCUSSION

At least 33 golden eagles (Aquila chrysaetos) and 14 other raptors were electrocuted on the INEL between 1978 and winter 1982 (Table 1). Seven raptors including four golden eagles were found in the adjacent off-site areas. Twenty-six eagle electrocutions occurred after January 1981, the remaining 11 before this date. A relatively high eagle population on the INEL during the winter of 1981-1982 (Craig et al., this volume) may have resulted in more electrocutions during this period. Seventeen (85%) of 20 electrocuted eagles for which ages were determined were subadults thus lending support to previous findings that young eagles are more susceptible to electrocution (Benson, 1981).

No electrocuted eagles were found under double-pole supported lines, including a 22 km line along which as many as 124 golden eagles roosted in February, 1982 (Craig et al., this volume). Crossarm and armless poles

TABLE 1. Transmission line mortality of raptors on the Idaho National Engineering Laboratory and adjacent offsite areas between 1978 and May 1982.

Species	Electrocution		Collision INEL
	INEL	Adjacent offsite ^a	
Golden eagle (<i>Aquila chrysaetos</i>)	33	4	
Rough-legged hawk (<i>Buteo lagopus</i>)	2	1	1
Red-tailed hawk (<i>Buteo jamaicensis</i>)	2	1	
Great horned owl (<i>Bubo virginianus</i>)	3		
American kestrel (<i>Falco sparverius</i>)	2		
Prairie falcon (<i>Falco mexicanus</i>)	2		
Ferruginous hawk (<i>Buteo regalis</i>)			1
Unidentified raptor	<u>3</u>	<u>1</u>	<u>—</u>
Total	47	7	2

^aNear Howe, Idaho and along "old" U.S. Highway 26.

TABLE 2. Summary of raptor electrocutions on the Idaho National Engineering Laboratory by distribution line.

Pole Type	Location	Length (km)	Owner	Number Electrocuted	
				Golden eagle	Total raptor
12.5 kv crossarm	TAN to Fire Sta. 2	37.0	INEL	14	15
13.8 kv crossarm	SPERT to ARA	3.4	INEL	5	5
7.2 kv crossarm	At. City to E INEL Boundary	16.3	ID POW ^a	4	5
13.8 kv crossarm	EOCR to SPERT	5.8	INEL	3	4
12.5 kv crossarm	CF690 to U.S. 26	3.8	INEL	2	4
unknown crossarm	Between Id 33 and Id 28	1.9	UNKNOWN	2	2
12.5 kv armless	EBR I to RWMC	2.9	INEL	2	2
7.2 kv armless	Howe Peak Road	6.4	INEL	1	1
12.5 kv crossarm	U.S. 20/26 to EBR I	1.8	INEL	0	1
12.5 kv armless	Van Buren Blvd. to Rest Area	3.4	INEL	0	5
12.5 kv armless	Exp. Field Station	.2	INEL	0	3

^aIdaho Power

owned and operated by the INEL electrocuted 40 raptors including 27 golden eagles (Table 2). The relative number of eagle electrocutions on all armless pole lines was similar (chi square test, $P > 0.05$), but total raptor electrocutions were not randomly distributed among armless pole lines (chi square test, $P < 0.001$). Three raptors were electrocuted on a 0.2 km line near the Experimental Field Station on the INEL, which comprised 1% of the total armless pole lines. Eagle and total raptor electrocutions were not randomly distributed among all crossarm pole lines (chi square test, $P < 0.001$). A 3.4 km pole line between SPERT and the Auxillary Reactor Area accounted for 5 of 30 golden eagle electrocutions and 5 of 36 total raptor electrocutions yet comprised 3% of the total length of crossarm pole lines inventoried. Fourteen of 30 (47%) eagle electrocutions on crossarm pole lines occurred between the Test Area North and Fire Station 2 on a 37 km line comprising 37% of the crossarm pole lines inventoried.

RECOMMENDATIONS

Because electrocution is a significant raptor mortality factor in the western United States (Benson, 1981), attempts should be made to modify dangerous poles when possible. Modification of specific hazard poles would prevent few raptor electrocutions since only one pole caused multiple electrocutions on the INEL. Thus the feasibility of whole line modifications should be evaluated for hazardous lines. Cost of most pole modifications ranges from \$40 to \$105 per pole (Ansell and Smith, 1980). Replacement of aged poles and establishment of future distribution lines on the INEL should involve use of modified poles.

LITERATURE CITED

- Ansell A. R., and W. E. Smith. 1980. Raptor protection activities of the Idaho Power Company. p. 56-70, In Proceedings of a workshop on raptors and energy developments. R. P. Howard and J. F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho.
- Benson, P. C. 1981. Large raptor electrocution and powerpole utilization: a study in six western states. Ph.D. Dissertation. Brigham Young University, Provo, Utah. 98 p.
- Kroodsma, R. L. 1978. Evaluation of a proposed transmission line's impacts on waterfowl and eagles. p. 69-76. In Impacts of transmission lines on birds in flight. M. L. Avery (ed.). U.S. Fish and Wildlife Service, Biological Services Program, Washington, D. C..

ECOLOGY OF EXPLOITED AND UNEXPLOITED BOBCAT POPULATION IN SOUTHEASTERN IDAHO

S. T. Knick and I. J. Ball

ABSTRACT

A study of the population dynamics and social organization of bobcats (Felis rufus) on and adjacent to the Idaho National Engineering Laboratory (INEL) was initiated in January 1982. Fourteen bobcats (11 on the INEL and three in an offsite area) have been trapped, tagged, and radio-instrumented. Movement data on two female kittens from 20 January to 7 March indicate that they are independent of maternal care but still remain within or near their mother's home range. Roadcounts of rabbits conducted in February and March on the INEL study area averaged 2.31 jack rabbits (Lepus californicus)/km and 0.62 cottontail rabbits (Sylvilagus nuttallii)/km. Blood samples were taken from each bobcat trapped; hematology and blood chemistry values are reported.

INTRODUCTION

Bobcat (Felis rufus) populations have been heavily harvested over much of their range because of high market demand and prices. Poor baseline knowledge of bobcat populations and an increasingly active demand by special interest groups for harvest justification or cessation (Anonymous, 1981; Frederickson, 1981; Ryden, 1981) have made the bobcat a highly controversial species.

Despite much recent information on bobcat populations, all reports of bobcat age structures, sex ratios, and reproductive parameters obtained from examination of carcasses are from harvested populations (Crowe, 1975; Fritts and Sealander, 1978; Gould, 1981). Most telemetry studies have investigated only a harvested (Berg, 1981) or more typically, an unharvested population (Marshall and Jenkins, 1966; Bailey, 1974; Zezulak and Schwab, 1981). Only one study has described a harvested and an adjacent unharvested population (Lembeck and Gould, 1981). Because of inadequate knowledge of harvest effects on bobcat populations, we initiated a study on two adjacent areas in southeastern Idaho. The INEL, closed to hunting and trapping, will be a control used in comparison to a harvested area near Big Southern Butte and Arco, southwest of the INEL. Hunting and trapping effects on population dynamics and social organization of bobcats in these areas will be documented. Other major objectives are:

1. Document kitten: female dependency period and how mortality in adult females affects subsequent vulnerability of kittens to natural and harvest mortality.
2. Establish time, distance, and direction of kitten dispersal.
3. Measure home range use by denning females and determine food requirements of raising kittens.

4. Describe food habits of bobcats in relation to prey abundance.
5. Test the validity of scent station census routes and other population indices with a known-density bobcat population.
6. Describe bobcat blood chemistry and hematology in relation to prey abundance.

METHODS

Bobcat social organization, kitten production and survival, and population densities will be determined by following radio-instrumented animals in two areas. Bobcats within the INEL have been live-trapped and radio-collared since 15 January 1982. An offsite area, southwest of the INEL, has been trapped since March 1982. Trapping efforts in both areas will be discontinued from May through August when den activities of females and newborn kittens will be observed. Trapping and tagging will resume in September 1982.

Bobcats are live-trapped with #2 coil spring traps. All trapped bobcats are immobilized with a dosage of approximately 11 mg/kg body weight ketamine hydrochloride and 0.05 mg/kg acepromazine. Anesthetized bobcats are sexed, aged (kitten or adult), ear-tagged, weighed, blood-sampled, radio-instrumented, and released at the capture site. Six ml of blood are collected in blood tubes containing an anticoagulant and the rest centrifuged to separate serum. Blood samples are immediately mailed to Dr. U. S. Seal, VA Hospital, Minneapolis, MN for hematology and blood chemistry analyses.

Rabbit population indices are obtained by driving standardized routes through the study areas. Census routes are started at sunset to correlate with the peak activity period of rabbits (Tiemier et al., 1965; Mech et al., 1966). Other lagomorph estimates are obtained by incidental trap captures and direct counts of rabbits observed during daily field activities. Small rodent population trends are determined by bimonthly snaptrap transects located in bobcat habitats. Four transects, consisting of 25, 2-trap stations 10 meters apart are checked four consecutive nights in each study area.

Bobcat food habits will be determined by examining feces collected in the study area, from stomach contents of carcasses obtained from hunters and trappers, and by direct observation of prey brought to kittens at dens. In addition to den observations, the adult female will be radio-tracked to determine the home range used and time spent while hunting. This should provide an additional indication of prey availability and may correlate with kitten survival.

Standard scent station routes (Linhart and Knowlton, 1975; Roughton and Sweeney, 1982) and possible alternatives specific for bobcats will be tested as an estimate of population trends in each area of known density.

RESULTS AND DISCUSSION

Eleven bobcats (one adult male, three adult females; three kitten males, four kitten females) have been radio-instrumented on the INEL since 15 January 1982. Two have been captured four times and one twice. Preliminary estimates of adult density of a 194 km² portion of the INEL based on four radioed adults, two radioed kittens with unradioed mothers, and track observations of three others, was 1/21.6 km² and compares with Bailey's (1972) estimate of 1/18.4 km² for this area. Three bobcats (one adult male, two adult females) have been radio tagged in an offsite area. Data are too few to permit density estimates for this area.

One family group consisting of adult female #1 and her kitten offspring #3 and #24 have been radio-instrumented. Both kittens were independent of their mother at the time of their captures, but remained in or near her home range (Fig. 1). Kitten #3 moved 3.2 km south of adult female #1's range on 6 March and lost her collar in that area. She was not observed or recaptured in #1's range after that time. Kitten #24 was less closely associated with #1, using the periphery of #1's range (Fig. 1). On 25 March, kitten #24 was captured in an unoccupied range adjacent to #1's and has since remained in that range.

Jack rabbits averaged 2.31/km (range 1.34-3.27) and cottontail rabbits 0.62/km (range 0.30-0.94) for census routes driven in the INEL study area in February and March. Bailey (1972) observed 2.6 and 3.1 rabbits (jack rabbits and cottontail combined)/km on the INEL during peak rabbit years in 1969 and 1970 and 0.4 rabbits/km after their decline in 1971. Daily numbers of rabbits observed during February averaged 4.62 jack rabbits and 3.45 cottontails/observer day (n = 21 observer days) (one observer day equals the number of rabbits observed per person during daily field activities).

Blood parameters of bobcats sampled on the INEL (Table 1) indicate a good nutritional state and are comparable to normal ranges for housecats fed an ad libitum, high-protein diet (Benjamin, 1978). Nutritional status indicating a sufficient food intake is also reflected in mean weights of five kittens captured after 15 January ($\bar{X} \pm SD = 8.7 \pm 0.5$ kg). Three female kittens averaged 8.8 ± 0.5 kg at their initial captures between 15 January and 17 April and had attained 78% of the average adult female weight ($\bar{X} = 11.3 \pm 0.5$, N = 3) in their first 9 months.

Nutritional status, growth rate, and survival of kittens in relation to prey base are essential elements in bobcat population dynamics. Prey base and availability changes may affect each of these parameters to be monitored during this study. Recruitment and dispersal into vacancies created by harvest are necessary to sustain exploited populations.

Table 1. Hematology and blood chemistry values from initial captures of bobcats on the Idaho National Engineering Laboratory since 15 January 1982.

Hematology	Kittens (N = 4)	Adults (N = 4)	Total (N = 8)
Hemoglobin (g%)	13.9+1.4 ^a	14.3+0.6	14.1+1.0
Red blood count (10 ⁶ /mm ³)	8.1+1.0	8.1+0.7	8.1+0.8
White blood count (10 ³ /mm ³)	12.3+3.1	13.4+3.9	12.9+3.4
Hematocrit (%)	42+4	44+3	43+3
Mean corpuscular volume (u ³)	53+2	54+2	53+2
M.C.H.C. (vol %) ^b	33.5+2.1	32.8+0.5	33.0+1.5
<u>Blood Chemistries^c</u>			
Calcium (mg %)			10.0+0.4
Alkaline phosphatase (K.A.U)			31.0+24.9
Creatine phosphokinase (I.U.)			1866+1130
Bilirubin (mg %)			0.2+0.0
Glucose (mg %) ^d			21.6+4.7

^a Mean + SD

^b Mean corpuscular hemoglobin concentration

^c Blood chemistries not available for bobcats captured after 21 February.

Results are from initial capture values of one adult and three kittens.

^d Glucose values are from initial captures of one adult and two kittens.

Figure 1. Home range use by adult female #1 and her kittens #3 and #24 on the Idaho National Engineering Laboratory from 20 January through 26 March 1982.

LITERATURE CITED

- Anonymous. 1981. Data support removing bobcat from CITES list. USFWS Tech. Bull. 4:6-8.
- Bailey, T. N. 1972. Ecology of bobcats with special reference to social organization. Ph.D. Thesis. Univ. of Idaho, Moscow. 82 p.
- Benjamin, M. M. 1978. Outline of veterinary clinical pathology. Iowa St. Univ. Press. 3rd. ed. 351 p.
- Berg, W. E. 1981. Ecology of bobcats in northern Minnesota. p. 55-61 In Escherich, P. C. and L. Blum, eds. Proc. 1979 bobcat research conference. Natl. Wildl. Fed. Sci. and Tech. Ser. 6.
- Crowe, D. M. 1975. A model for exploited bobcat populations in Wyoming. J. Wildl. Manage. 36:408-415.
- Frederickson, L. 1981. Bobcat management. S. D. Cons. Digest. 48:10-14.
- Fritts, S. H. and J. A. Sealander, Jr. 1978. Reproductive biology and population characteristics of bobcats (Lynx rufus) in Arkansas. J. Mammal. 59:347-353.
- Gould, G. I., Jr. 1981. Techniques used in assessing bobcat populations and harvest in California. p. 40-41 In Escherich, P. C. and L. Blum, eds. Proc. 1979 bobcat research conference. Natl. Wildl. Fed. Sci. and Tech. Ser. 6.
- Lembeck, M. and G. I. Gould, Jr. 1981. Dynamics of harvested and unharvested bobcat populations in California. p. 53-54 In Escherich, P. C. and L. Blum, eds. proc. 1979 bobcat research conference. Natl. Wild. Fed. Sci. and Tech. Ser. 6.
- Linhart, S. B. and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildl. Soc. Bull. 3: 119-124.
- Marshall, A. D. and J. H. Jenkins. 1966. Movements and home ranges of bobcats as determined by radio-tracking. Proc. S. E. Assoc. Game and Fish. Comm. 20:206-214.
- Mech, L. D., K. L. Heezen, and D. B. Siniff. 1966. Onset and cessation of activity in cottontail rabbits and snowshoe hares in relation to sunset and sunrise. Anim. Behav. 14:410-413.
- Roughton, R. D. and M. W. Sweeney. 1982. Refinements in scent-station methodology for assessing trends in carnivore populations. J. Wildl. Manage. 46:217-229.
- Ryden, H. 1981. Bobcat Year. Viking Press, New York, NY. 211 p.

- Tiemier, O. W., M. F. Hansen, M. H. Bartel, E. T. Lyon, B. M. Eli-Rawi, K. J. McMahon, and E. H. Herick. 1965. The black-tailed jackrabbit in Kansas. Univ. Kansas Ag. Expt. Stn. Tech. Bull. 140. 75 p.
- Zezulak, D. S. and R. G. Schwab. 1981. A comparison of density, home range and habitat utilization of bobcat populations at Lava Beds and Joshua Tree National Monuments, California. p. 74-79 In Escherich, P. C. and L. Blum, eds. proc. 1979 bobcat research conference. Nat. Wildl. Fed. Sci. and Tech. Ser. 6

SAGE GROUSE CENSUS METHODS AND POPULATIONS IN SOUTHEASTERN IDAHO

John W. Connelly and I. Joseph Ball

ABSTRACT

Sage grouse (Centrocercus urophasianus) population indices and a recent population decline in southeastern Idaho are discussed. Lek surveys and censuses and summer brood counts can provide useful information on population trends. However, leks are dynamic with respect to changing habitats; therefore, breeding complexes should be defined and leks within each complex should be censused on the same day. Arrival of lone females on summer range may provide an early indication of productivity. Winter census routes are not reliable indicators of population change. A decline in the 1980 sage grouse population was characterized by lower mean brood size, a decline in the juvenile:female ratio, and an increase in females/km of summer routes. In 1981, the winter sex ratio (female:male) decreased, mean male attendance at leks declined, and the number of active leks in one portion of the study area decreased.

INTRODUCTION

Sage grouse are dependent on sagebrush (Artemisia spp.) habitats throughout much of the year. Unfortunately, these habitats are being altered over much of the west (Braun et al., 1977). To assess the impact of habitat alteration on grouse populations, indices of population fluctuations are necessary.

Sage grouse populations may be migratory or non-migratory (Dalke et al., 1960; Eng and Schladoweiler, 1972; Beck, 1977). Migratory behavior makes it difficult to define a sage grouse population and complicates the calculation and interpretation of yearly population indices. For instance, a decrease in a summer population might result from damage to that particular summer range or from alteration of a winter range 50 km or more distant.

Yearly fluctuations of sage grouse populations have been attributed to nest predation (Batterson and Morse, 1948; Autenrieth, 1981), spring precipitation (Patterson, 1952; Gill, 1965; Wallestad, 1975), spring food supply (Blake, 1970), and disease (Patterson, 1952). However, no general agreement has been reached on the importance of these variables. The purposes of this paper are to discuss methods of obtaining sage grouse population indices on a seasonal basis and to examine a recent population decline of sage grouse in southeastern Idaho.

STUDY AREA AND METHODS

Sage grouse populations were monitored on the Idaho National Engineering Laboratory (INEL) in southeastern Idaho from June 1977 through April 1981. The INEL is a 230,000 ha area located in a semi-arid cold desert on the upper Snake River plain at the foothills of the Lost River, Lemhi, and Bitterroot mountain ranges. Topography is flat to rolling, and elevation ranges from 1,460 to 1,830 m. The INEL borders agricultural land for approximately 37 km. Irrigated lawns at a number of INEL facilities provide a predictable source of free water and forbs and are used each summer by sage grouse.

Sage grouse summer range is generally confined to moist areas near INEL facilities, agricultural areas bordering the INEL, and disturbed areas along the Big Lost River in the southern portion of the INEL. Nine summer areas occur within the INEL (Fig. 1). Sage grouse winter range occurs throughout the INEL (Fig. 1) and was described by Connelly (1982).

A spring population index was based on lek surveys (an enumeration of all leks in a specific area) and lek censuses (counts of grouse attending individual leks). The entire INEL, as well as areas within 10 km of its northern and southern boundaries, were searched for leks from light aircraft during springs, 1978 through 1980. Those areas that contained a high density of leks, and which were accessible, were also searched from the ground. Leks were censused along six vehicle routes according to recommendations made by Rogers (1964) and Jenni and Hartzler (1978). Records were also kept of newly developed and abandoned leks along these routes.

Spring populations were estimated using a method similar to Patterson's (1952:145):

$$P_i = L_i (M_i + F_i)$$

where P_i is the spring breeding population of sage grouse in year i , L_i is the number of leks in the study area, M_i is the mean number of males attending leks, and F_i is the estimated number of females, using a sex ratio calculated from winter census data. Summer and winter population indices were based on census routes conducted from 1977 through 1981.

Sage grouse populations in the lower Birch Creek valley were estimated during winters 1978-79 and 1979-80 from line transect sampling (Burnham et al., 1980). Snowmobiles and four-wheel drive vehicles were used to conduct nine line transects which varied from 2.3 to 14.3 km in length.

Figure 1. Seasonal ranges, breeding complexes and migration routes of sage grouse on the Idaho National Engineering Laboratory, 1978-81.

RESULTS AND DISCUSSION

Population Indices

Because of differences in topography and vegetation, the INEL was separated into mountain valley and plains areas. Fourteen leks were located in the mountain valley area (i.e., lower Birch Creek) and 53 were found in the plains area (Fig. 1). In the mountain valley area, the total number of active leks varied from 10 to 13 in any 1 year, and in the plains area the number of active leks varied between 48 and 64 from 1978-1981 (Table 1). Lek density was 0.07 leks/km² in the mountain valley area and 0.03 leks/km² in the plains area during this period. Mean male attendance varied from 26.8 to 35.7 grouse and from 21.5 to 39.8 grouse in the mountain valley and plains areas, respectively, from 1978-1981. Estimates of lek attendance are minimal because daily attendance by males fluctuates considerably (Dalke et al., 1963). Coefficients of variation (C.V.) of male attendance ranged from 5 to 108% among censused leks throughout the study (Table 2). Disregarding a lek that was abandoned early and one that was grazed by sheep in 1981, C.V.'s for mountain valley leks were slightly higher than those of plains leks. Autenrieth (1981) argued that lowland leks are more stable than leks at higher elevations. This study may lend some support for this notion, but our sample sizes were small and all leks censused were less than 1,707 m in elevation. Lek attendance was slightly lower than that reported by Patterson (1952) and Autenrieth (1981) but was similar to attendance reported by Wallestad (1975).

Table 1. Estimated spring sage grouse populations on the Idaho National Engineering Laboratory, 1978-1981.

Year	No. of Leks ^a	Leks/km ²	Male attendance		Sex ratio ^b	Breeding Population	Grouse/km ²
			$\bar{x} \pm S. D.$	N	(F:M)		
Mountain Valley (197 km ²)							
1978	10	0.05	35.7 $\pm$ 6.5	3	2.9:1.	1,392	7.1
1979	13	0.07	28.2 $\pm$ 4.0	4	3.0:1.	1,472	7.5
1980	13	0.07	34.7 $\pm$ 16.8	4	2.9:1.	1,764	9.0
1981	10	0.05	26.8 $\pm$ 29.3	4	1.9:1.	777	4.0
Plains Area (1,849 km ²)							
1978	48	0.03	21.5 $\pm$ 13.6	6	2.9:1.	4,024	2.2
1979	54	0.03	37.5 $\pm$ 26.4	11	3.0:1.	8,121	4.4
1980	64	0.03	39.1 $\pm$ 23.0	15	2.9:1.	9,934	5.4
1981	64	0.03	36.3 $\pm$ 19.1	15	1.9:1.	6,737	3.6

^aCorrected by calculating the percent change of leks each year along lek census routes.

^bCalculated from winter census route data; data from mountain valley and plains areas were grouped for calculations.

Table 2. Lek attendance by male sage grouse on the Idaho National Engineering Laboratory, 1978-1981.

Lek	1978				1979				1980				1981			
	$\bar{x}$	S.D.	C.V.	N	$\bar{x}$	S.D.	C.V.	N	$\bar{x}$	S.D.	C.V.	N	$\bar{x}$	S.D.	C.V.	N
Mountain Valley																
1	33.7	5.3	16	3	24.5	10.8	44	4	19.2	7.2	38	5	30.3	9.1	30	3
2	32.0	3.6	11	3	24.3	2.4	10	4	33.8	17.7	52	5	39.7	4.0	10	3
3					20.5			2	8.8	6.2	70	5	0.0	0.0		3
4	26.0	13.0	12	3	27.0	1.7	6	3	27.0	7.8	29	4	15.0	12.1	81	3
Plains Area																
1					56.0	33.8	60	3	62.8	47.7	76	5	49.3	29.7	60	3
2					22.5	6.8	30	4	29.0	5.2	18	5	20.5			2
3	d															
4e	23.7	23.0	97	3	13.7	11.6	85	3	4.5	4.9	109	5	20.3	20.0	99	3
5	6.7	3.1	46	3	13.0	1.0	8	3	14.0	4.5	33	4	12.0	4.0	33	3
6	23.7	4.0	17	3	68.0	8.7	13	3	57.3	11.2	20	4	36.7	8.5	23	3
7					16.5	2.1	13		43.5			2	52.0	11.3	22	
8	18.6	2.1	11	8	15.8	4.5	28	5	22.3	7.6	34	6	22.7	4.2	19	3
9									12.8	3.3	26	6	21.5	10.8	50	4
10					13.3	0.6	5	3	30.4	8.6	28	5	29.5	7.8	26	6
11	12.7	5.1	40	3	26.6	7.5	28	5	25.8	3.7	14	5	32.0	6.6	21	3
12									15.7	5.5	35	3	3.7	4.0	108	3
13									23.5	12.3	52	6	31.3	3.2	10	3
14									19.8	9.5	48	5	30.0	8.0	27	3
15					50.0	5.0	10	3	49.7	3.1	6	3	22.0	23.6	107	3 ^f

^aS.D. = Standard Deviation; not calculated when N < 3.

^bC.V. = Coefficient of Variation expressed in percent; not calculated when N < 3.

^cNumber of times lek censused.

^dFlooded

^eAbandoned early.

^fSheep grazing on lek.

Great variation in daily lek attendance by male sage grouse has been recognized (Dalke et al., 1960; Beck and Braun, 1980). Beck and Braun (1980) further indicated that the frequency and duration of lek attendance by males is not the same at all leks. Therefore, caution should be exercised in interpreting data from "non-typical" leks and satellite leks (i.e., leks used only during years of relatively high sage grouse populations). Sage grouse leks are dynamic with respect to changing habitats, and grouse will use newly cleared areas for display sites (Dalke et al., 1963; Connelly et al., 1981). During our study, early abandonment of one lek was documented (Fig. 2) and corresponded to an increase in attendance at nearby leks. At least some of this increase was due to the early abandoned lek because marked grouse from this lek were observed on nearby leks. Lek abandonment coincided with livestock moving onto the area, suggesting that this disturbance was responsible for the birds' behavior. Four female grouse were radio-marked on this lek and all nested, even though the lek was usually abandoned after the first week of April. Because of variation among leks, all leks within a breeding complex should be identified, and, if possible, should be censused on the same day.

Brood survey routes were established in various habitats on the INEL and counts were conducted from June 1977 through August 1981. Sage grouse congregate near moist areas during summer (Dalke et al., 1963; Klebenow, 1969; Connelly, 1982) and observations of color-marked grouse (Connelly, unpubl. data) suggest that these summering areas are traditional. Brood routes are most efficiently conducted in these concentration areas because they are easily defined and the maximum number of grouse may be observed per effort. Brood routes are most effective if conducted when grouse are moving between sagebrush loafing/roosting areas and feeding sites. This movement generally occurred in early to mid-morning and early evening. Summer census routes may be of most value at low elevations where summer ranges are usually discrete units. Water has a strong impact on sage grouse summer distribution (Patterson, 1952) and should be considered when establishing census routes.

Because unsuccessful females arrive on summering areas before females with broods, early census efforts can provide some basis for judging productivity. A relatively high count of females in June and early July appears to indicate poor production.

All leks were located adjacent to or within sage grouse winter range (Fig. 1); therefore, sage grouse did not migrate from winter to breeding range as did another population on the upper Snake River plain (Dalke et al., 1963). There was little overlap between winter and summer range on the INEL (Table 3). Winter survey routes indicated a decrease in grouse/km during 1979-80 (Table 3). This decrease may be attributable to mild weather that allowed sage grouse to winter closer to summer range and/or caused a wider distribution of wintering grouse. The low number of sage grouse during the 1980-81 winter was also probably due to mild weather and poor production during 1980. Sage grouse use of different sagebrush habitats is influenced by winter conditions (Connelly, 1982) and they may move farther to winter range as snow depth increases (Dalke et al., 1963). Therefore, winter survey routes are not a reliable population index; however, winter survey routes are useful for defining concentration areas.

Figure 2. Attendance by male sage grouse at an early abandoned lek compared to a nearby lek, on the Idaho National Engineering Laboratory, 1978-1981.

Burnham et al. (1980:26) suggested that line transect sampling was an appropriate method for estimating sage grouse populations. We used line transects to estimate winter populations of sage grouse in the mountain valley area of the INEL during 1978-79 and 1979-80. Transect lines were run twice in 1978-79 and three times in 1979-80 (Table 4). Correcting for differences in flock sizes among flock types (Connelly, 1982) and using the run which provided the largest sample size in each year, 2,746 grouse occurred in the mountain valley area in 1978-79 and 5,332 in 1979-80. The 1978-79 estimate was almost twice that of the 1979 breeding population from lek census data and the 1979-80 estimate was three times higher than the 1980 breeding population estimate. However, all estimates had relatively high standard deviations, and C.V.'s for all runs ranged from 42% to 98% ($\bar{x}$ = 59%). Further, estimates for the three runs during 1979-80 ranged from 1.7 flocks/km² to 3.8 flocks/km² ($\bar{x}$ = 2.7) (Table 4). Densities were expressed in flocks/km² because of differences in flock size due to flock type and habitat (Connelly, 1982). While band returns and past research (Dalke et al., 1960; 1963) suggest that more grouse winter in the northern portion of the INEL than breed there, the proportion of the population that breeds elsewhere is unknown.

The large variation associated with the population estimates may have resulted from several factors. Sage grouse usually occur in flocks or clusters (Connelly, 1982), and Burnham et al. (1980) indicated that the geometric center of a flock must be determined to apply line transect techniques. The accuracy of determining the geometric center of sage grouse flocks varies with flock size and snow conditions. Large flocks tend to be loosely aggregated and birds do not flush simultaneously. However, snow cover allows detection of the flock center with reasonable accuracy because tracks are visible. Sage grouse winter flocks vary from 1 to 200 or more birds. Both habitat and flock composition (i.e., male, female, or mixed-sex flocks) affect flock size (Connelly, 1982) but the impact of winter severity on flock size has not been resolved (Eng and Schladweiler, 1972; Beck, 1977; Connelly, 1982). Because the flock serves as the sampling unit (Burnham et al., 1980), flock size must be estimated for each habitat and flock type sampled; thus the estimate of density is complicated. Calculation of the statistic is further confounded by varying detectability of flocks near the transect line. Of the 79 flocks recorded on line transects in 1979-80, 10 (12.6%) were recorded as being on the line (Table 4). Also, traversing a line with a vehicle kills shrubs and may allow grouse to be detected more easily. Finally, problems occur with recording data. Burnham et al. (1980:35) stated that transect length should be sufficient to ensure that at least 40 objects are detected. Our transect lines totaled 91.8 km, yet we never counted more than 33 flocks (822 sage grouse). Moreover, measurements (i.e., right angle and sighting distances) could not be taken on all flocks (Table 4) because not all flocks were observed when they flushed and the flushing of one flock often influenced that of another; thus the assumption of independent sightings (Burnham et al., 1980:14) was not met.

Table 3. Changes in sage grouse abundance^a from summer to winter range on the Idaho National Engineering Laboratory, 1978-82.

Census Route	1978		1979		1980	
	Summer	Winter	Summer	Winter	Summer	Winter
1 (sagebrush/ disturbed areas)	---	0.43	0.73	0.56	0.27	0.65
2 (sagebrush/ agriculture)	1.98	0.00	4.05	0.00	4.31	0.00
3 (sagebrush)	---	4.61	0.10	1.39	0.02	0.60
4 (sagebrush)	---	0.85	0.00	0.22	0.00	0.47
5 (sagebrush)	---	1.33	0.02	0.53	0.10	0.51
Mean ^b	1.98	1.64	0.73	0.63	0.78	0.57

^aGrouse per km.

^bWinter means do not include route 2.

Table 4. Results of line transect sampling in the lower Birch Creek valley of the Idaho National Engineering Laboratory.

Sage Grouse	1978-79		1979-80		
	Run 1	Run 2 ^a	Run 1	Run 2	Run 3
No. Flocks	16	12	17	33	29
Total Grouse	114	217	152	822	539
$\bar{x}$ Flock Size (+SD)	7.1(10.1)	18.1(37.2)	8.9(8.2)	24.9(40.9)	18.6(26.8)
Density (Flocks/km ² (+ SD))	2.0(1.9)		2.5(1.1)	1.7(0.9)	3.8(1.7)
C.V. ^b for Density (%)	98		42	52	44
<u>Observations</u>					
Flocks recorded on line	0	0	3	3	4
No. Flocks did not flush	6	0	0	0	0
No. Flock Centers not located	0	0	2	0	0
No. Flocks Observed after flushing	2	0	2	10	9
No. Dependent ^c observations	0	4	2	9	9

^aDensity not calculated because of small sample size and 60% of total grouse observed occurred in 1 flock.

^bC.V. = Coefficient of Variation.

^cFlocks that flushed in response to the flushing of nearby flocks.

Population Changes

Both brood survey and lek census data suggested that breeding and summering populations of sage grouse on the INEL were stable to increasing from 1977 through 1979, but declined in 1980. The spring of 1980 was wet compared to preceding springs (Table 5). The decline in the summer population was characterized by a decrease in mean brood size, a decline in the juvenile: female ratio, and an increase in females/km of census route (Table 5).

Between 1978 and 1981 the breeding population in the mountain valley area varied from 771 grouse to 1,764 grouse (Table 1) and density varied from 4.9 to 9.0 grouse/km². In the plains area, the breeding population varied from 4,024 to 9,934 sage grouse and density varied from 2.2 to 5.4 grouse/km². The sage grouse breeding population increased from 1978 through 1980 and declined in 1981. This decline was evident throughout the INEL and was generally characterized by a decrease in the winter sex ratio (females:males), a decline in mean male attendance at leks, and a decrease in the number of active leks in the mountain valley area (Table 1).

CONCLUSIONS

Management of migratory sage grouse populations is more complex than that of sedentary populations because of the larger areas involved and the difficulty of defining a population. We suggest that migratory sage grouse populations be defined on a temporal rather than an area basis and that an effort be made to determine migration routes and seasonal concentration areas for each population.

Lek censuses and surveys do not provide acceptable indices to productivity, but they do indicate long term population trends and may be the easiest and least expensive method of obtaining this data. Because of variation among leks, a complete survey of leks should be made and updated periodically. All breeding complexes within the area of interest should be delineated and counts of leks within each complex should be made on the same day. Further, the establishment and abandonment of leks should be carefully recorded. Brood survey routes may be the only population index necessary for sedentary sage grouse populations. These routes should be conducted in early summer and, at lower elevations, can be limited to traditional summer ranges. The appearance of many broodless females in June, prior to brood arrival, could indicate poor productivity. However, this notion should be tested in different areas over a number of years. Winter census routes are useful for delineating critical habitat. Unfortunately, this type of census route is often expensive and time consuming; it appears to be a poor index to productivity and population trends.

Several factors affect sage grouse flock size and, during line transect sampling, problems occur with detectability and recording data. Therefore, line transect density estimators may not be appropriate for sage grouse populations even though they have been recommended for this species. More research is necessary to determine the applicability of line transects to estimating sage grouse population density.

Table 5. Sage grouse production on the Idaho National Engineering Laboratory. Data was collected during June and July, 1977-1980

Year	Mean Daily Temperature(C°)	Precip.(cm) ^a	Sagebrush				Agriculture ^b			
			Females/km	Juv:Female	Brood size		Females/km ^c	Juv:Female	Brood size	
					$\bar{x}$	S.D.			$\bar{x}$	+ S.D.
1977	8.06	3.94						2.93	3.38	+ 1.19
1978	7.50	5.23					0.21	2.79	3.02	+ 1.17
1979	8.50	3.73	0.03	2.81	4.75	2.41	0.31	3.08	3.75	+ 1.99
1980	9.00	6.91	0.05	0.79	2.58	1.68	1.27	0.68	2.85	+ 1.35

^a Weather data for April and May.

^b Includes INEL facilities.

^c Does not include INEL facilities

LITERATURE CITED

- Anderson, D. R., J. L. Laake, B. R. Crain, and K. P. Burnham. 1976. Guidelines for line transect sampling of biological populations. Utah Coop. Wildl. Res. Unit, Logan. 27 p.
- Autenrieth, R. E. 1981. Sage grouse management in Idaho. Idaho Department of Fish and Game Wildl. Bull. No. 9. 238 p.
- Batterson, W. M. and W. B. Morse. 1948. Oregon sage grouse. Oregon State Game Comm. Oregon Fauna Ser. No. 1. 29 p.
- Beck, T. D. I. 1977. Sage grouse flock characteristics and habitat selection in winter. J. Wildl. Manage. 41:18-26.
- Beck, T. D. I. and C. E. Braun. 1980. The strutting ground count: variation, traditionalism, management needs. Proc. Annual Conf. West. Assoc. Fish and Wildl. Agencies. 60:558-566.
- Blake, C. S. 1970. The response of sage grouse populations to precipitation trends and habitat quality in south central Idaho. Proc. West. Assoc. State Game and Fish Comm. 50:452-462.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildl. Soc. Bull. 5:99-106.
- Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72. 202 p.
- Connelly, J. W., Jr. 1982. An ecological study of sage grouse in south-eastern Idaho. Ph.D. Thesis, Washington State Univ., Pullman. 84 p.
- Connelly, J. W., W. J. Arthur, and O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. J. Range. Manage. 34:153-154.
- Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1960. Seasonal movements and breeding behavior of sage grouse in Idaho. Trans. N. Am. Wildl. Conf. 25:396-407.
- Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. J. Wildl. Manage. 27:811-840.
- Eng, R. L. and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. J. Wildl. Manage. 36:141-146.
- Gill, R. B. 1965. Effects of sagebrush control on distribution and abundance of sage grouse. Colorado Game, Fish and Parks Dept. Game Res. Rep. 185 p.

- Jenni, D. A. and J. E. Hartzler. 1978. Attendance at a sage grouse lek: implications for spring censuses. J. Wildl. Manage. 42:46-52.
- Patterson, R. L. 1952. The sage grouse in Wyoming. Sage Books, Inc. Denver, Co. 341p.
- Rogers, G. E. 1964. Sage grouse investigations in Colorado. Colorado Game, Fish and Parks Dept. Tech. Bull. No. 16. 132 p.
- Wallestad, R. 1975. Life history and habitat requirements of sage grouse in central Montana. Montana Dept. of Fish and Game, Helena. 65 p.

DISPERSAL AND HARVEST OF SAGE GROUSE UTILIZING THE TEST REACTOR AREA ON THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

A study was initiated in July 1980 to investigate sage grouse (Centrocercus urophasianus) use of the Test Reactor Area (TRA) during summer. Objectives include determination of habitat use, home range, activities, brood breakup, dispersal, and homing of sage grouse using the TRA. Juvenile and adult sage grouse were captured and radio-marked. Grouse fed at the TRA mostly in the mornings and evenings and generally spent the afternoons loafing in sagebrush (Artemisia spp.) habitat outside the facility. Brood breakup and fall dispersal data was gathered on two broods. Fall movements of five other juveniles and 10 adults were also documented. The study will be continued through 1982.

INTRODUCTION

Movements of sage grouse (Centrocercus urophasianus) during summer to moist areas for feeding has been well documented (Batterson and Morse, 1948; Patterson, 1952; Dalke et al., 1963; Klebenow, 1969; Oakleaf, 1971). These movements are often to natural upland meadows or to alfalfa fields (Girard, 1937; Patterson, 1952). Irrigated lawns of the Test Reactor Area (TRA) on the Idaho National Engineering Laboratory (INEL) support growths of dandelion (Taraxacum officinale) and clover (Trifolium spp.) and offer another type of feeding environment for sage grouse.

Several authors have reported on the duration of brood bonds among juvenile sage grouse (Patterson, 1952; Dalke et al., 1963; Oakleaf, 1971). Wallestad (1971) described movements of broods before brood breakup. General fall movements of juvenile sage grouse from brood rearing areas have also been described (Dalke et al., 1963; Connelly, 1982). However, specific information on the activities and movements of individual brood members and other juveniles after brood breakup is lacking.

The TRA as well as the entire INEL is closed to sport hunting. Connelly (1982) has documented radionuclide concentrations in sage grouse using the TRA. Although these concentrations are small and do not present a health hazard to humans, the possibility of harvesting a contaminated sage grouse off-site does exist. Therefore, the movements of sage grouse from TRA are especially important during the hunting season.

This study was designed to describe sage grouse use of the TRA as a summer area and to investigate movements of brood members, other juveniles, and adults from the TRA.

Specific objectives of this study are to (1) compare habitat use of juvenile and adult sage grouse summering near the TRA, (2) determine home range and general activity patterns of individual sage grouse using the TRA, (3) determine the portion of marked sage grouse returning to the TRA during successive summers, (4) document the permanence of sage grouse brood bonds

during late summer or fall dispersal, (5) examine dispersal patterns of adult and juvenile sage grouse from the TRA, (6) determine the portion of sage grouse summering near the TRA that are available to off-site hunters and document the percentage of these birds harvested.

STUDY AREA

The TRA is located in the southwestern portion of the INEL and provides facilities for studying the performance of nuclear reactor materials and equipment components. The TRA consists of two separate areas: the facilities area and the pond area. The facilities area consists of buildings housing two reactors, support facilities and offices. Irrigated lawns around the buildings support growths of forbs which attract feeding grouse. The pond area is used for the disposal of low level liquid radioactive waste. Both the facilities area and the pond area are enclosed by continuous woven wire and barbed wire fences. Vegetation surrounding the TRA consists primarily of big sagebrush (Artemisia tridentata) and various grasses (McBride et al. 1978).

METHODS

The study was conducted from July through December 1980-81. Sage grouse were captured with mist nets and drive traps. Age and sex was determined according to Petrides (1942), Crunden (1963), and Pyrah (1963).

All captured birds were fitted with \$5 reward bands. Most birds were fitted with either a poncho-mounted solar radio transmitter (Amstrup, 1980) or a back-mounted battery powered transmitter (Brander, 1968). Juveniles too small to carry transmitters and some adults were color-marked. Females were fitted with numbered poncho markers (Pyrah, 1970) and males were fitted with numbered patagial tags.

Radio-marked birds were located 1-4 times daily while on the summer range using a hand-held yagi antenna and portable receiver. Time, temperature, wind speed and direction, cloud cover, and precipitation were recorded for each radio location. In addition, both radio-marked and color-marked grouse were observed and counted while feeding in the facilities area.

To determine habitat use outside the TRA, grouse were flushed and the flushing site was marked with a numbered stake. A 9 m² plot with the flush site in the center was sampled several days later using a 1 m² point-frame (Floyd and Anderson, this volume). Vegetation characteristics measured included canopy coverage of shrubs, forbs and grasses, percent coverage of litter, bare soil and large rock, and tallest shrub height.

The minimum area method (Mohr, 1947) was used to estimate individual home ranges. Birds that were radio-located less than 12 times were not considered in home range calculations.

During fall (prior to December 15) dispersal, radio-marked birds were located from a light airplane. Equipment and techniques were similar to those described by Gilmer et al. (1981). Radio-marked grouse were located at least twice per month from initiation of fall movements through December and on an irregular basis from January through March in 1981.

RESULTS AND DISCUSSION

Home Range, Habitat Use, and Activities

Sage grouse began arriving at the TRA on 26 July 1980 and on 9 July 1981. Sage grouse use of the facility ceased by 6 September 1980 and 3 October 1981. The longer use period in 1981 could probably be attributed to the drought conditions. Total rainfall for June through September, 1981 was 1.6 cm compared to 9.4 cm for the same period in 1980.

A total of 688 locations of marked grouse were recorded at the TRA during the summers of 1980 and 81. Grouse generally fed in the morning and evening and spent the afternoon loafing in the sagebrush habitat surrounding the facility (Fig.1). The low use of the TRA by grouse during the mid-morning and afternoon hours was probably due to the activities of employees at the facility. However, sage grouse were often observed using the lawns of the Central Facilities Area (CFA), which is 6 km south of the TRA, in the afternoon. CFA lawns were larger and more accessible to grouse than TRA lawns, thus the effects of human disturbance were probably reduced.

Figure 1. Frequency of sage grouse usage of the TRA facility compared with time of day. Total number of locations for each time period are listed below the time.

Vegetative characteristics of sage grouse loafing sites in the sagebrush are presented in Table 1. Although total plant coverage averaged lower and shrub coverage averaged higher at adult locations than juvenile locations, the differences were not significant (ANOVA, $P > 0.05$). Tallest shrub height, however, was significantly higher at adult locations than at juvenile locations (ANOVA, $P < 0.05$).

Preliminary home range estimates are listed in Table 2. Connelly (1982) reported similar home range estimates for juveniles at the TRA during 1978 and 1979. Although he had no data for adult females at the TRA, Connelly (1982) reported a home range average three times greater for adult females at CFA during 1979 and 1980 than our data indicates for TRA birds.

Table 1. Vegetative characteristics of juvenile and adult sage grouse loafing sites outside the TRA during summer 1981.

Age	N	Total plant coverage	Shrub coverage	Tallest shrub height
		$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
Adult	12	33.2 ± 7.2	23.8 ± 8.8	58.2 ± 12.0
Juvenile	30	38.4 ± 8.3	22.3 ± 9.9	48.6 ± 12.8

Table 2. Home range estimates of juvenile and adult sage grouse using the TRA facility during 1980-1981.

Age and sex	N	$\bar{X}$ Number of locations	$\bar{X}$ Home Range (ha)	Range (ha)
All juveniles	10	34	74	40 - 121
Juvenile female	8	37	80	40 - 121
Juvenile males	2	25	50	47 - 53
Adult females	4	20	109	81 - 149

Brood Breakup and Dispersal

On 19 July 1981 a hen and four chicks (three females, one male) estimated to be 10 weeks old were captured and radio-marked. The hen and brood remained together until 23 July when the hen deserted the brood. Approximately 2 days later the brood breakup process began when the juvenile male (#208) moved to a sagebush area near the Big Lost River 18 km southwest of the TRA. The juvenile females remained at the TRA for the rest of the summer and much of the fall. The radio of juvenile hen #16 malfunctioned in mid-September before she left the TRA. Juvenile hen #22 left the study area

on approximately 8 October. Juvenile hen #17 stopped feeding at the TRA during the first week of October, but remained in the vicinity until late November when she was lost. It is not known whether she moved well off-site or if her radio malfunctioned.

On 12 August 1981, two female brood members estimated to be 10 weeks old were radio-marked. We were unable to estimate the time of the hen's desertion of the brood since she eluded capture, however, the brood disbanded 2 days later. Juvenile hen #27 departed from the TRA on approximately 2 September and moved 8 km north to another INEL facility, the Naval Reactor Facility (NRF). This bird remained near the NRF until early October and then moved 22 km south. Juvenile hen #28 departed the TRA on approximately 4 October and was last located on 21 October 1.8 km northwest of the TRA.

Movements of all juveniles appeared random and mostly in a northerly direction (Fig. 2). Radio-marked juveniles did not leave in groups (Table 3) and, to our knowledge, did not associate during dispersal.

A more radial movement pattern is exhibited by the adult sage grouse (Fig. 3) than by the juveniles (Fig. 2), although there appears to be no directional trend. Data is limited for radio-marked juveniles in 1980, but it appears that adult females began fall movements before juveniles (Table 3). Adults may leave summer range earlier than juveniles because juveniles had not yet established a traditional movement pattern. Juveniles may also remain on summer range longer to make maximum use of high protein foods.

Five female sage grouse (four adults, one juvenile) marked in the summer of 1980 were radio-tracked for a year or more. All four of the adult grouse returned to the INEL during the summer of 1981, however, only one grouse summered at the TRA (Fig. 4A). Two other birds (Fig. 4B and 4D) summered in 1981 near alfalfa fields to the north and west of the INEL and one bird (Fig. 4C) was not located again after June 1981.

Only 2 of 19 birds marked at the TRA in 1980 returned during the summer of 1981. This represented a return rate of 10.5%. Connelly (1982) reported an overall return rate of 14% for grouse marked at the TRA and CFA from 1977 through 1979. Only one bird (Fig. 4A) was off the INEL during the hunting season immediately following a summer spent at the TRA and it was not harvested. All other birds were well within INEL boundaries during the hunting seasons of 1980 and 1981. Thus the potential for harvest of a grouse from the TRA is low.

During 1982, additional data will be collected on sage grouse habitat use. In addition, we plan to capture and radio-mark at least one more brood and several more adults. We may have radios still functioning from 1981 and can continue to monitor yearly movements of grouse.

Figure 2. Fall dispersal (prior to 15 December) of radio-marked juvenile sage grouse from TRA during 1980 and 1981. An arrow indicates that a bird was still alive while an X indicates that a bird was found dead.

Figure 3. Fall movements (prior to 15 December) of radio-marked adult sage grouse from the TRA during 1980 and 1981. An arrow signifies that a bird was still alive while an X indicates that a bird was found dead.

Figure 4. Movements of four adult female sage grouse during 1980-81. All birds were radio-marked in August 1980. A gap between successive seasonal movements indicates that there was a period of time in which a bird was not located. An X indicates the bird was killed and the radio recovered.

Table 3. Fall dispersal distances and dates of departure of sage grouse adults and juveniles from the TRA. Distances are based on the last location prior to 15 December.

Age Class (N)	Distance from TRA (km)		Departure from TRA	
	Range	$\bar{X} \pm SD$	Range	$\bar{X}$
Adults (1980) (7)	4.5 - 34.1	11.8 $\pm$ 10.0	Sept. 3 - 18	Sept. 9
Adults (1981) (5)	1.3 - 8.3	3.8 $\pm$ 3.9	Aug. 13 - Sept. 16	Aug. 31
Juveniles (1980) (2)	8.0 - 10.3	9.1 $\pm$ 1.6	Sept. 4 -14	Sept. 9
Juveniles (1981) (7)	1.2 - 20.3	12.0 $\pm$ 8.3	July 26 - Oct. 14	Sept. 5

LITERATURE CITED

- Amstrup, S. C. 1980. A radio-collar for game birds. J. Wildl. Manage. 44:214-217.
- Batterson, W. M., and W. B. Morse. 1948. Oregon sage grouse. Oregon State Game Comm. Fauna Ser. 1. 29 p.
- Brander, R. B. 1968. A radio-package harness for game birds. J. Wildl. Manage. 32:630-632.
- Connelly, J. W., Jr. 1982. An ecological study of sage grouse in southeastern Idaho. Ph.D. Thesis, Washington State Univ., Pullman. 84 p.
- Crunden, C. W. 1963. Age and sex of sage grouse from wings. J. Wildl. Manage. 27:846-849.
- Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford and E. F. Schlatterer. 1963. Ecology, productivity and management of sage grouse in Idaho. J. Wildl. Manage. 27:811-841.
- Gilmer, D. S., L. M. Cowardin, R. L. Duval, L. M. Mechlin, C. W. Shaiffer and V. B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U. S. Fish and Wildl. Ser. Resour. Publ. 140. 19 p.
- Girard, G. L. 1937. Life history, habits and food of the sage grouse (*Centrocercus urophasianus*) Bonaparte. Univ. of Wyoming, Laramie Publ. 3:1-56.
- Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. J. Wildl. Manage. 33:649-662.

- McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. Nat. Tech. Inf. Ser., Springfield, VA.
- Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.
- Oakleaf, R. J. 1971. The relationship of sage grouse to upland meadows in Nevada. M. S. Thesis, Univ. of Nevada, Reno. 73 p.
- Patterson, R. L. 1952. The sage grouse in Wyoming. Sage Books, Inc., Denver. 341 p.
- Petrides, G. A. 1942. Age determination in American gallinaceous game birds. Trans. N. Am. Wildl. Conf. 7:308-328.
- Pyrah, D. B. 1963. Sage grouse investigations. Idaho Fish and Game Dept., Wildlife Restoration Div. Job Compl. Rep. Proj. W-125-R-2. 71 p.
- Pyrah, D. B. 1970. Poncho markers for game birds. J. Wildl. Manage. 34:466-467
- Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. J. Wildl. Manage. 35:129-136.

SAGE GROUSE ON THE IDAHO NATIONAL ENVIRONMENTAL RESEARCH PARK

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ABSTRACT

A comprehensive study of sage grouse (Centrocercus urophasianus) ecology was conducted on the Idaho National Engineering Laboratory (INEL) site between June 1977 and May 1981. Sage grouse used lawns surrounding INEL facilities for feeding and loafing throughout the summer. Mean summer home range was 406 ha for adult female sage grouse and 94 ha for juveniles. Radionuclide concentrations in grouse summering near a liquid radioactive waste disposal area (N=29) were significantly higher than those in grouse summering near a solid radioactive waste disposal area (N=14) or control areas (N=20).

Sage grouse moved from 2 to 83 km during seasonal migration. Fall movements from INEL facilities to winter range were slow and meandering. Spring movements of females from leks to summer range were also slow and meandering but male movements appeared rapid and direct.

Sage grouse remained in segregated flocks during early summer but the number of mixed sex flocks increased in late summer. Sage grouse occurred in segregated flocks throughout the winter. Both flock type and habitat influenced winter sage grouse flock size. Mean flock size remained relatively constant as winter weather became more severe. Agricultural areas were an important component of sage grouse summer range and were preferred by all sage grouse sex and age classes. Sage grouse winter range was generally characterized by sagebrush stands with 11 to 30% canopy coverage.

INTRODUCTION

Sage grouse dependence on sagebrush (Artemesia spp.) has been well documented (Patterson, 1952; Klebenow, 1969, 1970; Eng and Schladweiler, 1972; Wallestad, 1975; Beck, 1977). Unfortunately, over 2 million ha of western rangeland have experienced some form of sagebrush control during the past 40 years (Braun et al., 1977). To fully understand the impact of habitat loss on sage grouse, it is necessary to first understand sage grouse seasonal habitat use and movements.

The Idaho National Engineering Laboratory (INEL) is located in southeastern Idaho and was designated a National Environmental Research Park in 1975. Because of relatively unaltered habitat in most areas of the INEL, and its inaccessibility to the general public, a unique opportunity is available to study sage grouse in a relatively natural environment and in areas altered by man. The purposes of this paper are to present a summary of: 1) movements and radionuclide concentrations of sage grouse summering near INEL nuclear facilities; and 2) sage grouse seasonal movements, flocking characteristics and habitat use. Additional information on this study has been published (Connelly, 1982; Connelly et al., 1981; Connelly and Markham, 1983) or will be published later.

STUDY AREA AND METHODS

Radionuclide Concentrations

During summers, sage grouse were studied near 3 INEL facilities and in 2 off-site areas. The Central Facilities Area (CFA) and the Test Reactor Area/Idaho Chemical Processing Plant Complex (TRA/ICPP) are located in the south-central portion of the INEL site along the Big Lost River. TRA and ICPP were grouped because grouse moved between these facilities. Both areas contain irrigated lawns, abundant forbs, and sources of free water. Additionally, TRA contains a leaching pond complex that has been used for the disposal of low-level, liquid radioactive waste since 1952 (Halford and Markham 1978). TRA is an advanced nuclear materials testing complex, and the ICPP recovers uranium from spent nuclear fuels and processes radioactive liquid waste into noncorrosive solid form. CFA contains various support services for the INEL and is not a nuclear facility. The Radioactive Waste Management Complex (RWMC) is located in the southern portion of the INEL and has been used since 1952 to store transuranic contaminated waste and to dispose of waste contaminated with activation and fission radionuclides. This facility has many disturbed sites containing a variety of forbs and free water is often available. An agricultural area at the mouth of the Little Lost River (Howe area) and a big sagebrush (*A. tridentata*)/low sagebrush (*A. arbuscula*) habitat in lower Birch Creek were used as control areas.

During summers, 1977 through 1980, 43 sage grouse were collected near nuclear facilities and 21 grouse were collected in control areas. A 70 g muscle sample and the gastrointestinal (G.I.) tract from each grouse were analyzed for gamma emitting radionuclides using a 65 cm³ lithium-drifted germanium crystal coupled to a computerized multi-channel analyzer. All tissues were gamma-scanned as fresh or frozen material with uniform dimensions and volumes. The minimum detection limit for all nuclides detected ranged from 0.14 to 2.20 pCi/g for muscle samples and from 0.04 to 1.78 pCi/g for G.I. tract samples. Sample results were corrected for radioactive decay.

All data were coded and log-transformed prior to statistical analyses (Steel and Torrie, 1980). Analysis of variance (ANOVA) and Student's t-test were used to make statistical comparisons. The 1st test for unequal sample sizes (Steel and Torrie, 1980:114) was used to compare means when ANOVA indicated a significant difference between groups ($P < 0.05$).

Average and maximum potential whole-body dose commitments to a person consuming sage grouse muscle were calculated using a method suggested by Hoenes and Soldat (1977). Calculations were based on the assumption that the entire muscle mass of one sage grouse was consumed on the same day the bird left the nuclear facility.

Movements, Flocking Characteristics and Habitat Use

Sage grouse were captured and marked during summers on lawns at CFA and TRA using drive traps (Gill, 1965) and mist nets. Sage grouse were captured by night-lighting (Labisky, 1968) on and near leks during March

and April. All captured birds were marked with numbered aluminum leg bands. Additionally, females were color-marked with numbered ponchos (Pyrah, 1970) or were radio-marked with a poncho harness (Amstrup, 1980) or back-pack harness. Males were color-marked with numbered patagial tags or were radio-marked with a backpack harness. Ponchos and patagial tags were color-coded to allow immediate identification of the capture site. Movement data were obtained from radio locations, band returns, and reobservations of marked grouse.

The size, sex, and age composition of flocks were recorded throughout the year. If a single sex appeared to comprise at least 3/4 of a flock, the flock was classified as that sex, otherwise it was recorded as a mixed sex flock. All flocks were flushed to ensure an accurate count and classification.

Analyses of seasonal habitat use were based on data collected while conducting monthly census routes. During summers, flock location, cover type, and the flock's proximity to water were recorded. Flock location, cover type, snow depth, and mean daily temperature were recorded during winter. A circular plot technique (Lyon, 1968; Peek et al., 1978) was used to quantify the winter habitat at locations of flocks numbering 3 or more birds. At each site, sagebrush canopy coverage, height, and density were estimated. Sagebrush habitat that was not used as sage grouse winter range was analyzed in a similar fashion for comparative purposes.

RESULTS

Radionuclide Concentrations

Seventeen radionuclides were detected in TRA/ICPP sage grouse and 2 in RWMC grouse (Table 1). Seven radionuclides were detected in control grouse. Radionuclide concentrations in muscle samples of TRA/ICPP grouse ($\bar{X} = 0.29$ pCi/g, $N=29$) were significantly higher than those of control grouse ($\bar{X} = 0.13$ pCi/g, $N=20$) (ANOVA, $P<0.05$). No difference could be demonstrated in muscle concentrations between TRA/ICPP and RWMC samples ($\bar{X} = 0.14$ pCi/g, $N=14$) or between RWMC and control samples ($P>0.05$). G.I. tract radionuclide concentrations in TRA/ICPP sage grouse ($\bar{X} = 0.80$ pCi/g, $N=29$) were significantly higher than those of RWMC ($\bar{X} = 0.05$ pCi/g, $N=14$) or control birds ($\bar{X} = 0.11$ pCi/g, $N=19$) ($P<0.01$). No significant difference existed between G.I. tract radionuclide concentrations in RWMC and control samples ($P>0.05$).

The average and maximum potential dose commitments to a person consuming the entire muscle mass of a sage grouse were greater for TRA/ICPP birds than for either RWMC or control grouse. The highest estimated potential dose commitment was 2.37 mrem and would have resulted from consuming an adult male sage grouse that summered near TRA/ICPP. In contrast, the highest estimated potential dose commitments from grouse using the RWMC and control areas were 0.02 mrem and 0.04 mrem, respectively.

Table 1. Frequency of occurrence (%) and maximum and mean^a radionuclide concentrations (pCi/g fresh weight) in tissue samples from sage grouse collected during summer and fall, 1977 through 1979, at the Test Reactor Area/Idaho Chemical Processing Plant (TRA/ICPP) complex, the Radioactive Waste Management Complex (RWMC), and control areas.

Nuclide	TRA/ICPP						RWMC						Control Areas					
	G.I. Tract (N=29)			Muscle (N=29)			G.I. Tract (N=14)			Muscle (N=14)			G.I. Tract (N=19)			Muscle (N=20)		
	Freq.	Max.	$\bar{X}$	Freq.	Max.	$\bar{X}$	Freq.	Max.	$\bar{X}$	Freq.	Max.	$\bar{X}$	Freq.	Max.	$\bar{X}$	Freq.	Max.	$\bar{X}$
Cr-51	38	539.0	60.3		ND ^b			ND			ND			ND			ND	
Cs-137	93	107.0	6.2	86	30.1	1.8	100	0.2	0.1	100	0.4	0.3	89	0.2	0.1	90	0.4	0.3
Co-60	31	25.2	2.0	24	1.9			ND			ND			ND			ND	
Ce-144	7	7.1			ND			ND			ND		5	1.5			ND	
Cs-134	28	26.8	1.3	14	5.8			ND			ND			ND			ND	
Nb-95	24	1.8		3	0.2			ND			ND		16	0.7			ND	
Zr-95	10	1.1			ND			ND			ND		11	0.7			ND	
Ce-141	3	2.2			ND			ND			ND		11	0.8			ND	
Ru-103	7	0.9		3	0.4			ND		7	0.6		11	0.6		5	0.3	
La-140	7	0.6			ND			ND			ND			ND			ND	
Se-75	17	4.5		3	1.4			ND			ND			ND			ND	
Na-24		ND		3	3.8 ^c			ND			ND			ND			ND	
Ru-106		ND			ND			ND			ND			ND		11	1.5	
Co-58	3	0.1			ND			ND			ND			ND			ND	
Hg-203	7	0.6		7	0.5			ND			ND			ND			ND	
Ba-140		ND		3	2.7			ND			ND			ND			ND	
Mn-54	14	0.7		3	0.3			ND			ND			ND			ND	
Zn-65	34	12.7	0.9	7	1.5			ND			ND			ND			ND	

^a Means only given for those radionuclides occurring in at least 25% of the samples, and 0 was used in computing means when nuclides were below detection limits.

^b ND = Not detected.

^c pCi/g, see Connelly (1982) for explanation.

Movements, Flocking Characteristics and Habitat Use

Movements. Two hundred and forty five sage grouse were marked at CFA and TRA during the study, and movement data were obtained on 29 grouse, 14 of which were radio-marked. We determined summer ranges for 5 adult females, 2 juvenile males, and 1 juvenile female. All adults were marked at CFA and 4 had broods when captured. Females with broods remained at CFA for an average of 47 days and had a mean summer range of 406 ha. The female without a brood remained at CFA for 25 days and occupied a summer range of 174 ha. The 3 juveniles were marked at TRA, remained at this facility for an average of 35 days, and had a mean summer range of 94 ha.

From 1 July to 7 September, 72% of all radio-locations (N=131) were made within 1 km of the facilities and 95% were within 2 km. The last 3 weeks of September appeared to be a transition period in which relatively few locations were made within 1 km of summer feeding sites at the facilities. During October and November, 82% of the radio-locations (N=22) were over 2 km from the facilities and ranged from 2 to 32 km. The average 1-way movements to winter range from CFA and TRA were 19.9 and 15.5 km, respectively, and ranged from 0.2 to 81.0 km (Fig. 1).

A total of 195 sage grouse were marked on 4 leks in the mountain valley area and 178 grouse were marked on 9 leks in the plains area of the INEL. Of 26 summer reobservations, radio-locations, and band returns of mountain valley birds, 23 occurred in the Birch Creek valley. Male sage grouse from the mountain valley population left their leks in late April and May. Their movements to summer range were more rapid and direct than those of females. Three radio-marked males moved an average of 0.9 km per day during spring migration. Four radio-marked females from the mountain valley area moved an average of 0.3 km per day during spring.

Sage grouse males from the plains population usually moved in a southwesterly direction to summer range while females moved north. Limited data on males from this population suggested that they also moved directly to summer range after leaving their leks in late April and May. Females made relatively extensive movements during spring. Three radio-marked females moved an average of 0.6 km per day during spring.

Flocking. During summer, 635 sage grouse flocks were recorded. Grouse occurred in segregated flocks in June and July; mixed sex flocks accounted for less than 10% of the total flocks observed during this period. The frequency of mixed sex flocks increased in late summer and comprised 36% of the total number of flocks observed during September.

During winter, 469 sage grouse flocks were recorded. Most grouse remained in segregated flocks throughout the winter. Mixed sex flocks never comprised more than 16% of all flocks recorded in any month from November through March. In all areas mixed sex flocks were largest and male flocks smallest.

During winter 1978-79, more snow fell and mean daily temperatures were lower than in the following winters of 1979-80 and 1980-81 (Connelly 1982). However, no single environmental variable (i.e. snow depth, temperature, sagebrush height, or sagebrush canopy coverage) had a strong influence on sage grouse flock size.

Habitat Use. Summer habitat was classified into 4 cover types: sagebrush, agriculture/sagebrush, disturbed areas, and crested wheatgrass (Agropyron cristatum). During summers, 289 sage grouse flocks totaling 1,930 birds were recorded along 5 census routes. Of all grouse observed along these routes, 79.0% were in agricultural areas. Sage grouse were never observed in crested wheatgrass plantings during the summer. Differences in habitat use were significant for all flock types (chi-square analysis, $P < 0.01$) (Connelly 1982).

Winter habitats in both the mountain valley and plains areas were characterized according to the 3 most abundant plant species. Four cover types were recognized in the mountain valley area and 6 in the plains area. During winters, 103 flocks totaling 1,993 sage grouse were recorded in the mountain valley area. Habitat use by these birds varied significantly from the expected (chi-square analysis, $P < 0.01$) (Connelly 1982).

In the plains area, 127 flocks totaling 1,229 sage grouse were recorded during winters. Habitat use by these grouse also differed significantly from the expected (chi-square analysis, $P < 0.01$) (Connelly 1982). Sage grouse were never observed in crested wheatgrass plantings or in the agricultural area during winter.

DISCUSSION

Lawns surrounding INEL facilities provide a unique substitute for natural meadows, as do the alfalfa fields near the Howe study area. Both provide a predictable source of forbs, insects, and free water during summer and early fall. Also, because they are irrigated, neither type of summering area is as seriously affected by drought as are natural meadows.

The highest radionuclide concentrations in sage grouse occurred in samples from TRA/ICPP. However, the number and concentration of radionuclides in grouse muscle and G.I. tract samples from this area were generally lower than those reported for waterfowl (Halford et al., 1981) and mourning doves (Zenaida macroura) (Markham and Halford, 1982) in the same area. ^{137}Cs concentrations reported for dove muscle were approximately 3 times greater than ^{137}Cs concentrations in sage grouse muscle. ^{137}Cs concentrations reported for waterfowl muscle were over 400 times greater than those in sage grouse. The higher concentrations in doves and waterfowl were probably due to their greater use of the TRA ponds. The relatively large summer range of INEL sage grouse also reduced their exposure to these contaminated areas. The difference in radionuclide concentrations between TRA/ICPP and RWMC grouse suggests that the transfer of radioactivity from liquid waste systems is greater than the transfer from solid waste systems.

The maximum potential whole-body dose commitment to a person eating a sage grouse shortly after it left the vicinity of an INEL facility was estimated at 2.37 mrem (Connelly and Markham 1983). The recommended maximum permissible whole-body dose commitment to an individual in the general public is 500 mrem per year (International Commission on Radiological Protection, 1959) or 208 times the maximum dose commitment from a grouse summering near an INEL facility. To exceed the 500 mrem per year maximum recommended dose, a person would have to eat approximately 422 kg of sage grouse meat or about 211 sage grouse containing maximum concentrations in 1 year (Connelly and Markham 1983). Therefore, based on current guidelines, the potential dose commitment to a person consuming a sage grouse shortly after it left an INEL facility does not constitute a radiation health hazard.

Summer home ranges averaged 260 ha (Connelly, 1982) and were generally smaller than spring and fall ranges (Connelly 1982). These seasonal ranges are relatively large and support the contentions that grouse need vast expanses of suitable habitat (Eng and Schladweiler, 1972; Wallestad, 1975) and that the protection of sagebrush within a 3.2 km radius of leks is not sufficient (Beck, 1977).

Some adult sage grouse summering on the INEL moved more than 60 km to winter range and juveniles dispersed over 80 km, even though radio-telemetry data indicated suitable winter range occurred much closer to summer range. Because grouse winter range occurs in close proximity to leks on the INEL (Connelly 1982), adult movements to winter range represent their return to traditional breeding areas. Fall movements of juvenile grouse suggest that these birds are dispersing in random directions (Connelly 1982).

Spring movements of female sage grouse were slow and meandering when compared to the rapid and direct movements of males. Many grouse moved relatively long distances from leks to summer range, even though there was suitable summer habitat much closer (Connelly 1982). These movements are probably the result of traditional migratory patterns established before agricultural developments created suitable summer range closer to breeding areas.

Patterson (1952) indicated that sage grouse remained in segregated flocks throughout the summer. During this study, grouse occurred in segregated flocks during early summer but the number of mixed sex flocks increased in August and September. Past research has also suggested that flock size increased during late summer (Dalke et al., 1963). However, the size of male and female/juvenile flocks on the INEL did not increase in late summer.

Wallestad (1971) indicated that sage grouse spent a large portion of the summer in sagebrush habitats. In this study, less than 15% of all grouse observed during summers were in sagebrush habitats. Sage grouse showed a strong preference for agricultural and disturbed areas and both of these habitats were vital components of grouse summer range at low

elevations. Patterson (1952) reported that sage grouse do not need free water but will use it when available. Similarly, INEL grouse that summered in sagebrush habitats were not closely associated with water.

Both Ihli et al. (1973) and Beck (1977) reported little use of crested wheatgrass plantings by sage grouse. The crested wheatgrass plantings used as leks on the INEL contained small, scattered stands of sagebrush. In spite of this, grouse were never observed in these areas at any other time of the year, suggesting that these plantings are totally unsuitable as winter or summer range. During this study, 53% of sage grouse observed on winter range occurred in areas with more than 20% canopy coverage and 89% of the observations occurred in areas with more than 10% canopy coverage (Connelly 1982). Montana sage grouse preferred winter range with sagebrush canopy coverage greater than 20% (Eng and Schladweiler, 1972).

LITERATURE CITED

- Amstrup, S. C. 1980. A radio-collar for game birds. J. Wildl. Manage. 44:214-217.
- Beck, T. D. I. 1977. Sage grouse flock characteristics and habitat selection in winter. J. Wildl. Manage. 41:18-26.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildl. Soc. Bull. 5:99-106.
- Connelly, J. W. 1982. An ecological study of sage grouse in southeastern Idaho. Ph.D. Dissertation, Washington State Univ., Pullman. 84p.
- Connelly, J. W., W. J. Arthur and O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. J. Range Manage. 34:153-154.
- Connelly, J. W. and O. D. Markham. 1983. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. J. Wildl. Manage. 47:169-177.
- Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. J. Wildl. Manage. 27:811-841.
- Eng, R. L., and P. Schaldweiler. 1972. Sage grouse winter movements and habitat use in central montana. J. Wildl. Manage. 36:141-146.
- Gill, R. B. 1965. Effects of sagebrush control on distribution and abundance of sage grouse. Colorado Game, Fish, and Parks Job Compl. Rep., Proj. W-37-R-17. 185 p.
- Halford, D. K., and O. D. Markham. 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. Ecology 59:1047-1054.
- Halford, D. K., J. B. Millard, and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. Health Phys. 40:173-181.
- Hoenes, G. R., and J. K. Soldat. 1977. Age-specific radiation dose commitment factors for a one-year chronic intake. Battelle Pacific N.W. Lab. Nat. Tech. Inf. Serv., Springfield, VA. 39 p.
- Ihli, M., P. Sherbenou, and C. W. Welch. 1973. Wintering sage grouse in the upper Big Lost River. Idaho Acad. Sci. 1973:73-80.
- International Commission on Radiological Protection; Committee II. 1959. Permissible doses for internal radiation, publication 2. Pergamon Press, London. 223 p.

- Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. J. Wildl. Manage. 33:649-662.
- Klebenow, D. A. 1970. Sage grouse versus sagebrush control in Idaho. J. Range Manage. 23:396-400.
- Labisky, R. F. 1968. Nightlighting: its use in capturing pheasants, prairie chickens, bobwhites and cottontails. Illinois Nat. Hist. Surv. Ecol. Notes No. 62. 12 p.
- Lyon, L. J. 1968. Estimating twig production of serviceberry from crown volumes. J. Wildl. Manage. 32:115-119.
- Markham, O. D. and D. K. Halford. 1982. Radionuclides in mourning doves near a nuclear facility complex in southeastern Idaho. Wilson Bull. 94: 185-197.
- Patterson, R. L. 1952. The sage grouse in Wyoming. Sage Books, Denver, Colo. 341 p.
- Peek, J. M., F. D. Johnson, and N. N. Pence. 1978. Successional trends in a ponderosa pine/bitterbrush community related to grazing by livestock, wildlife, and to fire. J. Range Manage. 31:49-53.
- Pyrah, D. B. 1970. Poncho markers for game birds. J. Wildl. Manage. 34:466-467.
- Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics. 2nd ed. McGraw-Hill Book Co., New York. 633 p.
- Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. J. Wildl. Manage. 35:129-136.
- Wallestad, R. O. 1975. Life history and habitat requirements of sage grouse in central Montana. Montana Department of Fish and Game, Helena. 65 p.

TRANSURANIUM NUCLIDES IN PELAGIC AND BENTHIC COMPONENTS OF TEST REACTOR LEACHING PONDS

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ABSTRACT

Concentrations of ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , ^{242}Cm , and ^{244}Cm were studied in both abiotic and biotic matrices of test reactor leaching ponds located on the Idaho National Engineering Laboratory. Input of low-level liquid radioactive wastes to these leaching ponds has resulted in elevated concentrations of these nuclides in ecosystem components. Highest concentrations of nuclides were recorded in seston and periphyton with lowest concentrations in filtered water. Significant differences in concentrations were observed among components and also through a 52 day sampling period for each component. No consistently significant correlations relating component concentrations through time with changing limnological characteristics were found. Concentration ratios (CR's) for each nuclide differed among components. Highest CR's were calculated for the seston and periphytic matrices ($10^4 - 10^5$) and lowest values for sediments ($10^2 - 10^3$). Concentration ratios were similar for the phytoplankton and zooplankton components (10^4). Within each component, plutonium isotopes had consistently higher CR's than americium and curium nuclides. Intra-element differences were observed between the isotopes of plutonium and also the isotopes of curium. Inventories in the pelagic environs were in the MBq (μCi) range for all nuclides. Although transuranium inventories in waste water input to the ponds were greatly reduced during the 52 day study, inventories in the pelagic environs did not decrease as expected.

INTRODUCTION

Since 1952 the Test Reactor Area (TRA) leaching ponds located on the Idaho National Engineering Laboratory (INEL) have received liquid wastes containing low level quantities of radionuclides produced during normal TRA operations (Ayers et al., 1977). The release of contaminated effluents into these ponds has resulted in a unique freshwater system containing components which have above background concentrations of various radionuclides, among which are five transuranium isotopes.

The proximate and ultimate ecological distributions of these long-lived transuranium elements have been of considerable concern as a result of their potential hazard to man (Bulman, 1978; Hanson, 1975; Price, 1973). Investigation of transuranium elements in ecosystems is difficult because of the typically low concentrations and comparatively difficult assay methods. Thus, locally contaminated systems such as the TRA leaching ponds provide a unique opportunity for radioecological

studies concerning transuranium nuclides. Furthermore, the TRA leaching pond system is unique in that easily detectable quantities of five transuranium nuclides ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , ^{242}Cm , and ^{244}Cm can be studied comparatively.

The purpose of this report is to present comparative concentration data for five transuranium nuclides in leaching pond components from June through August 1979. Of the matrices sampled, major emphasis is directed to a presentation of pelagic component data and limnological characteristics of this freshwater ecosystem. Also, transuranium inventories in unfiltered water and their transfer from the ponds by water flow to a leaching area and by percolation into ponds sediments are presented.

MATERIALS AND METHODS

Study Area The TRA leaching area consists of three ponds dug in gravel, sand, and silt of the Big Lost River alluvium located on the INEL Site (Fig. 1). Ponds 1 and 2, constructed in 1952 and 1957, respectively, constitute a single body of water which had been thought to be partially sealed on the bottom and lower sides by CaCO_3 precipitate and detritus (Morris et al., 1964). The capacity of these ponds is approximately $2.9 \text{ E}+4 \text{ m}^3$ when filled to their mean depth of 3.7 m. As

Figure 1. Diagram showing TRA leaching ponds: Ponds 1 and 2, water volume $2.9 \text{ E}+4 \text{ m}^3$; Pond 3, leaching area.

a result of discharges into these ponds from normal test reactor operations, water flows through a flume into Pond 3 which was constructed in 1964. This pond is only partially covered with water and serves as the major leaching area, having an infiltration rate of approximately $25 \text{ L hr}^{-1} \cdot \text{m}^{-2}$ (Millard et al., 1976). Recent evidence indicates active percolation in all three ponds (Barracough et al, 1982). Although water passed continuously through the parshall flume into the 1964 pond during the study, this water flow was not measured. Therefore, we were unable to determine the portion of TRA in flow which passed from ponds 1 and 2 through the flume into the 1964 pond. The effluent water released to the ponds contains low level wastes, liquids having radionuclide concentrations below guidelines established by USDOE for release to a controlled area (USDOE, 1981). From June through August approximately $7.8 \text{ E}+4 \text{ m}^3$ of liquid waste were discharged to the pond basin. This effluent released to the ponds originally was reported to have no measurable alpha activity (TRA Liquid Waste Summary, 1980); however, on the 17 July sampling date, the probable release of contaminated liquid containing transuranic nuclides was noted (Beatty, pers. comm.). No data concerning the transuranic nuclides and amounts released were available.

The components of this ecosystem have been described elsewhere (Kuzo, et al., 1978). For this investigation, filtered water, seston, net plankton, metaphyton, periphyton, zooplankton, and sediment were sampled. For these matrices, excluding sediments, a time dependent sampling regime was conducted. The sediment component was sampled once. Although periphyton and sediment are not pelagic components, their importance as a sink for transuranium nuclides in freshwater ecosystems necessitated inclusion in this study.

Table 1. Summer 1979 sampling regime and sample numbers for components of the Test Reactor Area (TRA) leaching ponds.

Date	Sample numbers					
	Water	Seston	Net plankton	Zooplankton	Periphyton	Limnology
June 08						X
11	3	3	6			
13					6	X
19				5	3	
21	3	3	5		2	X
25 ^a					4	
27				5		X
July 02	3	3				
06						X
09			5	5		X
11						
17	3	3	5			X
18				5		
23		3	5			X
25					6	
August 02	3	3	5			X
08						X
15			5			X

a Several sediment samples collected.

Limnological Monitoring and Component Analysis Procedures All sampling and limnological monitoring of the TRA ecosystem were conducted from 8 June through 22 August 1979. The sampling schedule and sample number for each component are listed in Table 1. The physiochemical parameters of temperature, dissolved oxygen, conductivity, and pH were monitored weekly using a calibrated Hydrolab Surveyor Model 6D in situ water quality analyzer. To check for stratification of limnological parameters, measurements were made at 0.5 m depth intervals in the pelagic zone. Also, secchi disc measurements were conducted at the same time periods to determine vertical penetration of light.

Component sample masses collected for transuranium analyses varied depending on analytical detection limits and estimated transuranium concentrations using previous TRA leaching pond studies for reference (Kuzo et al., 1978). Concentrations for filtered water, a 3 L volume collected for each sample, were determined on a volume basis. For the nonsoluble matrices, transuranium concentrations were determined on a dry mass basis. The material collected was dried at 40 to 60°C until a constant mass was obtained. Sample mass (dry) for seston ranged from 0.01 to 0.1 g; whereas for zooplankton, net plankton, and metaphyton, sample masses ranged from 0.5 to 5 g. For periphyton and sediments, 5 to 10 g samples were submitted for analyses.

Water samples were collected using a Kemmerer water sampling bottle. Samples were collected from pelagic areas at a depth of 0.5 m. Each 3.0 L sample was filtered immediately through 0.45 μ m pore size membrane filters. The filtrate was transferred to plastic 3.8 L cubitainers and acidified to approximately 1 N using concentrated HCl. To remove any nuclides adsorbed to the filtering apparatus, glassware was washed with concentrated HCl and this wash solution was then added to the sample.

Seston, the suspended particulate material in the water column, was collected by filtration of 3.0 L of pond water through 0.45 μ m pore size membrane filters. Three separate samples were collected for each sampling date. Dependent upon the amount of suspended material in the water column, the number of filters utilized for each 3.0 L volume of water varied between 10 and 15. Filters from each water sample were combined for mass estimates and radiochemical analyses.

Net plankton, i.e. algal material collected by a 64 μ m mesh netting, was sampled by conducting vertical hauls with a 12 cm diameter plankton net. Each haul was pulled upward from a 3 m depth, thus sampling a 0.034 m³ volume of the water column. The collected material was filtered to dryness in the field using a portable filtering apparatus fitted with membrane filters, 0.45 μ m pore size. To obtain sufficient mass for transuranium analyses, each sample consisted of one to two hauls. The total number of samples for any date varied between 6 and 20. Data from each sampling date were grouped to determine a mean plankton mass per unit volume. Metaphyton, algae aggregated in the littoral zone neither attached to substrata nor truly planktonic (Wetzel, 1975), was collected using a dip net and then filtered as above. No quantitative mass estimates were conducted for this component. These algal components were collected periodically and preserved for species identification and composition analyses conducted by Mr. Richard Dufford, Department of Botany and Plant Pathology, Colorado State University.

Periphyton was sampled qualitatively from 12 June through 24 July by netting the algal mat from the pond bottom. If necessary, attached sediment particles were removed by hand from the periphyton prior to processing for transuranic analyses. As for the net plankton, aliquots were collected for species identification. Biomass data were not collected for this component during the summer 1979 sampling period.

Zooplankters were sampled using a dip net. However, zooplankters were not distributed uniformly throughout the water column during daylight hours, thus, only qualitative sampling was conducted. Zooplankters were located near benthic areas in the deepest sections of the pond in association with metaphytic algal material. The zooplankters were rinsed with deionized water and then filtered to dryness. Sufficient numbers of zooplankters to allow quantitative measurement of transuranium activity were found only from 19 June through 18 July.

The sediment component was sampled once during the study period. Seven cores (15 cm diameter) were collected at random locations within each of the filled ponds. Only the top 5 cm of each core were analyzed for transuranium nuclides. All algal material covering the core and particulates greater than #6 (3.35 mm) mesh size screen were removed prior to processing.

Water and sediment samples were submitted to Environmental Analysis Laboratories (Richmond, California) for transuranic analyses. All other transuranium analyses were completed by the Radiological and Environmental Sciences Laboratory at the INEL. Approximately 10% of all samples submitted to each laboratory were blanks and spikes to serve as quality controls. Analyses for transuranium elements followed published radiochemical separation and electrodeposition procedures (Wessman, et al., 1976; 1976a; R. P. Bernabee, unpublished data). Electrodeposited samples were counted using alpha spectrometry with the appropriate background corrections.

Mathematical and Statistical Procedures The activity concentration values reported in this study represent complete data sets as discussed by Gilbert and Kinnison (1981). In most instances the standard deviations associated with transuranium analyses for each sample were less than five percent of the reported data values. Eberhardt and Gilbert (1980) have reported that frequency distributions of environmental transuranium concentrations are often dramatically skewed. Thus, statistical analyses were conducted utilizing transformed data, i.e., the natural logarithm of the activity concentration. In preliminary analyses, this procedure improved normality in all data sets relative to the non-transformed data. Also, transformed data reduced differences in the variances among the time dependent data collected for each component, thereby, improving the homogeneity of variance among separate sampling dates.

Concentration ratios were utilized to compare the distribution of the transuranium nuclides within and among components of the ecosystem. This procedure accounted for the nearly four orders of magnitude difference in specific activities among transuranium nuclides, and normalized component concentrations to their respective levels in filtered water. Concentration ratios were calculated using the mean summer values of activity concentrations for each component. Herein the concentration ratio is defined as:

$$CR = \frac{\text{Concentration in Component of Interest (Activity } g^{-1} \text{ [dry])}}{\text{Concentration in Filtered Water (Activity } cm^{-3})}$$

In utilizing these ratios in statistical analyses, we assumed that the radionuclide activity was homogeneously dispersed throughout the medium (Doctor et al., 1980). For many ecosystems where transuranium nuclides previously have been studied, e.g., terrestrial systems, the assumption of a homogeneous distribution is invalid. However, with constant mixing by wind action and a 34 d residence time (τ) for the TRA water column, we assumed that the concentrations of the five transuranium nuclides in ecosystem matrices were homogeneously dispersed within the pelagic environs and that normal statistical analyses were valid.

The pelagic inventory, defined here as the inventory in unfiltered water, was determined for each radionuclide. For each sampling date, separate nuclide inventories were calculated by combining filtered water plus sestonic inventories. These calculations assumed the pond volume was constant, $2.9 \text{ E}+4 \text{ m}^3$, and seston mass estimates represented non-soluble material throughout the water column. Thus, any change in pelagic inventories through time reflected changes in seston mass estimates and/or transuranium concentrations in these two components.

TRA effluents pumped into the ponds percolated into the sediments or resulted in the subsequent movement of water through the overflow flume into the leaching area. Normal flow of the water column, containing transuranium nuclides in soluble and non-soluble form, transferred activity either into sediments under ponds 1 and 2 and/or from these ponds into the leaching area. Assuming first-order rate kinetics, we calculated the rate of pelagic inventory removal from the ponds during the study. Determination of the expected decreases in inventories were made based on the following assumptions: there was no significant input of transuranium nuclides into the system from TRA operations; the outflow of water from the system by percolation and by flowing into the leaching area and equalled the rate of effluent release to the system; pond volume remained constant ($2.9 \text{ E}+4 \text{ m}^3$); and radiological decay was insignificant for all nuclides, excluding ^{242}Cm , during the 52 day study.

Based on the above assumptions, the effective transfer rate constant (k_1) for pelagic inventory transferred from the ponds through water flow into the leaching area and into the sediments below ponds 1 and 2 was determined as follows:

At equilibrium: Inflow = Outflow

That is: $R = k_1 \cdot V$

Rearranging terms: $k_1 = R/V$)

Where: $R = \text{Input Rate } [8.44 \pm 1.72 \text{ E}+2 \text{ m}^3 \cdot \text{d}^{-1}]$

$V = \text{Pond Volume } [2.9 \text{ E}+4 \text{ m}^3]$

$k_1 = \text{Effective Transfer Rate Constant } [\text{d}^{-1}]$

Solving: $k_1 = [.029 \text{ d}^{-1}]$

The expected decrease in pelagic inventories resulting from water flow into the leaching area, into the sediments and from radioactive decay then were calculated following first-order rate kinetics:

$$I_t = I_0 e^{-k_2 t}$$

Where: I_t = Calculated Inventory in Water Column Time(t)

I_0 = Measured Inventory in Water Column, Time(0)

k_2 = Calculated Effective Loss Rate Constant

$(R/V + .693/T_p)$; where T_p = physical half-life

$0.029 \text{ d}^{-1} = {}^{238}\text{Pu}, {}^{239,241}\text{Pu}, {}^{241}\text{Am},$

and ${}^{244}\text{Cm}$

$0.033 \text{ d}^{-1} = {}^{242}\text{Cm}$

t = Time Interval

RESULTS

Limnology of the TRA Pond Temperature, dissolved oxygen, pH and conductivity values in surface waters (0.5 m depth) are plotted in Fig. 2. Stratification for these parameters was not observed during the summer. Temperatures varied between 16.0 and 22.5°C during the sampling period. Dissolved oxygen concentrations ranged from 7.1 to 10.8 ppm with

Figure 2. Limnology of TRA leaching ponds; Summer 1979.

maximum concentrations during windy periods and minimal concentrations occurring during calms. Conductivity of the system was relatively low, ranging from 100 to 180 $\mu\text{mhos} \cdot \text{cm}^{-1}$. From mid- to late June, the pH increased markedly from approximately 7 to 10; most likely as a result of caustic chemical releases into the leaching ponds from TRA operations. However, such chemical releases could not be confirmed. The secchi disc readings prior to 9 July were always to the bottom of the pond with the variable readings representing changes in bottom depth where the measurements were conducted. The increased turbidity from mid-July corresponded to an increase in algal growth within the water column.

The fluctuations in seston mass (Fig. 3A) reflected various external and internal parameters which affect the pond ecosystem, e.g., turbulence causing resuspension of bottom detritus and/or increased planktonic material in the upper water column. Mass estimates among individual sampling dates were not statistically different ($P > 0.05$; Analysis of Variance [AOV]; Ryan et al., 1976). Mean values and the associated standard deviations range from 0.92 ± 0.17 to $2.09 \pm 0.50 \text{ g m}^{-3}$ with an overall summer average of $1.53 \pm 0.63 \text{ g m}^{-3}$. Qualitatively, the seston composition changed from principally dead organic material early in the summer period to mainly live algal material from midsummer until the termination of sampling.

Mass estimates for the net plankton component followed a sigmoid growth pattern through the summer (Fig. 3B). Net plankton biomass estimates increased significantly ($P \leq 0.05$) through the sampling period from $0.05 \pm 0.02 \text{ g} \cdot \text{m}^{-3}$ in late June to sustained maximum values of approximately $1.8 \pm 0.2 \text{ g} \cdot \text{m}^{-3}$ in August. The biomass increase was the result of a bloom of the green filamentous alga Spirogyra sp. (Division, Chlorophyta).

Spirogyra sp. cell types represented more than 97% of the net plankton species composition for all samples collected from 17 June until the termination of sampling. Similarly, this species was the dominant algae in the metaphyton samples. Quantitatively, pelagic algal species compositions were characterized by low cell numbers, less than 1-3% in each analysis, of diatoms (Division, Bacillariophyta) and blue-green algae (Division, Cyanophyta). For these two algal groups, Navicula sp. (Bacillariophyta) and Oscillatoria sp. and Anabaena sp. (Cyanophyta) were the principal species and these were collected mainly in samples prior to 19 June and subsequent to 2 August. Thus, the net plankton and metaphyton samples represented a relatively homogeneous sample of cell types. This phenomenon controlled several confounding variables which affect interpretations of data in other studies, e.g., cell surface characteristics and species composition.

For all sampling dates, qualitative periphyton species composition included diatoms (Bacillariophyta), green algae (Chlorophyta), and blue-green algae (Cyanophyta) cell types. Diatoms included Amphora veneta, Cymbella prostrata, Navicula sp., and Nitzschia frustulum. Principal green algae species included Cosmarium sp., Pediastrum sp., Scenedesmus sp., and Spirogyra sp.. The only genera of Cyanophyta in periphyton samples were Oscillatoria sp. and Anabaena sp.

Figure 3. Pelagic component mass estimates (dry) [mean +1 SD] for Test Reactor Area (TRA) leaching ponds: (A) Seston, (B) Net plankton

In the zooplankter samples analyzed only one genus, *Daphnia* sp., was observed. As in the case of net plankton samples, this limited several of the variables which may confound interpretation of the results, for example, changing species composition and/or feeding habits.

Concentration Data Transuranic concentrations differed among components (Figs. 4-5). Filtered water had lowest concentrations, ranging from approximately 10 to 100 $\mu\text{Bq} \cdot \text{cm}^{-3}$ [0.3 to 3.0 $\text{fCi} \cdot \text{cm}^{-3}$] (Fig. 4). Highest concentrations, which were found in the sestonic and periphytic components, ranged from approximately 0.1 $\text{Bq} \cdot \text{g}^{-1}$ [3.0 $\text{pCi} \cdot \text{g}^{-1}$] to 100 $\text{Bq} \cdot \text{g}^{-1}$ [3.0 $\text{nCi} \cdot \text{g}^{-1}$]. Concentrations in these components were approximately an order of magnitude higher relative to concentrations in other nonsoluble components. Only for the ^{242}Cm nuclide (Fig. 5C) did the concentration levels between periphyton and seston differ, with the periphytic values being lower than seston. Net plankton, metaphyton, and zooplankton concentrations were between the values for filtered water and seston and periphyton, ranging from .01 to 1.0 $\text{Bq} \cdot \text{g}^{-1}$ [0.3 to 30 $\text{pCi} \cdot \text{g}^{-1}$].

Figure 4. Filtered water transuranium activity concentrations through time: Summer 1979

Filtered water concentrations differed among individual sampling dates ($P \leq 0.05$; One-way Analysis of Variance [AOV]). Variability among the transformed data for each sampling date was small; coefficients of variation were less than 5% for all nuclides. Follow-up tests, using a sequential method of comparing means (Snedecor and Cochran, 1978), indicated ²³⁸Pu, ²⁴¹Am, ²⁴²Cm, and ²⁴⁴Cm concentrations were higher for 11-12 June compared to 2 August samples. This trend was not observed for ^{239,240}Pu concentrations which remained unchanged. Also, filtered water concentrations, excluding ²⁴²Cm, were significantly elevated for samples collected 17 July. Thus, except for 17 July data, transuranium concentrations in filtered water decreased or remained unchanged from June through August (Fig. 4).

Transuranium concentrations for seston differed significantly ($P \leq 0.05$) among sampling dates. Coefficients of variation for concentrations within the individual sampling dates ranged between 1 to 30%. Excluding ²⁴²Cm data, concentrations increased for each sampling time through 2 July, decreased 17 July, and then increased to their previous concentrations on 3 August. These trends in seston concentrations were opposite the trends for filtered water. In general, highest concentrations in seston were noted for those sampling dates when filtered water concentrations were lowest. There is the possibility that this relationship resulted from improper filtering techniques, i.e., sestonic material being incorporated into the filtrate for those water samples with the greatest values. However, there was no visual evidence of filter breakage nor were there any significant negative correlations ($P > 0.05$) between seston mass collected and the activity concentrations

in the resultant filtrate. In fact, the highest sestonic mass estimates were recorded for the samples collected on 17 July, the day when water concentrations were also at their highest level.

For each sampling date, the range of variability in net plankton concentrations among individual samples was large, coefficients of variation from 2 to 128%. For all transuranium elements, excluding ^{242}Cm , the mean concentration values decreased in late July after which all nuclide concentrations increased until the termination of sampling (Fig. 5). Transuranium concentrations in metaphyton samples either remained unchanged or decreased with successive sampling periods. Thus, net plankton and metaphyton transuranic concentrations and their associated trends were similar.

Concentrations of the transuranium nuclides in zooplankters were generally similar to values in the pelagic algal species (Fig. 5). Differences among the separate samples for each sampling date were large for several samples, coefficients of variation ranging from 6 to 89%; however, only two of the values had CV's of 25% or greater. Transuranium concentrations, excluding ^{244}Cm , decreased significantly ($P < 0.05$) in successive sampling dates through the summer. Concentrations of ^{244}Cm increased on 25 June and decreased through the remaining sample dates (Fig. 5D).

Coefficients of variation for periphyton concentrations ranged from 2 to 9% among samples collected on the same sampling date. For the isotopes of plutonium and also the ^{242}Cm nuclide there were no significant differences ($P > 0.05$) in periphyton concentrations among sample dates. However both ^{244}Cm and ^{241}Am (Fig 5D-E) concentrations in periphyton changed significantly ($P < 0.05$) among sample dates. Concentrations of the above nuclides decreased from highest values 19 June to lowest values for samples collected 25 June.

To determine if the activity concentration changes recorded were correlated with varying abiotic and biotic parameters of the ecosystem, trends in concentration data for ecosystem components were analyzed using multiple regression techniques (Ryan et al., 1976). The activity concentration of each nuclide in filtered water was regressed against pH, conductivity, temperature, and dissolved oxygen concentrations. There were no consistently high correlations ($P > 0.05$) nor significant regression parameter estimates ($P > 0.05$) among the limnological parameters and water concentrations for the five transuranium nuclides. Multiple regression analyses of the concentration levels in zooplankton, net plankton, seston, and filtered water with each other and the limnological parameters listed did not result in the formulation of any definite predictive equations. Furthermore, in the regression analyses conducted, concentrations in filtered water did not have any significant influence in predicting the resultant pelagic component concentrations. Water serves as a source and/or transfer mechanism of activity among the pelagic components and thus this result was not expected. As a result of the inability to establish trends in component concentrations through time and to simplify other statistical comparisons, the average transuranic component concentrations were utilized in determining nuclide concentration ratios.

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Figure 5. Time dependent transuranium concentrations in Test Reactor Area (TRA) ecosystem matrices: (A) ^{238}Pu , (B) $^{239,240}\text{Pu}$, (C) ^{242}Cm , (D) ^{244}Cm , (E) ^{241}Am .

Concentration Ratios The concentration ratios for the transuranium nuclides among the ecosystem components are represented by three definite groupings (Fig. 6). Highest ratios, approximately 10^5 for all nuclides, were calculated for the sestonic and periphytic components. The second group of CR's in the 10^3 to 10^4 range, were observed for net plankton, metaphyton, and zooplankton. Sediments generally had the lowest values, ranging from 10^2 to 10^4 .

Significant differences ($P < 0.05$; AOV; Sequential Follow-up Test, Snedecor and Cochran, 1978) and general trends among the geometric mean CR's in each component were as follows (Table 2). For all components, isotopes of plutonium had highest concentration ratios. Concentration

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Figure 6. Concentration ratios [geometric mean $\pm$ 1 SD] of transuranium nuclides in Test Reactor Area (TRA) ecosystem matrices: Summer 1979.

ratios for $^{239,240}\text{Pu}$ were significantly greater ($P < 0.05$) than the values for americium and curium isotopes in all matrices. For metaphyton and the benthic components, sediment and periphyton, the CR's for both plutonium isotopes were significantly elevated ($P < 0.05$) relative to the values for americium and the isotopes of curium. No significant ($P > 0.05$) differences in concentration ratios among the nuclides of ^{241}Am and ^{244}Cm were found for any component. Furthermore, in seston, net plankton, and zooplankton there were no significant differences among the CR's of ^{238}Pu , ^{241}Am , and ^{244}Cm . Finally, for all components except seston and zooplankton, concentration ratios for ^{242}Cm were significantly lower ($P \leq 0.05$) than the other nuclides.

Differences were noted in comparing CR's between isotopes for both the plutonium and curium elements. Mean concentration ratios for $^{239,240}\text{Pu}$ relative to ^{238}Pu , ranged from approximately 1.4 to 3.5 times greater, and except for sediments, were significantly different ($P < 0.05$) for all components. A similar trend, excluding seston and zooplankton data, was found between curium isotopes, with statistically ($P \leq 0.05$) higher CR's reported for ^{244}Cm relative to ^{242}Cm .

Pelagic Inventory and Transfer Filtered water and seston inventory estimates through the study period for the five transuranium nuclides are shown in Figure 7A-B. In the pelagic environs there were definite trends in the distribution of the transuranium nuclides for the particulate (seston) and filtered water matrices as shown by differences in activity concentrations through time (Fig. 4, 5A-E). Inventories for all transuranium nuclides were in the MBq (μCi) range for these two components (Fig. 7A-B). Excluding 17 July data, individual transuranium nuclide inventories remained constant or decreased in filtered water (Fig. 7A); whereas, seston inventories remained constant or increased (Fig. 7B). Pelagic inventories in the TRA ponds were in the MBq (μCi) range for all nuclides (Fig. 7C). These pelagic inventory values, excluding ^{242}Cm , were constant during the study. That is, significant slopes ($P < 0.05$; Regression Analysis; Ryan et al. 1976), representing changing inventories with time were not found by regression analyses for any of the nuclides except ^{242}Cm . For ^{242}Cm a significant negative slope ($P < 0.05$) in regression analyses indicated a decrease in inventory through time.

Throughout the sampling period the input of water to the system averaged $8.44 \pm 1.72 \text{ E}+2 \text{ m}^3 \text{ d}^{-1}$. The water volume in the filled ponds remained constant as a result of percolation in ponds 1 and 2 sediment and/or water movement from these ponds through the overflow flume into the leaching pond. This movement of water from the ponds resulted in a transfer of activity to the leaching pond which was dependent upon flow rate, water column inventory and percolation into the sediments beneath ponds 1 and 2.

The constant water flow through the system either by movement through the flume or through percolation could be expected to result in a first order loss of radionuclides in the water column. We calculated that 78 to 82% of water column inventories measured 11 June

Figure 7. Inventory estimates through time for Test Reactor Area (TRA) water column components: (A) Filtered water, (B) Seston, (C) Pelagic [filtered water + seston].

were removed from the ponds during the 52 day study. The calculated final (2 August) inventory estimates based on no transuranium input to the pelagic environs are listed in Table 3. Also listed are the observed inventory values for each transuranium nuclide on the initial and final sampling dates. For four out of the five transuranium nuclides, the final pelagic inventory estimates were similar to the initial estimates. Only ^{242}Cm inventory decreased ($P < 0.05$) through the 52 day interval of the study; however, not to the level predicted. Based on a regression analysis of the transformed concentration data versus time, an effective loss rate constant of $0.014 \pm 0.004 \text{ d}^{-1}$ was calculated for the ^{242}Cm nuclide. This value is lower than the expected effective loss rate constant of 0.033 d^{-1} previously determined for this nuclide based on water transfer from the ponds and radioactive decay. Thus, for all five transuranium nuclides, measured pelagic inventories either remained constant or did not decrease throughout the study.

DISCUSSION

Among several anthropogenic freshwater systems where transuranium elements recently have been investigated (Emery et al., 1978; Kuzo et al., 1978; Paine, 1980) the TRA leaching ponds provide a unique opportunity to conduct comparative studies concerning the kinetics and distribution of five radionuclides. Although serving as a leaching area, these ponds have developed into a freshwater ecosystem with characteristic physiochemical and associated abiotic and biotic parameters (Kuzo et al., 1978, Millard et al., 1978).

During this summer study, TRA pond limnology was characterized by physiochemical data and species types indigenous of a small pond ecosystem. The shallowness of the ponds prevented stratification of the various limnological parameters. Water temperature followed trends associated with the ambient air temperatures and although the water column was highly mixed, dissolved oxygen concentrations decreased with increasing water temperature as a result of decreased saturation levels. Changes in pH and conductivity, more likely, were influenced by changes in the characteristics of the effluent liquids released from TRA operations. For example, the low conductivity may have resulted from liquid effluent from TRA operations being passed through demineralizers prior to discharge into the ponds. The shallowness of the ponds and constant turbulence of the water column in late spring contributed bottom detritus to the seston mass early in the study. Later, the major contributing factor to the seston mass was the bloom of net plankton which occurred from mid-July until the termination of sampling. This plankton bloom of the green algae Spirogyra sp. showed classic sigmoid population growth characteristics. For the water temperatures recorded during the study period, mainly above 15°C , the increased dominance of green algae relative to other phytoplankton species, e.g., diatoms, was expected (Wetzel, 1975).

Table 2. Comparisons of concentration ratios among transuranic nuclides for Test Reactor Area pond components: Summer 1979.

Component	Comparisons (a)								
Seston	239,240pu	>	238pu	=	241Am	=	244Cm	=	242Cm
Net Plankton	239,240pu	>	238pu	=	241Am	=	244Cm	>	242Cm
Metaphyton	239,240pu	>	238pu	>	241Am	=	244Cm	>	242Cm
Zooplankton	239,240pu	>	238pu	>(b)	241Am	=	244Cm	=	242Cm
Periphyton	239,240pu	>	238pu	>	241Am	=	244Cm	>	242Cm
Sediments	239,240pu	=	238pu	>	241Am	=	244Cm	>	242Cm

(a) Results of sequential follow-up tests ($p \leq 0.05$ [Snedecor & Cochran, 1978, pp. 273-275])

(b) ^{238}Pu CR $> ^{244}\text{Cm}$ CR

Table 3 Observed and expected(a) transuranium pelagic(b) inventory estimates for selected sampling dates during the 1979 summer Test Reactor Area (TRA) leaching ponds study.

Nuclide	11 June Observed	Inventory [MBq (+ 1 SD)]		2 August Expected ^a
		2 August Observed		
^{238}Pu	2.8 (+ 1.4)	2.2 (+ 0.9)		0.63 (+ 0.22)
$^{239,240}\text{Pu}$	0.44 (+ 0.19)	0.67 (+ 0.21)		0.10 (+ 0.03)
^{241}Am	1.4 (+ 0.9)	1.4 (+ 0.5)		0.30 (+ 0.19)
^{242}Cm	2.5 (+ 0.5)	1.0 (+ 0.5)		0.44 (+ 0.09)
^{244}Cm	2.5 (+ 0.9)	2.3 (+ 1.0)		0.56 (+ 0.19)

(a) Calculations of expected inventories based on 11 June observed values and first order rate kinetics for loss of inventory from the ponds; effective rate constants:
 -0.029 d^{-1} for ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , ^{244}Cm , and
 -0.033 d^{-1} for ^{242}Cm .

(b) Pelagic inventory = filtered water inventory + seston inventory

The failure to find any ecosystem parameters which could be used to predict the changes observed for component transuranium concentrations through time may have resulted from several factors. Limnological characteristics other than those monitored have been shown to effectively influence transuranium element accumulation and/or kinetics in freshwater systems. The presence of anthropogenic or naturally occurring inorganic and/or organic ligands may have maintained the high level of transuranium elements in filtered water even at the pH values reported for the ponds. Bondietti, et al. (1976) discussed the importance of biogeochemical cycling mechanisms involving organic complexes (humic and fulvic acids) which maintain plutonium in forms which are potentially transferable to biota. Ligands of low molecular weight inorganic molecules and carbonate complexes also may enhance the solubilities of transuranium nuclides in aquatic ecosystems. For example, the relatively high solubilities of fallout plutonium and several naturally occurring actinides reported for Mono Lake, a saline and highly alkaline lake (pH ~10), were attributed to complexing of actinides with carbonate ions and/or low molecular weight inorganic ligands (Anderson et al, 1982; Simpson et al., 1980; 1982). Furthermore, the decreases in TRA pond filtered water nuclide concentrations may have resulted from sorption by increased numbers of phytoplankton cells during the study. Edgington et al. (1975) reported that plutonium concentrations in Lake Michigan surface waters decreased by a factor of three during the summer as a result of sorption by phytoplankton and subsequent settling of phytodetritus and zooplankton fecal pellets. Also, the changes in concentrations for individual samples may not have been large and consistent enough to determine statistically significant correlations and trends by regression analysis. Although the number of replicates and frequency of sampling were greater than in previous studies, the development of predictive models may require increased sample number and decreased within-date sampling variability prior to the determination of statistically significant relationships among the various ecosystem parameters.

One of the observed changes noted for filtered water, increased concentrations on 17 July, may have resulted from the release of contaminated effluent from TRA operations. Although levels were elevated for all nuclides excluding ^{242}Cm on this day, all transuranium concentrations returned to their previous or lower values by the following sampling period. Thus, with the termination of transuranium input, the concentrations decreased rapidly to previous levels.

In general, concentrations and concentration ratio data for these nuclides corroborate data from other aquatic studies. For instance, highest values were observed for seston. Many investigators have reported that the accumulation of these radionuclides by seston and phytoplankton principally was the result of surface adsorption (Folsom, et al., 1975; Hodge et al., 1974; Wong et al., 1975; Yaguchi et al., 1974). Seston in the TRA ponds, which is composed of both detrital and algal material and therefore has a large surface to volume ratio, was expected to have maximum transuranic concentrations and concentration ratio values. The relatively high periphyton CR's most likely resulted from adsorption of these nuclides on the bottom algal material and the settling of sestonic material onto this component.

Concentration ratios were similar among net plankton, metaphyton, and the zooplankton components for all nuclides. Values for net plankton and metaphyton were alike as a result of their similar species composition. Furthermore, the values obtained, in the 10^3 to 10^4 range, are similar to the range of values listed for plutonium in plankton from various natural (Noshkin, 1972) and contaminated aquatic ecosystems (Johnson et al., 1975). The concentration ratios for zooplankton were higher than expected. This component provided an estimate of transuranium nuclide accumulation in an upper trophic level organism for this system. In many freshwater and marine ecosystems studied, transuranium nuclides are discriminated against at successive trophic levels resulting in zooplankton CR values being lower than those of phytoplankton species (Marshall et al., 1975; Schell and Watters, 1975; Paine, 1980). This trophic level discrimination was not observed for zooplankton in the TRA ponds. The relatively high CR values of these transuranium nuclides in zooplankton compared to phytoplankton most likely resulted from a combination of surface adsorption phenomena and gut loading of contaminated food material. These elevated values could be explained by the zooplankton feeding mainly on the small organic detritus in seston which has the highest concentrations of these nuclides. Another factor which could enhance the uptake of these nuclides by upper trophic levels is the chemical species of these radionuclides in the pond system. However, additional studies of these components and trophic level transfer mechanisms are necessary prior to making definite conclusions.

Studies conducted in freshwater systems have determined that transuranium nuclides are ultimately concentrated in the sediments (Edgington, et al., 1976; Emery et al., 1978; Paine, 1980; Rees, et al., 1978). In this study sediment transuranium CR values were lower than values reported for other abiotic and biotic components. Similar results were reported for select γ -emitting radionuclides in the TRA Pond components, i.e., concentration ratios for sediments generally were lower than seston, periphyton, and zooplankton values (Millard et al., 1978). The low sediment CR values compared to other components in this pond reflect the bottom characteristics of the leaching system. As a result of their recent origin, frequent mixing of the entire water column by wind turbulence, and the large gravel material lining the sealed ponds, fine-grained bottom sediments have not developed as in many other systems. Where sampled, sediment material was composed primarily of particles with diameters greater than $180\text{ }\mu\text{m}$. This large particle size of sediments and the resuspension of fine-grained bottom detritus would decrease sediment concentration ratios relative to those for the periphytic components. Furthermore, during the study, the mat of periphyton covered the sediment, thus trapping settling particles in its matrix prior to reaching the sediments. This intermixing of detrital particles with the bottom algal layer, forming a mixture of living and dead material similar to seston composition, could explain the similar nuclide concentrations between the seston and periphyton components in this study.

Specific differences among the various nuclides within each matrix are difficult to explain. The increased concentrating effect noted for the plutonium isotopes may have resulted from the decreased solubility of these isotopes relative to americium and curium radionuclides in this system. For example, sorption to soil particles by these transuranium elements occurs in the following sequence: $Pu > Am = Cm$ (Watters et al., 1980). However, the consistently greater CR's for $^{239,240}Pu$ relative to ^{238}Pu and for ^{244}Cm relative to ^{242}Cm were not expected. A possible explanation for isotopic differences is that chemical speciation differed between these isotopes. These differences could have resulted from isotope-specific conditions under which these elements were produced and/or introduced into the system. Additional physiochemical analyses of these transuranium nuclides are necessary prior to making definite conclusions.

The TRA leaching ponds represent an ecosystem where there was continuous movement of water from the ponds into leaching areas of the three ponds. With the reported lack of transuranium input into the system from TRA operations one might have expected a decrease in the pelagic inventory of the ponds. This calculated decrease in pelagic inventory was not observed for any of the five transuranium nuclides. Thus, there must have existed other sources which released these nuclides into the water column. Potential sources include undetected releases from TRA operations, periphyton, and sediment. Of the two pond matrices, periphyton interfaced directly with the pelagic environs during the summer and could have served as a nuclide source through its frequent resuspension caused by turbulence in the water column. Other investigators have reported similar resuspension of bottom detritus to account for the steady-state fallout plutonium concentrations which occur in Lake Michigan waters (Wahlgren et al., 1974; 1975; 1976).

The TRA leaching ponds represent a controlled environment where an understanding of principles regulating the distribution of transuranium nuclides in a freshwater ecosystem can be sought. As this pond develops through its seral stages the kinetics and distribution of these transuranium nuclides within and among components should be investigated more fully in relation to changing abiotic and biotic parameters. Studied parameters should include more data concerning the chemical parameters of the system and the chemical speciation of these nuclides within it. Also, a more detailed investigation of the physical processes affecting transuranium nuclide accumulation, sedimentation, and remobilization within the ponds are needed. From such investigations, predictive models of transuranium nuclide behavior in this freshwater system may be made.

LITERATURE CITED

- Anderson, R. R., M. P. Bacon and P. G. Brewer. 1982. Elevated concentrations of actinides in Mono Lake. *Science*. 216:514-516.

- Ayers, A. L., Jr., R. N. Beatty, S. L. Friedericks, R. A. Morneau, D. E. Sheldon and F. A. Siedenstrang. 1977. Conceptual design report for TRA water recycle and pollution control. Phase II. Technical Report Number RE-77-149, EGG Idaho, Inc. 113 p.
- Bondietti, E. A., S. A. Reynolds and M. H. Shanks. 1976. Interaction of plutonium with complexing substances in soils and natural waters. In: *Transuranium Nuclides in the Environment*, IAEA-SM-199/51, IAEA, Vienna (ed.).
- Barracough, J. B., D. Lewis and R. G. Jensen. 1982. Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho emphasis: 1974-1978. U.S. Geological Survey Water-Supply Paper 1911, Alexandria, VA.
- Bulman, R. A. 1978. The movement of plutonium, americium, and curium through the food chain. *Naturwissenschaften*. 65:137-143.
- Doctor, G. R., G. Gilbert and J. E. Pinder. 1980. An evaluation of the use of ratios in environmental transuranic studies. *J. Environ. Qual.* 9:539-546.
- Eberhardt, L. L. and R. O. Gilbert. 1980. Statistics and sampling in transuranic studies. pp. 173-186. In: W. C. W. Hanson (ed.), *Transuranic elements in the environment*, DOE/TIC-22800, Washington, D.C.
- Edgington, D. N., M. A. Wahlgren and J. S. Marshall. 1975. The behavior of plutonium in aquatic ecosystem: a summary of studies on the Great Lakes. pp. 45-79. In: M. W. Miller and J. N. Stannard (eds.), *Environmental toxicity of aquatic radionuclides: models and mechanisms*, Ann Arbor Science.
- Edgington, D. N., J. J. Alberts, M. A. Wahlgren, J. O. Karttunen and C. A. Brever. 1976. Plutonium and americium in Lake Michigan sediments. pp. 493-516. In: *Transuranium nuclides in the environment*, IAEA-SM-199/47, IAEA, Vienna (ed.).
- Emery, R. M., C. K. Klopfer and M. C. McShane. 1978. The ecological export of plutonium from a reprocessing waste pond. *Health Phys.* 34:255-269.
- Folsom, T. R., V. F. Hodge and M. E. Gurney. 1975. Plutonium observed on algal surfaces in the ocean. *Marine Science Communication* 39:49-81.
- Gilbert, R. O. and R. R. Kinnison. 1981. Statistical methods for estimating the mean and variance from radionuclide data sets containing negative, unreported or less-than values. *Health Phys.* 40:377-390.
- Hanson, W. C. 1975. Ecological considerations of the behavior of plutonium in the environment. *Health Phys.* 28:529-537.
- Hodge, V. F., F. L. Hoffman and T. R. Folsom. 1974. Rapid accumulation of plutonium and polonium on giant brown algae. *Health Phys.* 27:29-35.

- Johnson, J. E., S. Svalberg and D. Paine. 1974. The study of plutonium in aquatic systems of the Rocky flats environs, Third Technical Progress Report. Dow Chemical Company No. 41493-F.
- Kuzo, G. B., L. Fraley, Jr. and O. D. Markham. 1978. Transuranic concentrations in selected biotic and abiotic components of the INEL Test Reactor Area ponds. pp. 15-27. In O. D. Markham (ed.). Ecological studies on the Idaho National Engineering Laboratory site. 1978 Progress Rep. IDO-12087. Nat. Tech. Inf. Serv., Springfield, VA.
- Marshall, J. S., B. J. Waller and E. M. Yaguchi. 1975. Plutonium in the Laurentian Great Lakes: food-chain relationships. Verh. Internat. Verein. Limnol. 19:323-329.
- Millard, J. B., F. W. Whicker and O. D. Markham. 1976. An ecological study of the Test Reactor Area Radioactive Leaching ponds. pp. 17-18. In O. D. Markham (ed.). 1975 Progress Report Idaho National Engineering Laboratory Site Radioecology-Ecology Programs. IDO-12080. Nat. Tech. Inf. Serv. Springfield, VA.
- Millard, J. B., F. W. Whicker and O. D. Markham. 1978. Gamma emitting radionuclides of the Test Reactor Area leaching ponds. pp. 28-46. In O. D. Markham (ed.) Ecological studies on the Idaho National Engineering Laboratory site. 1978 Progress Rep. IDO-12087. Nat. Tech. Inf. Serv. Springfield, VA.
- Morris, D. A., J. T. Barraclough, G. H. Chase, W. E. Teasdale and R. G. Jensen. 1964. Hydrology of subsurface waste disposal. USGS Annual Progress Report IDO-20047. 147pp.
- Noshkin, V. E. 1972. Ecological aspects of plutonium dissemination in aquatic environments. Health Phys. 22:537-549.
- Paine, D. 1980. Plutonium in Rocky Flats freshwater systems. pp. 644-658. In W. C. Hanson (ed.). Transuranic elements in the environment. DOE/TIC-22800.
- Price, K. R. 1973. A review of transuranic elements in soils, plants, and animals. J. Environ. Qual. 2:62-66.
- Rees, T. F., J. M. Cleveland and W. C. Gottschall. 1978. Dispersion of plutonium from contaminated pond sediments. Environ. Sci. Technol. 12(9) :1085-1087.
- Ryan, T. A., Jr., B. L. Joiner and B. F. Ryan. 1976. Minitab Student Handbook. Duxbury Press.
- Schell, W. R. and R. L. Watters. 1975. Plutonium in aqueous systems. Health Phys. 29:589-597.

- Simpson, H. J., R. M. Trier, C. R. Olsen, D. E. Hammond, A. Ege, L. Miller and J. M. Melack. 1980. Fallout plutonium in an alkaline, saline lake. *Science*. 207:1071-1073.
- Simpson, H. J., R. M. Trier, J. R. Toggweiler, G. Mathier, B. L. Deck, C. R. Olsen, D. E. Hammond, C. Fuller, and T. L. Ku. Radionuclides in Mono Lake, California. *Science*. 216:512-514.
- Snedecor, G. W. and W. G. Cochran. 1978. *Statistical Methods*. 9th ed. Iowa State University Press. Ames, Iowa.
- TRA Liquid Waste Summary, January through December 1979. INEL Waste Management Information System Sched. No. INF-6112-A. U.S. Energy Research and Development Administration, Idaho Operations Office.
- USDOE 1981. Requirements for radiation protection. USDOE Order 5480.1a, Chapter XI 36 p.
- Wahlgren, M. A. and J. S. Marshall. 1975. The behavior of plutonium and other long-live radionuclides in Lake Michigan. pp. 227-243. In Int. Atomic Energy Agency, Vienna (ed.). Impacts of nuclear releases into the aquatic environment. IAEA-SM-198/39.
- Wahlgren, M. A., J. J. Alberts, D.M. Nelson and K. A. Orlandini. 1976 Study of the behavior of transuranic and possible chemical homologues in Lake Michigan water and biota. pp. 9-24 In Int. Atomic Energy Agency, Vienna (ed.). Transuranium nuclides in the environment. IAEA-SM-199/44.
- Wahlgren, M. A. and D. M. Nelson 1974. Studies of plutonium cycling and sedimentation in Lake Michigan. *Proc. 17th Conf. Great Lakes Res.* 1974:212-218.
- Watters, R. L., D. N. Edgington, T. E. Hakonson, W. C. Hanson, M. H. Smith, F. W. Whicker and R. E. Wildung. 1980. Synthesis of the research literature. pp. 1-44. In W. C. Hanson (ed.). Transuranic elements in the environment. DOE/TIC-22800.
- Wetzel, R. G. 1975. *Limnology*. W. B. Saunders. Philadelphia, Pennsylvania.
- Wessman, R. A., M. Benz, B. Curry and L. Leventhal. 1976. Procedures for the Analysis of NAEG Small Vetebrate Samples. pp. 315-323 In M. G. White and P. B. Dunnaway (eds.). Nevada Applied Ecology Group Procedures Handbook for Environmental Transuranics. Report NVO-166.
- Wessman, R. A., K. D. Lee, B. Curry and L. Leventhal. 1976a. Transuranium Analysis Methodologies for Biological and Environmental Samples. LFE Reports, TLW-6155. Submitted for publication, Environmental Chemistry and Cycling Processes Symposium Proceedings, Savannah River Ecology Laboratory., University of Georgia, Aiken, S.C.

Wong, K. M., V. F. Hodge and T. R. Folsom. 1972. Plutonium and polonium inside giant brown algae. *Nature* 237:460-462.

Yaguchi, E. M., B. J. Waller and J. S. Marshall. 1974. Plutonium distribution in Lake Michigan biota. *Proc. 17th Conf. Great Lakes Res.* 1974:150-157.

UPTAKE OF γ -EMITTING RADIONUCLIDES BY SOILS PLACED IN TEST REACTOR LEACHING PONDS

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ABSTRACT

Uptake of 11 γ -emitting nuclides by two soil size fractions, $X < 45 \mu\text{m}$ and $75 < X < 180 \mu\text{m}$, placed in water permeable containers and suspended in reactor leaching ponds was determined. Using least-square regression analyses, curves were fitted to a polynomial model and uptake rates were determined for the nuclides in each soil size fraction. Excluding ^{40}K , soil nuclide concentrations continually increased during the 15 d study. For ^{54}Mn , ^{60}Co , ^{95}Zr , ^{95}Nb , and ^{144}Ce nuclides, uptake rate estimates were significantly ($P < 0.05$) higher in the smaller diameter soil size fraction. Individual nuclide uptake rates were constant throughout the study for ^{51}Cr , ^{54}Mn , ^{60}Co , ^{95}Zr , ^{95}Nb , ^{134}Cs , ^{137}Cs , and ^{144}Ce . For ^{131}I and ^{141}Ce nuclides, nuclide accumulation rates were constant from approximately 1 to 50 h and then decreased for the remainder of the experiment. Uptake rates were positively correlated ($P \leq 0.05$) with nuclide concentrations in filtered water and/or seston.

INTRODUCTION

Radioecological studies conducted at the Test Reactor Area (TRA) leaching ponds on the Idaho National Engineering Laboratory (INEL) have been concerned with the kinetics and distribution of both α - and β - γ -emitting radionuclides among various ecosystem components. Both fission and activation products are easily detected in ecosystem components, thus allowing comparative studies among nuclides. Experiments conducted at these ponds have determined the retention (Halford, et al., 1978) and the uptake and distribution of selected nuclides in waterfowl (Halford et al., 1981) and barn swallows (Millard et al., 1978). These studies have detailed system parameters necessary to evaluate the radiological impact of these nuclides on the organisms, the adjacent terrestrial ecosystem, and eventually on man.

In these ponds, sediment and plankton have the highest accumulations of both α - and β - γ -emitting radionuclides (Kuzo et al., 1978; Millard et al., 1978a). For these components, investigations of comparative radionuclide kinetics have not been conducted. Data collected using in situ techniques to determine and compare rates and uptake modes of these pollutants by these ecosystem constituents were needed. The objective of this study was to investigate the comparative uptake of γ -emitting nuclides by soils placed in the TRA ponds.

MATERIALS AND METHODS

The TRA leaching system consists of three ponds constructed in the Big Lost River alluvium on the INEL (Fig. 1). Ponds 1 and 2, constructed in 1952 and 1957 respectively, constitute a single body of water which is effectively sealed as a result of CaCO_3 precipitate and detritus on the bottom and sides of the pond (Morris et al., 1964). Capacity of these

Figure 1. Diagram of the Test Reactor Area (TRA) leaching ponds showing study area location.

filled ponds is approximately $2.9 \text{ E}+4 \text{ m}^3$ (Barracough, 1966). As a result of liquid input to these ponds from TRA operations, water flows through a Parshall overflow flume into Pond 3 which presently serves as the major leaching area of the system. During the experiment, continuous flow from the filled ponds to the leaching areas below the filled ponds or to pond 3 averaged $8.44 (+1.72) \text{ E}+2 \text{ m}^3 \cdot \text{d}^{-1}$, resulting in a 34 d mean residence time (τ) for water in Ponds 1 and 2 (Kuzo et al., this volume).

Water in this system of ponds consists of liquids with complex physicochemical and radiological properties. Low-level wastes (USD OE, 1981) released to the ponds contain both fission and activation products from TRA operations. White (1978) estimated that approximately $1.8 \text{ E}+6 \text{ GBq}$ ($4.8 \text{ E}+4 \text{ Ci}$) of β - γ activity has been released to the ponds since their construction. Estimates of α -activity released to the ponds have not been made.

The *in situ* soil uptake study of γ -emitting radionuclides was conducted from 7 through 22 August 1979. Soil used for the uptake experiment, having only background levels of γ -emitting nuclides, was collected from an undisturbed desert area approximately 8.0 km south of Howe, ID. Vegetation in the area was comprised of bluebunch wheatgrass *Agropyron spicatum*, Indian ricegrass *Oryzopsis hymenoides*, big sagebrush *Artemisia tridentata* and other characteristic species of the area (McBride et al., 1978). One meter square quadrats were placed randomly within the sampling area and 15 cm diameter by 5 cm deep cores were collected at each corner. Soil was mechanically dry-sieved

and two size fractions, $X < 45 \mu\text{m}$ and $75 < X < 180 \mu\text{m}$, were selected for the experiment. Soil organic matter, cation exchange capacity, extractable Mn and Fe, and texture were determined for each size fraction and the unsieved soil by the Colorado State University Soils Testing Laboratory.

Intermixing of sestonic particulates with experimental uptake materials was minimized by maintaining soils within polyethylene frustrum-shaped containers; 12 cm in depth, top and bottom diameters of 16.5 and 12.0 cm, respectively. Nitex bolting cloth affixed to the open ends of the containers excluded particles larger than $20 \mu\text{m}$ in diameter. To facilitate sampling, one end of the container was removable. Containers were suspended in Pond 2, approximately 0.5 m from the NE shoreline (Fig. 1) at depth of 1 to 2 m. This region was devoid of aquatic macrophytes but the bottom substrate was covered by a layer of periphyton.

Empty containers were placed within the pond 48 h prior to initiation of the experiment to allow γ -emitter concentrations to equilibrate between pond water and the containers. To place soils in the pond, 500 g of a soil size fraction were mixed with deionized water and the resulting slurry was poured into a container. Repeating this procedure, soils were placed in six containers, three for each soil size fraction. During the experiment, the suspended containers were agitated by turbulence in the water column. This movement continually mixed the soils, thus maximizing contact between water and the individual soil particles within the containers.

Soil samples, approximately 5 g aliquots, were collected from all containers at 1, 4, 11, 24, 48, 72, 144, 192, 240, and 360 h subsequent to initiation of the experiment. Sampling was terminated after 360 h because of noticeable algal growth within the experimental containers. Immediately following collection, samples were filtered to dryness using a filtering apparatus fitted with $0.45 \mu\text{m}$ pore size membrane filters. Samples were returned from the field to the laboratory where they were oven-dried for 48 h at 60°C or until a constant mass was obtained. For γ -emitter analyses, soil samples were encased in plastic bags and enclosed in 50 mm diameter and 9 mm deep plastic petri dishes.

To determine the effect of the experimental containers on water and seston nuclide concentrations within, two containers without soils were suspended in the pond. Water samples were collected from the containers on 7, 15, and 22 August 1979. For each date, samples from the containers were combined and filtered immediately through $0.45 \mu\text{m}$ pore size membrane filters and the resultant filtrate acidified to approximately 1 N using concentrated HCl. Water samples, 400 ml, were placed in glass containers for γ -emitter analyses. The filters, containing seston from within the experimental containers, were oven-dried for 48 h at 60°C or until a constant mass was obtained. Filters from each sampling date were encased in plastic and enclosed in plastic petri dishes for nuclide analyses.

Samples were analyzed for γ -emitter concentrations using a $65 \text{ cm}^3 \text{ Ge(Li)}$ crystal coupled to a multichannel analyzer. Average minimum detectable concentrations ($P < 0.05$) for the samples ranged from approximately 1.3 E-2 to $3.3 \text{ E-1 Bq} \cdot \text{g}^{-1}$ (3.5 E-1 to $8.9 \text{ E+0 pCi} \cdot \text{g}^{-1}$) for soils and 9.6 E-4 to $2.1 \text{ E-2 Bq} \cdot \text{cm}^{-3}$ (2.6 E-2 to $5.6 \text{ E-1 pCi} \cdot \text{cm}^{-3}$) for water.

A Hydrolab Surveyor Model 6D water quality analyzer was used to monitor water temperature, conductivity, dissolved oxygen, and pH. All measurements were made at a depth of 1.0 m, in the area of the pond where the containers were placed.

Only those γ -emitting radionuclides consistently detected in the experimental soils, i.e., detected in more than 50% of the samples, were included in statistical analyses. Other nuclides occasionally detected in filtered water, seston, and the experimental soils were not included in analyses because of their low frequency of occurrence.

For each radionuclide, changes in soil concentrations through time for the two size fractions were analyzed using linear regression analyses (Nie, et al., 1975). To quantitatively analyze uptake rates for the individual nuclides, the data were fitted to a zero intercept second-order linear model (Draper and Smith, 1966). For each nuclide, the data were fitted and tested for significant ($P \leq 0.05$) constant (linear) and/or changing (quadratic) uptake rates through time. Additionally, the model included terms to test for differences in uptake rates between the two size fractions. The model was as follows:

$$C_i = B_1 t_i + B_2 S_i t_i + B_3 t_i^2 + B_4 S_i t_i^2 + E_i$$

Where:

- C_i = Concentration of nuclide (i) in soil at time (t)
- B_i = Uptake rate estimates for nuclide (i)
- S_i = Dummy variable to test for effect of soil fraction
- t_i = Time interval subsequent to initiation of the experiment
- E_i = Random error term

Using data from all nuclides, the relationship of the estimated soil uptake rates to concentrations in filtered water and/or seston was analyzed. Because of the four orders of magnitude range of specific activity among nuclides, atom concentrations, herein defined as the number of atoms of each nuclide per unit mass, were utilized in analyses. Because of their high atom concentrations relative to the other nuclides, ^{51}Cr and ^{137}Cs had a large influence in preliminary statistical analyses and were considered as outliers (Ryan et al., 1976). That is, inclusion of data from these nuclides in the regression analyses for soil uptake rates as a function of either filtered water or seston atom concentrations resulted in correlation coefficients (r) of 100%. To weight these extreme concentrations relative to the other nuclides in the experiment, transformed data, i.e., the natural logarithm of the nuclide atom concentrations were utilized in these analyses.

RESULTS

Both size fractions of the experimental soils had low organic matter content, <3.0%, and similar cation exchange capacities, ranging from 22.3 to 23.4 meq $\cdot$ g $^{-1}$ (Table 1). Extractable Mn and Fe were elevated in each size fraction relative to the unsieved soil, most likely resulting from contamination of the soils by the metal sieving apparatus (CSU Soils Testing Laboratory, pers. comm.). The percentage of clay was similar among the

unsieved soil and the two size fractions. However, the percentage of sand and silt in the size fractions differed, with the $X < 45 \mu\text{m}$ fraction having a higher percentage of silt and the $75 < X < 180 \mu\text{m}$ fraction having a higher percentage of sand. Prior to placement in the ponds, only ^{40}K and ^{137}Cs nuclides, concentrations of $9.3 \text{ E-1 Bq} \cdot \text{g}^{-1}$ ($2.5 \text{ E+1 pCi} \cdot \text{g}^{-1}$) and $6.9 \text{ E-2 Bq} \cdot \text{g}^{-1}$ ($1.9 \text{ E+0 pCi} \cdot \text{g}^{-1}$) respectively, were detected in soils.

Physicochemical characteristics of the TRA pond water for 7 through 22 August are shown in Fig. 2. Both temperature, ranging between 21 to 22°C, and dissolved oxygen concentrations, ranging between 7.7 to 9.6 ppm, remained reasonably constant during the study. Conductivity decreased from 170 to 110 $\text{mho} \cdot \text{cm}^{-1}$. The pH of water was basic throughout the experiment, ranging from 9.7 to 10.3.

In general, concentrations of γ -emitting radionuclides in filtered water were in the $\text{mBq} \cdot \text{cm}^{-3}$ ($\text{fci} \cdot \text{cm}^{-3}$) to $\text{Bq} \cdot \text{cm}^{-3}$ ($\text{nCi} \cdot \text{cm}^{-3}$) range (Table 2). For each radionuclide, concentrations decreased between the start and termination of the experiment. Filtered water concentrations of ^{51}Cr , ^{131}I , and ^{141}Ce nuclides decreased in the successive sampling dates with effective half-lives of 15.7, 7.8 and 6.4 d, respectively. For ^{134}Cs and ^{137}Cs , concentrations were similar in the 7 and 15 August samples, but then decreased in the 22 August samples. Although detected on only two of the three sampling dates, concentrations of ^{60}Co decreased between successive collection dates and ^{95}Zr values were higher in 7 August than 22 August samples.

Seston nuclide concentrations ranged from $\text{kBq} \cdot \text{g}^{-1}$ ($\text{nCi} \cdot \text{g}^{-1}$) to $\text{MBq} \cdot \text{g}^{-1}$ ($\mu\text{Ci} \cdot \text{g}^{-1}$) in 7 and 22 August samples (Table 3). The seston sample from 15 August was lost prior to γ -emitter analyses and thus, concentration data for this date are not available. Two additional nuclides, ^{54}Mn and ^{144}Ce , that were not detected in filtered water were detected in seston. For all nuclides, excluding ^{131}I , concentrations decreased between the sampling dates. The failure to detect ^{131}I in the 7 August sample may have resulted from the time interval (> 5 half-lives) between sample collection and analysis.

For nuclides detected in both filtered water and seston samples, seston concentrations were 3 to 5 orders of magnitude greater than filtered water concentrations. For transformed data, seston concentrations were significantly correlated ($P \leq 0.05$) with filtered water concentrations (Fig. 3A). However, there were no significant ($P > 0.05$) trends between concentration ratios (CR's)^a and the individual nuclide atom concentrations (Fig. 3B). That is, excluding ^{131}I , seston CR's for the individual nuclides were similar, ranging from 10^5 to 10^6 . Only ^{131}I , which had the lowest CR value, 10^3 , varied from this trend as shown by its large (> 2.00) standard residual error computed in the regression analyses.

^a $\text{CR} = \frac{\text{Seston nuclide concentration (Activity} \cdot \text{g}^{-1} \text{ dry mass)}}{\text{Filtered water nuclide concentration (Activity} \cdot \text{cm}^{-3})}$

Table 1. Physicochemical properties of soils placed in the Test Reactor Area (TRA) leaching ponds.

Properties	Size Fraction		
	Unsieved	X < 45 μm	75 < X < 180 μm
Organic Matter (%)	2.7	2.2	3.0
Cation Exchange Capacity ($\text{Meq} \cdot \text{g}^{-1}$)	21.4	22.3	23.4
Extractable Mn (ppm)	3.6	31.2(a)	14.2(a)
Extractable Fe (ppm)	8.7	11.7(a)	11.9(a)
Sand (%)	29	14	45
Silt (%)	53	67	34
Clay (%)	18	19	21

(a) Elevated levels likely resulted from sieving apparatus contamination

Table 2. Gamma-emitting radionuclide concentrations in filtered water collected from experimental containers.

Radionuclide	Concentration(a) ($\text{Bq} \cdot \text{cm}^{-3}$)		
	7 August 1979	15 August 1979	22 August 1979
^{51}Cr	1.2 (0.03) E+2	7.8 (0.2) E+1	6.2 (0.2) E+1
^{60}Co	7.3 (0.6) E-2	7.0 (0.5) E-2	ND(b)
^{95}Zr	2.1 (0.7) E-2	ND(b)	1.4 (0.4) E-2
^{95}Nb	2.8 (0.3) E-2	2.1 (0.2) E-2	6.8 (2.0) E-3
^{131}I	9.3 (0.8) E-1	4.5 (0.3) E-1	2.7 (0.02) E-1
^{134}Cs	4.1 (0.6) E-2	4.7 (0.3) E-2	3.2 (0.3) E-2
^{137}Cs	1.1 (0.07) E-1	1.3 (0.06) E-1	7.1 (0.4) E-2
^{141}Ce	4.5 (0.3) E-1	3.0 (0.2) E-1	1.0 (0.01) E-1

(a) Concentration ($\pm$ 1SD) Counting Standard Deviation

(b) Not Detected

Figure 2. Limnological parameters of Test Reactor Area (TRA) leaching pond surface waters during the soil uptake experiment, 7 to 15 August 1979. (Note X-axis scales change at 100 h).

Table 3. Gamma-emitting radionuclide concentrations in seston collected from experimental containers.

Radionuclide	Concentration(a) (Bq · g ⁻¹)	
	7 August 1979	22 August 1979
⁵¹ Cr	1.7 (0.05) E+6	1.1 (0.03) E+6
⁵⁴ Mn	9.8 (1.9) E+2	4.3 (0.4) E+2
⁶⁰ Co	8.7 (0.5) E+3	2.9 (0.1) E+3
⁹⁵ Zr	5.5 (0.4) E+3	3.1 (0.1) E+3
⁹⁵ Nb	5.1 (0.3) E+3	2.3 (0.08) E+3
¹³¹ I	ND(b)	1.0 (0.09) E+3
¹³⁴ Cs	5.8 (0.4) E+3	2.3 (0.08) E+2
¹³⁷ Cs	1.8 (0.07) E+4	3.0 (0.1) E+3
¹⁴¹ Ce	2.3 (0.08) E+4	8.6 (0.4) E+3
¹⁴⁴ Ce	2.1 (0.2) E+4	8.6 (0.4) E+3

(a) Concentration (+ 1SD) Counting Standard Deviation

(b) Not Detected

Figure 3. (A) Seston nuclide concentrations and (B) seston concentration ratios as a function of filtered water nuclide concentrations in the Test Reactor Area (TRA) leaching ponds.

For ^{54}Mn , ^{60}Co , ^{95}Zr , ^{95}Nb , and ^{144}Ce , the estimated uptake rate parameters were significantly ($P < 0.05$) higher in the smaller diameter ($< 45\ \mu\text{m}$) soil size fraction (Table 4). For the other γ -emitting nuclides there were no significant ($P > 0.05$) differences in the uptake rates between the two size fractions.

To facilitate comparisons among nuclides, uptake parameter estimates were determined for the combined soil fractions (Table 5). Three general trends in soil nuclide uptake data, as illustrated by specific examples in Fig. 4, were observed. Concentrations of ^{40}K , the only radionuclide detected in soils but not detected in filtered water or seston samples, remained constant during the study (Fig. 4A). That is, the estimated rate of change in ^{40}K soil concentrations through time, $4.8 (+0.4) \text{ E}+13 \text{ atoms}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ (Table 5), was not significant ($P > 0.05$). All other nuclide soil concentrations increased significantly ($P \leq 0.05$) throughout the experiment but never reached equilibrium.

Table 4. Linear model regression coefficients for select nuclide uptake by soil size fractions^(a) placed in the Test Reactor Area (TRA) leaching ponds.

Radionuclide	Uptake Model Coefficients	
	$X < 45\ \mu\text{m}$	$75 < X < 180\ \mu\text{m}$
	Size Fraction ^b (Atoms $\cdot\text{g}^{-1}\cdot\text{h}^{-1}$)	Size Fraction ² (Atoms $\cdot\text{g}^{-1}\cdot\text{h}^{-1}$)
^{54}Mn	3.3 (0.3) E+4	1.6 (0.3) E+4
^{60}Co	2.6 (0.2) E+6	1.7 (0.2) E+6
^{95}Zr	2.4 (0.2) E+4	9.7 (1.6) E+3
^{95}Nb	3.2 (0.5) E+4	1.9 (0.3) E+4
^{144}Ce	4.6 (0.4) E+5	3.1 (0.4) E+5

(a) Significant differences between size fractions ($P < 0.05$).

(b) Linear model uptake coefficients ($\pm 1\text{SE}$), significant at $P < 0.05$ level.

Table 5. Polynomial model regression coefficients for nuclide uptake by soils^(a) placed in the Test Reactor Area (TRA) leaching ponds.

Radionuclide	Uptake Model Coefficients	
	Linear Term(b)	Quadratic Term(b)
	$B_1 + B_2$ (Atoms $\cdot g^{-1} \cdot h^{-1}$)	$B_3 + B_4$ (Atoms $\cdot g^{-1} \cdot h^{-1}$)
⁴⁰ K	4.8 (0.4) E+13*	
⁵¹ Cr	1.7 (0.1) E +7	
⁵⁴ Mn	4.5 (0.3) E+5	
⁶⁰ Co	2.2 (0.2) E+6	
⁹⁵ Zr	1.8 (0.2) E+4	
⁹⁵ Nb	3.3 (0.3) E+4	
¹³¹ I	2.5 (0.03) E+4	-4.8 (1.1) E+1
¹³⁴ Cs	2.4 (0.09) E+6	
¹³⁷ Cs	1.1 (0.05) E+8	
¹⁴¹ Ce	8.5 (0.1) E+4	-1.0 (0.4) E+2
¹⁴⁴ Ce	4.2 (0.3) E+5	

(a) Calculated for combined soil size fractions

(b) Coefficient values ($\pm$ 1SE), significant at P 0.05 level.

*Not Significant (P 0.05) for Table 4 and 5.

Figure 4. Uptake of selected radionuclides in the Test Reactor Area (TRA) leaching ponds: (A) ^{40}K , (B) ^{131}I , (C) ^{137}Cs .

Two trends in nuclide uptake for the combined soil size fractions were observed. For ^{51}Cr , ^{54}Mn , ^{60}Co , ^{95}Zr , ^{95}Nb , ^{134}Cs , ^{137}Cs (Fig. 4C), and ^{144}Ce nuclides, uptake rates were linear throughout the study, ranging from $1.8 (+0.2) \times 10^4$ to $1.1 (+0.05) \times 10^8 \text{ atoms} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ for ^{95}Zr and ^{137}Cs , respectively (Table 5). These linear uptake rates were significantly ($P < 0.05$) correlated with the nuclide concentrations in filtered water and/or seston (Fig. 5A-B). For ^{131}I (Fig. 4B) and ^{141}Ce , the concentration data were best fit using the two component uptake model, i.e., both linear and quadratic terms describing the data were significant ($P < 0.05$) (Table 5). For these nuclides the initial rates of accumulation from approximately 0 to 50 h were higher compared to their uptake rates during the remainder of the experiment.

DISCUSSION

In this study, concentrations of γ -emitting nuclides in filtered water were similar to values reported for samples collected in the fall season 1977 (Millard et al., 1978a). During this experiment, filtered water nuclide concentrations were not in equilibrium, i.e., concentrations consistently decreased. The effective half-lives calculated for ^{51}Cr , ^{131}I , and ^{141}Ce in filtered water were all less than the known physical half-lives. Several mechanisms, in combination with physical decay, could explain the decreasing filtered water nuclide concentrations during the experiment. For example, the rates and quantities of nuclide input to and loss from the water column were not known. Changing mass-to-volume ratios and composition of seston in the water column could influence the relative amount and specific nuclides removed from filtered water. Limnological parameters, e.g., decreasing conductivity in the ponds, also may have influenced the filtered water concentrations by changing sorption/desorption mechanisms between nuclides in filtered water and particulates suspended in the water column. Finally, assuming a 34 day average residence time (τ) for water in the filled ponds, substantial nuclide inventories are removed from the water. (Kuzo et al., this volume). Without subsequent nuclide input to the water column from TRA operations or other major pond components, e.g., sediments, the flow of water containing nuclides in dissolved and/or suspended forms to the leaching area would have decreased filtered water concentrations.

Seston concentrations of select γ -emitting radionuclides, excluding ^{137}Cs , were below values reported for samples collected in 1977 (Millard et al., 1978a). Seston concentrations of ^{137}Cs were similar to values from samples collected in fall 1977. The particle size for seston collected in this study ranged between 0.45 to $20 \mu\text{m}$ as a result of the pore sizes in the filtering apparatus and netting utilized in the experimental containers. Thus, comparisons to seston data from previous studies conducted during a different season and which included all particulates greater than $0.45 \mu\text{m}$ diameter suspended in the water column, may not be applicable. Also, these lower seston concentrations relative to previous studies could be the result of decreasing nuclide concentrations in filtered water. Although data were available for only two sampling dates, all seston nuclide concentrations decreased, thus indicating non-equilibrium conditions. As for the filtered water concentrations, non-equilibrium most likely resulted from a combination of factors; nuclide availability in the filtered water, changing seston mass and composition, and changing pond limnology.

Figure 5. Soil uptake rates for emitting nuclides as a function of (A) filtered water nuclide concentrations, and (B) seston nuclide concentrations in the Test Reactor Area (TRA) leaching ponds.

As expected, ^{40}K concentrations, a naturally occurring γ -emitting radionuclide in soils but not a contaminant in the ponds, remained unchanged. Concentrations of the other radionuclides in the soils increased during the experiment. A simplified uptake model for this experiment can be visualized as:

Where:

- $W(i)$ = Inventory of nuclide (i) in the water column
- $C(i)$ = Concentration of nuclide (i) in soil
- k_1 = Effective soil uptake rate constant of nuclide (i)
- k_2 = Effective soil loss rate constant of nuclide (i)

In the experiment, the source of nuclide input to soils, i.e., the total inventories in pond water (W_i), could be considered infinite relative to the quantities adsorbed by the soils. The small mass of the experimental materials would not be expected to greatly influence the concentrations of these nuclides in the pond. In the above model, the product of the effective uptake rate coefficients (k_1) and the source quantities (W_i) would be the controlling factors in the initial accumulation of nuclides by soils. Individual nuclide uptake rates were related to both filtered water and seston concentrations. Similar results have been reported for controlled laboratory experiments. For example, using tracer nuclide concentrations and unsaturated sediment materials, the equilibrium concentrations of ^{60}Co and ^{65}Zn in marine (Chester, 1965) and/or river (Murray and Murray, 1973) sediments were proportional to concentrations of the nuclides in water. This relationship between water concentrations and adsorption also may explain similarities in the seston CR's among the various nuclides.

Excluding ^{131}I and ^{141}Ce , the rate of nuclide accumulation was constant and thus, the effective loss of the individual nuclides from the experimental soils was minor relative to uptake during the 15 d experiment. The loss rate of the individual nuclides would be dependent on soil concentrations (C_i) and the magnitude of the effective loss rate constant (k_2). For ^{131}I and ^{141}Ce , having 8.05 and 32.5 d half-lives, respectively, the process of physical decay may have increased the effective loss rate of nuclides in the soils relative to the longer-lived nuclides and may explain, at least in the case of ^{131}I , the decreased accumulation rates approximately 50 h subsequent to initiation of the experiment. A similar decrease in nuclide accumulation was not observed for the 284 d physical half-life ^{144}Ce isotope, suggesting that physical decay rather than the nuclide chemistry explained the decreased rates of accumulation for ^{131}I and ^{141}Ce .

Because the uptake of most radionuclides by soils was entirely linear during the experiment, concentrations of γ -emitting nuclides at equilibrium could not be calculated. The experiment was stopped after 15 d because of noticeable algal and most-likely bacterial growth within the experimental containers. Aston and Duursma (1973) reported that microbiological

materials in sediments markedly affected sediment sorptive properties. However if this study was continued under constant conditions for an indefinite period of time, the concentrations for all nuclides in soils eventually would be expected to reach maximum levels and then decrease.

The observed differences between the nuclides which showed a soil size fraction effect in uptake rates and those that did not, may have resulted from characteristics of the soil size fractions and/or the individual nuclides. Surface area to volume ratios are greater for smaller grain size particles; however, similar physicochemical characteristics between the soil size fractions, especially cation exchange capacity, would be expected to minimize differences in adsorption. Other physicochemical soil properties which were not determined may also affect sorption/desorption mechanisms. For example, Duursma and Eisma (1973) reported that the surface area calculated from particle grain sizes did not equal the active surface area for marine sediments. In a laboratory study of the uptake of γ -emitting nuclides from seawater to various marine sediments, these investigators reported distribution coefficients (K_d 's) to be principally correlated with base exchange capacities of the sediments. If similar experiments are conducted in the TRA leaching ponds, soils and sediments of widely varying physicochemical properties would be expected to yield different rates of radionuclide accumulation for all the radionuclides.

Differences in uptake rate between the size fractions also may be affected by chemical properties influencing nuclide adsorption. Duursma and Eisma (1973) reported that sorption of ^{137}Cs by marine sediments was a pure ion exchange process, but for nuclides of ^{95}Zr , ^{95}Nb , ^{60}Co , ^{54}Mn , and ^{144}Ce , adsorption was primarily the result of precipitation or a combination of precipitation, ion exchange, and/or complex compound formation. Their study provided no data on the sorption mechanism(s) of chromium nor iodine. In our study, a significant soil size fraction effect was observed for ^{95}Zr , ^{95}Nb , ^{60}Co , ^{54}Mn , and ^{144}Ce but not for isotopes of Cs. Thus, similar adsorption chemistry phenomena may also affect the uptake of nuclides by soils in the TRA ponds. However, if these size effect differences between the two nuclide groups were entirely due to radionuclide chemical characteristics, a similar dichotomy among the nuclides also could be expected for seston concentration ratios. Such differences were not observed in this study.

In aquatic uptake studies, radionuclides are assumed to be adsorbed directly from the filtered water onto the uptake materials. However, this mechanism of uptake may not be applicable for ^{54}Mn and ^{144}Ce which were not detected in the filtered water. Assuming a seston CR range of 10^5 to 10^6 for these nuclides and then calculating the expected filtered water concentrations, ^{54}Mn data should be near minimum detectable concentrations but ^{144}Ce should have been easily detected in the samples. Hirano et al. (1975) reported that ^{144}Ce in seawater eventually formed particulates greater than $1.2\ \mu\text{m}$ in diameter, and at pH 6 and above, formed chemical complexes or polymers. Thus, the lack of ^{144}Ce in filtered water from the TRA ponds may be the result of interaction of nuclide and water chemistries. Additional studies on the concentrations and chemical speciation of ^{54}Mn and ^{144}Ce nuclides in filtered water using larger sample mass should be conducted.

In this study, the use of plankton netting in the containers minimized the mixing of large sestonic particulates, mainly comprised of the algae (*Spirogyra* sp. (Kuzo et al., this volume), with the experimental soils. However, as shown by the collection of seston in the experimental containers, the 20 μ m diameter netting did not eliminate seston entirely as a variable in the experiment. Thus, a second possible mechanism for nuclide accumulation in this experiment could be the adhesion of small sestonic particulates, 20 μ m diameter, to the soils. This mechanism would explain the uptake of ^{54}Mn and ^{144}Ce in the soils although these nuclides were not detected in filtered water.

To more thoroughly understand the uptake phenomena observed in this experiment, studies of pond limnology, the quantities and chemical speciation of these nuclides in filtered and unfiltered water, and the physical, chemical and radiological characterization of seston in the TRA ponds should be conducted. By using select barrier materials in the experimental container, e.g., differing size plankton netting and dialysis membrane materials, physical and chemical characteristics of the nuclides and experimental materials could be controlled in future studies. For example, the relative diameters of seston particles which mix with and possibly adhere to the experimental materials could be further decreased or even eliminated using finer plankton netting and/or dialysis membrane filters. Using select size dialysis membrane material, the molecular weight of radionuclides complexed to naturally occurring or anthropogenic chelating agents which enter the experimental containers could be controlled. Similar experiments have determined the molecular weight of complexing ligands which caused the elevated plutonium concentrations observed in Mono Lake, California (Simpson et al., 1982). However, in conducting experiments using a dialysis system to determine uptake through time, the effect of the barrier materials on the movement of water into the system and the rate of equilibrium must be examined (Dawson and Duursma, 1974). Using such experimental techniques, mechanisms influencing the kinetics and ultimate distribution of these elements in sediments and algal material of the system may be determined.

In this experiment we attempted to develop methodology for investigating the uptake of radionuclides by soils in a contaminated aquatic ecosystem. The large number of γ -emitting nuclides and the relatively rapid and easy analytical analyses of these nuclides make additional in situ studies at the TRA leaching ponds advantageous.

LITERATURE CITED

- Aston, S. R. and E. K. Duursma. 1973. Concentration effects on ^{137}Cs , ^{65}Zn , ^{60}Co and ^{106}Ru sorption by marine sediments, with geochemical implications. *Neth. J. Sea Res.* 6:225-240.
- Barracough, J. T., W. E. Teasdale, J. B. Robertson and R. G. Jensen. 1966. Hydrology of the National Reactor Testing Station, Idaho. USGS-File Report TID-4500.
- Chester, R. 1965. Adsorption of zinc and cobalt on illite in sea-water *Nature*. 206:884-886.

- Dawson, R. and E. K. Duursma. 1974. Distribution of radioisotopes between phytoplankton, sediment and sea water in a dialysis compartment system. *Neth. J. Sea Res.* 8:339-353.
- Duursma, E. K. and D. Eisma. 1973. Theoretical, experimental and field studies concerning reactions of radioisotopes with sediments and suspended particles of the sea Part C: Applications to field studies. *Neth. J. Sea Res.* 6:265-324.
- Draper, N. R. and H. Smith. 1966. Applied regression analysis. John Wiley and sons, Inc. New York. 407 p.
- Halford, D. K., J. B. Millard and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. *Health Phys.* 40:173-181.
- Halford, D. K., J. B. Millard and R. G. Schreckhise. 1978. Retention of activation and fission radionuclides by mallards from the Test Reactor Area Radioactive leaching ponds. pp. 56-63. *In* O. D. Markham (ed.). Ecological studies on the Idaho National Engineering Laboratory site. 1978 Progress Rep. IDO-12087. Nat. Tech. Inf. Serv., Springfield, VA.
- Hirano, S., T. Koyanagi and M. Saiki. 1973. The physico-chemical behaviour of radioactive cerium in sea water. pp. 47-55. *In* Int. Atomic Energy Agency, Vienna (ed.). Radioactive contamination of the marine environment. Symposium proceedings. 10-14 July 1972. Seattle. IAEA-SM-158/3.
- McBride, R., N. R. French, A. H. Dahl and J. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory site. IDO-12084 Technical Report. Nat. Tech. Inf. Serv., Springfield, VA.
- Millard, J. B., F. W. Whicker and O. D. Markham. 1978. Barn swallows nesting near radioactive leaching ponds in southeastern Idaho. pp. 1-14. *In* O. D. Markham (ed.). Ecological studies on the Idaho National Engineering Laboratory site. 1978 Progress Rep. IDO-12087. Nat. Tech. Inf. Serv., Springfield, VA.
- Millard, J. B., F. W. Whicker and O. D. Markham. 1978a. Gamma-emitting radionuclides of the Test Reactor Area leaching ponds. pp. 28-46. *In* O. D. Markham (ed.). Ecological studies on the Idaho National Engineering Laboratory site. 1978 Progress Rep. IDO-12087, Nat. Tech. Inf. Serv., Springfield, VA.
- Morris, D. A. J. T. Barraclough, G. H. Chase, W. E. Teasdale and R. G. Jensen. 1964. Hydrology of subsurface waste disposal. USGS Annual Progress Report. IDO-20047. 147 p.

- Murray, C. N. and L. Murray. 1973. Adsorption-desorption equilibria of some radionuclides in sediment-fresh-water and sediment-seawater systems. pp. 105-124. In Int. Atomic Energy Agency, Vienna (ed.). Radioactive contamination of the marine environment. Symposium proceedings, 10-14 July 1972. Seattle. IAE-SM-158/7.
- Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Brent. 1975. Multiple regression analysis: subprogram regression and special topics in general linear models. p. 320-397. In SPSS-Statistical Package for the Social Sciences. 2nd edition. McGraw-Hill New York, N.Y.
- Ryan, T. A., B. L. Joiner and B. F. Ryan. 1976. Minitab student handbook. Duxbury Press, North Scituate, Mass. 341 p.
- Simpson, H. J., R. M. Trier, J. R. Toggweiler, G. Mathieu, B. L. Deck, C. R. Olsen, D. E. Hammond, C. Fuller and T. L. Ku. 1982. Radionuclides in Mono Lake, California. Science. 216:512-514.
- USDOE 1981. Requirements for radiation protection. USDOE Order 5480.1a, Chapter XI 36 p.
- White, S. S. 1978. Radioactive waste management information 1977 summary and record to date. Radioactive Waste Programs Branch, Nuclear Fuel Cycle Division, Idaho Operations Office, IDO Report 10054(77).

EFFECT OF COOKING ON RADIONUCLIDE CONCENTRATIONS IN WATERFOWL TISSUES

Douglas K. Halford

ABSTRACT

Twenty-four commercially raised mallard ducks (*Anas platyrhynchos*) were released at the Test Reactor Area radioactive leaching ponds, and subsequently collected 56 to 188 days later. Liver, gizzard, and carcass were analyzed for radionuclide concentrations before and after cooking. Significant decreases ($P < 0.05$) in ^{137}Cs , ^{134}Cs , ^{60}Co , ^{140}La and $^{110\text{m}}\text{Ag}$ concentrations in carcass and liver samples occurred after cooking. Radionuclide concentrations in gizzard showed no significant change in radionuclide concentrations after cooking. Cesium-134 and ^{137}Cs concentrations decreased by 27% in carcass after cooking and reduced the dose commitment to man by that amount.

INTRODUCTION

Radiation doses to man consuming waterfowl tissues from birds using a liquid radioactive waste pond on the Idaho National Engineering Laboratory (INEL) have been documented (Halford et al., 1981). These doses were based on radionuclide concentrations in uncooked waterfowl; cooking was assumed not to alter radionuclide concentrations in tissue. However, literature indicates that some radionuclides may volatilize from muscle when exposed to heat (Martin and Blanchard, 1969) depending upon the chemical form (Anonymous, 1970). The effects of nuclide volatilization on radionuclide concentrations and the resultant dose to man ingesting contaminated tissues have not been assessed. Therefore I conducted a study to determine the effects of cooking on radionuclide concentrations in waterfowl tissue and the subsequent dose to man.

METHODS

The study was conducted at the Test Reactor Area (TRA) radioactive leaching ponds on the Idaho National Engineering Laboratory (INEL) site in southeastern Idaho. The TRA ponds have been used for the disposal of low-level liquid radioactive wastes from three experimental reactors (Halford et al., 1981).

Eight adult (4 male, 4 female) and 16 young (8 male, 8 female) mallard ducks (*Anas platyrhynchos*) were used in the study. All adults were wing-clipped and all birds were weighed and banded before release on the TRA ponds. Two to three ducks were collected periodically from December 1980 to June 1981. Duck residence time on the ponds ranged from 56 to 188 days. Three of 24 ducks were killed by predators and were not used in the study.

Birds were skinned, dissected and washed thoroughly. Carcasses were taken from all birds (21) and liver and gizzard were obtained from 16 ducks. Dissection tools were washed and changed with each tissue dissection to reduce cross contamination. Tissue samples were placed in

70-ml plastic vials, weighed and then analyzed for gamma emitting radionuclides on a 65 cm³ germanium-lithium crystal coupled to a computerized multichannel analyzer to determine radionuclide content. Carcasses (entire muscle and bone with skin and viscera removed) were placed in plastic bags, weighed, and whole body counted in a latex cylinder to analyze for radionuclide content (Morton et al., 1980). After analyses, the carcasses and corresponding liver and gizzard samples were placed together in an aluminum pan, covered with aluminum foil and baked for 60 min at 210 or 235°C (higher temperature was used when more than two carcasses were baked at one time). After cooking, the samples were again analyzed for radionuclide content as previously described.

Calculation of whole body and thyroid dose commitments to persons consuming cooked duck carcass, liver and gizzard were based on previous data (Halford et al., 1981). Doses were not calculated with radionuclide concentrations from the present study because the experimental ducks were on the TRA ponds much longer than wild ducks (Halford et al., 1982) and would result in much higher estimated doses than would occur from wild waterfowl using the ponds. Experimental waterfowl were left on the ponds for an extended period to enable sufficient buildup of radionuclides in tissue to enable detection before and after cooking. Formulae for dose calculations were from the International Commission on Radiological Protection (ICRP, 1959; ICRP, 1968). I assumed that waterfowl were killed and eaten the day they left the TRA ponds. Doses were based on consumption of entire muscle from the carcass, gizzard and liver mass, and only one contaminated duck was consumed by a person over a lifetime. Data were statistically analyzed with paired t-test and significance was $P < 0.05$.

RESULTS AND DISCUSSION

Ten radionuclides were detected consistently in waterfowl tissues before and after cooking (Table 1). Of those detected, ¹³⁷Cs, ¹³⁴Cs and ¹³¹I were previously determined to be the major dose contributors to man consuming waterfowl from the TRA ponds (Halford et al., 1981).

Most radionuclides had no decrease in concentration after cooking (Table 1). Cesium-137, ¹³⁴Cs, and ⁶⁰Co concentrations decreased significantly ($P < 0.05$) in all tissues but gizzard. Lanthanum-140 was detected only in carcass samples and showed a significant loss ($P < 0.05$) after cooking. Much of the loss of La can be attributed to radioactive decay because it was not decay corrected as were the other isotopes. It would be expected that radionuclides in the gizzard would behave similarly to muscle since gizzard is predominantly muscle tissue. However, there was no significant reduction ($P > 0.05$) of any radionuclide concentrations in gizzard after cooking. These results are currently unexplainable.

Doses originally calculated by Halford et al. (1981) for wild ducks collected from the TRA ponds during 1974 through 1978 were modified based upon the reduction of activity as a result of cooking as found in this study (Table 2). The average reduction of ¹³⁷Cs and ¹³⁴Cs loss in carcass (27%) was used to modify dose from duck muscle to man. Doses from eating liver were modified by the mean radionuclide loss (10%) after

Table 1. Radionuclide concentration loss by mallard tissue samples from the Test Reactor Area radioactive leaching ponds after baking.

Nuclide	Nuclide Concentration Loss (%)		
	Carcass (N = 21)	Gizzard (N = 21)	Liver (N = 16)
	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
Cs-137	27 + 7	NS	10 + 17
Cs-134	27 + 7	NS	10 + 17
La-140	21 + 12	ND	ND
Co-60	7 + 8	NS	49 + 13
I-131	NS ^a	ND	ND
Zn-65	NS	NS	NS
Se-75	NS	NS	NS
Hg-203	NS	NS	NS
Cr-51	ND ^b	ND	NS
Ag-110m	ND	ND	44 + 18

^a NS = No significant ($P \geq 0.05$) nuclide loss from tissue due to cooking.
All loss values were 1% or less.

^b ND = Not detected

Table 2. Ranges and mean whole body and thyroid doses^a to a person consuming one cooked mallard collected from the Test Reactor Area radioactive leaching ponds.

Tissue Consumed	Whole-body dose (mrad)		Thyroid dose (mrad) ^c	
	$\bar{X}$	Range	$\bar{X}$	Range
Muscle (carcass)	8(11) ^b	0.001 - 38(.001-50)	5	0 - 72
Liver	.9(1)	.02 - 4(.03-4)	2	0 - 14
Gizzard	1.5(1.5)	0.12 - 4(0.12-4)		^b
Muscle (carcass), liver and gizzard	10(13.5)	0.14 - 46(0.15-58)	7	0 - 86

^a Data modified from Halford et al., (1981).

^b () = doses before cooking. From Halford et al. (1981).

^c Thyroid doses were the same before and after cooking.

^d No ¹³¹I detected in gizzard samples.

cooking. Total dose to man including that contributed by gizzard was reduced 19% of that reported by Halford et al. (1981) (Table 2). The dose reduction would be 26% if gizzard was not ingested. No reduction occurred in thyroid dose because ^{131}I concentrations did not decrease.

The volatilized radionuclides (Cs, Co, La, Ag) could potentially be inhaled and contribute to internal dose as the ducks were cooking. The actual dose contributions from inhalation would be difficult to assess; however, it is likely to be an insignificant part of the dose to man.

Although data indicates that cooking does affect radionuclide concentrations in waterfowl tissue, it does not significantly ($P < 0.05$) reduce the dose calculated from uncooked tissues (Halford et al., 1981). Therefore, dose calculations from radionuclide concentrations in uncooked waterfowl tissue are viable estimators of dose received by man consuming contaminated waterfowl which have resided at the IRA ponds.

LITERATURE CITED

- Anonymous 1970. Handbook of chemistry and physics. CRC Press, Cleveland. 2356 p.
- Halford, D. K., J. B. Millard, and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. Health Physics 40: 173-181.
- Halford, D. K., O. D. Markham and R. L. Dickson. 1982. Radiation doses to waterfowl using a liquid radioactive waste disposal area. J. Wildl. Manage. 46: 905-914.
- International Commission on Radiological Protection. 1959. Permissible doses for internal radiation. ICRP Publication 2. Pergamon Press, Oxford. 233p.
- International Commission on Radiological Protection. 1968. Evaluation of radiation doses to body tissues from internal contamination due to occupational exposure. ICRP Publication 10. Pergamon Press, Oxford. 94p.
- Martin, A. and R. L. Blanchard. 1969. The thermal volatilisation of caesium-137, polonium-210 and lead-210 from in vivo labelled samples. The Analyst 94: 425-512.
- Morton, J. S., D. K. Halford, and D. Parker. 1980. A confinement device for the determination of whole body radionuclide concentrations in live ducks. Health Physics 38: 234-236.

RESIDENCE TIME, DISPERSAL, AND HARVEST
OF WATERFOWL USING A RADIOACTIVE LEACHING
POND IN SOUTHEASTERN IDAHO

Howard W. Browers, Jr. and Lester D. Flake

ABSTRACT

A study was initiated in the fall of 1980 to determine residence times, dispersal, and harvest of waterfowl using the Test Reactor Area (TRA) radioactive leaching pond complex on the Idaho National Engineering Laboratory (INEL) site. Attempts were made to capture and band waterfowl using the ponds during migration. Three common goldeneyes (Bucephala clangula) and six mallards (Anas platyrhynchos) were captured in the fall of 1980. Three mallards were also captured in the fall of 1981. Two bands have been recovered to date. In addition, daily observations were made from August to December 1980 and from October to December 1981 and the number and species of waterfowl were recorded. As of December 15, 1981, 665 waterfowl representing 14 species had been observed. However, the total number of waterfowl observed does not represent an accurate census due to recounts of some individuals.

INTRODUCTION

The radioactive leaching pond complex at the Test Reactor Area (TRA) is used primarily as a resting stop by migrating waterfowl. Halford et al. (1981) recorded over 3,100 waterfowl using the pond from January 1974 through March 1978. However, no information was gathered concerning residence times or dispersal of waterfowl using the TRA ponds.

The objectives of this study are to:

- (1) Examine pond residence times of waterfowl as related to radionuclide body burdens.
- (2) Evaluate dispersal patterns and harvest rates in waterfowl utilizing the TRA pond.

STUDY AREA

The TRA is located in the southwestern part of the Idaho National Engineering Laboratory (INEL). The TRA leaching ponds are used for disposal of low level liquid radioactive wastes.

Three ponds excavated in 1952, 1957, and 1964 comprise the leaching pond complex. At present, the ponds excavated in 1952 and 1957 constitute one continuous body of water with an area of 8200 m² and an average depth of 3.0 m. The 1964 pond is partially covered with shallow water which overflows from the first two ponds. The 1964 pond is a marshy area of about 1250 m² (Halford and Millard, 1978). The TRA pond area as well as the entire INEL is closed to sport hunting.

METHODS

Waterfowl were observed and counted each day from August to December 1980 and October to December 1981. Numbers of waterfowl, sex composition, and activities were recorded. We attempted to distinguish between unmarked waterfowl that were observed only once and those that were observed more than once. Flocks consisting of the same number of individuals and the same species composition were considered recounts if viewed on successive days.

Trapping took place from September to December 1980 and November to December 1981. Methods used consisted of mist nets and baited box traps. Two 3 x 13 m and 1, 3 x 18 m mist nets were joined end-to-end and suspended on 3 m poles. This assembly was stretched across the pond and secured in place so that most of the net was suspended over the water. Baited box traps were similar to those described by Joanen (1964). Several box traps were floated on the pond by attaching an individual box trap to a 1 x 2 m sheet of plywood. A 1 x 2 m sheet of 2.5 cm thick styrofoam was glued to the bottom of the sheet of plywood to float the traps. The traps were baited with wheat and cast adrift. Some box traps were not floated but were placed directly in shallow water or when the pond was partially frozen, the traps were placed on the ice near the pond edge and baited.

All captured waterfowl were banded and mallards were fitted with color coded nasal discs. Age and sex of waterfowl was determined according to Carney (1964) and the North American Bird Banding Manual, Volume 2 (U.S. Fish and Wildlife Service and Canadian Wildlife Service, 1977).

RESULTS AND DISCUSSION

Twelve ducks (three common goldeneyes and nine mallards) have been captured and banded as of December 15, 1981. Three goldeneyes and six mallards were captured in 1980. Three mallards were captured in 1981. Goldeneyes were captured with mist nets and mallards were captured in box traps.

A total of 665 waterfowl representing 14 species were observed from August through December 1980 and October through December 1981 (Table 1). The total number of waterfowl observed does not represent a true census figure since some unmarked individuals were probably recounted. We estimate that 410 of the 665 waterfowl (61.6%) were counted only once (Table 2).

The highest number of total observations of all waterfowl for each year occurred in December (Table 2). However, an estimated 87% and 74% of all waterfowl observed in December 1980 and 1981 respectively were recounts (Table 2). High numbers of mallards were observed in December of both years (Table 3). Observations of marked mallards revealed that several small flocks accounted for these large totals. Members of a group of 14 mallards were observed in different combinations nearly every day in December 1980. In 1981 a flock of 19 mallards was observed for three successive days in early December and a flock of six mallards was observed for six successive days later in the month.

Table 1. Numbers and species of waterfowl observed using the Test Reactor Area ponds from August to December 1980 and October to December 1981.

Species	Number Observed
Mallard (<u>Anas platyrhynchos</u>)	385
Cinnamon/Blue-winged teal ^a (<u>Anas cyanoptera</u> / <u>A. discors</u>)	87
Common goldeneye (<u>Bucephala clangula</u>)	41
Northern shoveler (<u>Anas clypeata</u>)	32
American green-winged teal (<u>Anas crecca</u>)	28
American wigeon (<u>Anas americana</u>)	23
American coot (<u>Fulica americana</u>)	14
Bufflehead (<u>Bucephala albeola</u>)	13
Pintail (<u>Anas acuta</u>)	5
Lesser scaup (<u>Aythya affinis</u>)	4
Ruddy duck (<u>Oxyura jamaicensis</u>)	3
Hooded merganser (<u>Mergus cucullatus</u>)	2
Gadwall (<u>Anas strepera</u>)	2
Redhead (<u>Aythya americana</u>)	1
Unknown	25
TOTAL	665

^aCinnamon and blue-winged teal were grouped together since most observed were either hens or drakes in eclipse plumage and therefore could not be positively identified.

Table 2. Monthly Observations of Waterfowl at the Test Reactor Area Ponds 1980-81.

Month	days	Total Number Observed ^a	Average Number waterfowl per observation day	Estimated Number of recounts ^b
1980				
August	17	99	5.8	8
September	17	64	3.7	1
October	25	52	2.0	7
November	19	106	5.5	6
December	23	186	8.0	161
TOTALS	101	507	5.0	183
1981				
October	14	17	1.2	0
November	16	43	2.7	0
December	11	98	8.9	72
TOTALS	41	158	3.8	72

^aThese totals do not represent accurate census figures since there were occasions when waterfowl remained on the pond longer than 1 day and were recounted.

^bWe attempted to distinguish between ducks using the ponds for the first time and those that had been observed more than 1 day. Estimates of recounts were based on flock size and species composition and reobservation of marked birds.

Table 3. Number of observations of each species of waterfowl for each month from August to December 1980 and October to December 1981 at the Test Reactor ponds.

Species	August	September	October	November	December
Mallard	3	0	19	105	258
Cinnamon/Blue-winged teal	51	19	16	1	0
Common goldeneye	0	0	4	16	21
Northern shoveler	6	20	5	1	0
American green-winged teal	21	6	0	1	0
American wigeon	2	7	5	2	7
American coot	13	1	0	0	0
Bufflehead	0	0	2	11	0
Pintail	0	0	2	3	0
Lesser Scaup	0	0	3	1	0
Ruddy duck	0	1	1	1	0
Hooded merganser	0	0	1	1	0
Gadwall	0	0	0	0	2
Redhead	0	1	0	0	0

Mallards will winter in the northern states if open water and food are available (Johnsgard, 1975; Bellrose, 1976). During December the TRA pond area supplied both of these needs for the small flocks of mallards present. The periodic inflow of water from the reactor facilities kept the pond at least partially open. Wheat placed in and around the traps as bait provided a food source. Wheat was also being used to feed a small flock of captive mallards being used for another study in 1981 (Halford, this volume).

Accurate residence times for months other than December were difficult to determine due to low numbers of marked birds. We assumed a bird's residence time to be 1 day unless it was considered a recount. Prior to December, only 6% of the total number of waterfowl observed for both years were estimated to be recounts. Thus, 94% of the total number of waterfowl observed before December used the TRA pond for 1 day or less. Species other than mallards comprised 67% of the total number of waterfowl observed prior to December for both years (Table 3).

Two bands (16.7%) have been recovered to date. An adult drake mallard banded on December 7, 1980 was shot 185 km southwest of the INEL site on January 10, 1981. This recovery came from Hagerman Wildlife Management Area on the Snake River. This drake was observed on the TRA ponds every day after capture until it was last seen on December 24, 1980. An adult drake mallard banded on December 11, 1981 was shot 180 km southwest of the INEL on December 25, 1981. This drake was last seen on the TRA ponds on December 12, 1981 but was believed to have been on the pond 4 days preceding its capture.

Data collected thus far suggest that most waterfowl do not use the TRA pond area for more than 1 day. The longer residence times of mallards can be attributed in part to the availability of wheat used as bait for capture and as food for the 1981 experimental mallard flock. When these studies have ended and this food source removed, future mallard residence times should be reduced.

The small sample size of banded birds precludes drawing conclusions concerning dispersal of waterfowl visiting the TRA ponds even though the two recoveries came from the same general area. However, Idaho Fish and Game personnel have determined that the majority of banded mallards in southeastern Idaho winter on the Snake River from 69 to 331 km south and west of the INEL. Most of the mallard harvest comes from this area of the state. (Dick Norell, personal communication). Our band recoveries also came from this area.

Halford et al. (1981) have determined that the potential whole-body radiation dose to man from harvesting a contaminated duck averaged 2.5% (12 mrem) of the recommended 500 mrem/yr maximum whole-body dose commitment for an individual in the general population (International Commission on Radiological Protection, 1959). They also determined that the entire muscle and liver mass of a contaminated duck would have to be consumed for a person to receive the 12 mrem average whole-body radiation dose. Based on the low contamination potential for humans and the relatively low numbers of waterfowl using the TRA, we see no hazards to waterfowl hunters and others

consuming wild waterfowl in southeastern Idaho. If the project is continued, we recommend intensive late fall, winter, and spring banding efforts over a period of several years.

LITERATURE CITED

- Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 544 p.
- Carney, S. M. 1964. Preliminary keys to waterfowl age and sex identification by means of wing plumage. U.S. Fish and Wildl. Serv. Spec. Sci. Rep., Wildl. 82. 47 p.
- Halford, D. K. and J. B. Millard. 1978. Vertebrate fauna of a radioactive leaching pond complex in southeastern Idaho. Great Basin Natur. 38:64-70.
- Halford, D. K., J. B. Millard and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid waste disposal area and the potential radiation dose to man. Health Physics 40:173-181.
- International Commission on Radiological Protection. 1959. Permissible doses for internal radiation. ICRP Publication 2, Pergamon Press, Oxford. 94 p.
- Joanen, T. 1964. Methods and trap designs for lesser scaup in Louisiana. Proc. Annu. Conf. S. E. Assoc. Game and Fish Comm. 18:106-109.
- Johnsgard, P. A. 1975. Waterfowl of North America. Indiana University press, Bloomington. 575 p.
- U.S. Fish and Wildlife Service and Canadian Wildlife Service. 1977. North American Bird Banding Manual, Volume II: Bird Banding Techniques. Populations and Surveys Div., Can. Wildl. Serv., Ottawa.

TRACE ELEMENT CONCENTRATIONS IN DIFFERENT TROPHIC LEVELS
NEAR THE SITE OF A FUTURE COAL-FIRED POWER PLANT
AND RELATED FACILITIES

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ABSTRACT

During summer 1981 soil, vegetation, herbivore tissue, coyote feces and raptor casting, feather, shell and tissue samples were collected near the Idaho National Engineering Laboratory Chemical Processing Plant, the site of a future coal-fired plant. Samples were also collected at two control areas in Idaho and in the vicinity of two already existing coal-fired plants. All samples were analyzed for Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P (PO₄), K, Si (SiO₂), Ag, Na, Sr, Sn, V, Zn, F, Hg, and Se. Primary research objectives are to determine: 1) currently existing levels of trace elements in the INEL environment prior to coal plant operations; 2) possible biomagnification of trace elements in various terrestrial ecosystem components; 3) differences in trace element concentrations within each media at varying distances and directions from the coal-fired plants; and 4) which tissues are good indicators of elemental concentrations.

INTRODUCTION

In recent years increased levels of various trace elements have been detected in the environment as a result of fossil-fuel power facilities, ore smelters, municipal incinerators and automobile emissions (Natusch et al., 1974; Lee et al., 1975; Klein et al., 1975; Connor et al., 1976; Phung et al., 1979; Wangen and Turner, 1980). Emissions from coal-fired plants can be responsible for the addition of a significant quantity of the trace metal burden to the atmosphere (Lee et al., 1975).

Particles ranging from 0.01 to 100 μ m in diameter are released during coal combustion at power plants. Emission control devices can be very efficient (>99%) in removing the large particles from stack emissions (USF&WS, 1978); however, a large portion of the materials that are released from coal-fired facilities are comprised of small particles (<20 μ m) (Lee et al., 1975; Schulz et al., 1975) and vapors which can be transported great distances in the atmosphere and which have the greatest potential environmental impacts (USF&WS, 1978). Certain trace elements in coal, particularly Pb, Cd, Zn, Cr, V, Ni, Mn, Sb, and Cu, are preferentially concentrated on small particles (Lee et al., 1975; Natusch et al., 1974; Klein et al., 1975; Davison et al., 1974). In addition, some trace elements (Hg, Se, As, Br and Cl) are released from power plants partially and sometimes primarily as a gas (USF&WS, 1978).

Studies on environmental enrichment of trace elements near coal-fired plants have produced varying results. Cannon and Swanson (1975) reported that increases in some trace elements in certain environments could have beneficial effects. Bolton et al. (1973), Vaughan et al. (1975), Bradford et al. (1978), Wangen and Williams (1978)

and Crockett and Kinnison (1979) found little or no elemental increases that could be attributed to power plant emissions. However, a number of researchers have reported trace element enrichment in soil and vegetation that they related to atmospheric emissions from coal-fired facilities (Klein and Russell, 1973; Anderson et al., 1975; Connor et al., 1976; Horton et al., 1977; Wanger and Turner, 1980).

Little data have been collected to examine elemental enrichment in several ecosystem components simultaneously. Additionally, information is lacking on long-term build up of these trace minerals in terrestrial ecosystems (USF&WS, 1978; Turner and Strojan, 1978).

The planned construction of a coal-fired plant on the Idaho National Engineering Laboratory (INEL) in southeastern Idaho has provided a unique opportunity to study trace element concentrations in ecosystem components and to document potential environmental effects of atmospheric emissions from this coal-burning facility. Therefore, research studies were initiated at the INEL in summer 1981 to: 1) monitor trace element concentrations in various ecosystem components before and during operation of a coal-fired steam generation plant; 2) provide control samples from nearby unimpacted areas for comparison with the INEL environment; 3) document levels and variability of trace element concentrations in various ecosystem components as a function of distance and direction from existing coal-fired electrical generating facilities and the INEL, and 4) compare concentrations of trace elements in various animal tissues to determine the most appropriate tissue media for monitoring trace element build-up in wildlife populations.

STUDY AREA

The study was conducted in five locations, three of which are in Idaho. The INEL is the future site of a coal-fired plant which will be operational by 1984. This facility will be built adjacent to the Idaho Chemical Processing Plant (ICPP) which has reprocessed and recovered uranium from spent nuclear fuels since the mid-1950's. In addition to releases of low level radioactive effluents and SO_x and NO_x into the atmosphere, trace elements have likely been emitted during nuclear fuel reprocessing. Twin Falls and Lemhi County, Idaho were selected for control areas since both are assumed to be relatively free of industrial pollutants. All three Idaho sampling locations are representative of a cold desert ecosystem with big sagebrush (Artemisia tridentata) the dominant vegetative species.

To determine which media are best suited for a long-term monitoring of trace element concentrations in various ecosystem components and to assess possible changes which will occur on the INEL as a result of the coal-fired facility, two other sampling locations at coal-fired plants were selected: Four-Corners Power Plant (Fruitland, New Mexico) and the Jim Bridger Thermal-Electrical Generation Project (Point of Rocks, Wyoming). These facilities have been in operation since 1963 and 1974,

respectively, and descriptions of each facility have been reported by Wanger and Williams (1978) and U.S. Department of Interior (1972). The Jim Bridger Project is located in a cold desert ecosystem where big sagebrush predominates, while around the Four-Corners Plant, Atriplex spp. are the most commonly occurring vegetation.

METHODS

Field sampling was conducted between May and August 1981. Sampling lines were selected at the INEL, Jim Bridger, and Four Corners based on annual wind plume characteristics obtained from environmental impact statements and National Oceanic and Atmospheric Administration (NOAA) records. Three transect-lines were selected at the Four-Corners Plant and Jim Bridger Project while four transect-lines were selected at the INEL (Fig.1). Two of the sampling lines chosen (three at the INEL) were in the center of the predominant downwind plumes while the third was selected upwind of the facilities. Sampling stations were selected at 1, 2, 5 and 10 kms. Because there was no point source of environmental pollutants at the two Idaho control areas, only one sampling line was selected and five sampling stations approximately 500 m apart were chosen along each line.

Variability of trace element concentrations at each sampling station were determined, by collecting soil and vegetation samples at each of three sites: one at the center of the sampling line and one 50 m in each direction perpendicular to the line.

Surface soil samples (0-2.5 cm) were collected at each sample site by removing five 260 cm³ samples with an aluminum trowel. Four of the samples were taken at each of the corners and one from the center of an approximate 10 m square. The samples were composited, mixed in a plastic bag and an aliquot of 400 ml subsampled. When the sampling site occurred in a disturbed area, we selected a nearby undisturbed site. The trowel was rinsed with demineralized water between samples to minimize sample cross-contamination.

Vegetation samples were collected from dominant shrubs (400 ml) and grasses (70 ml). Because of the difficulty in collecting a complete sample of annual growth from the xerophyllic vegetation, we usually collected material from several plants of the same species. When vegetation was unavailable on a sampling plot, samples were collected as close to the plot as possible (within: 50 m). Big sagebrush was the primary shrub collected at all study areas except Four Corners where Atriplex spp. predominated. Bluegrass (Poa spp.) and bottlebrush (Sitanion hystrix) were the dominant grasses collected at the INEL and in Twin Falls and Lemhi Counties. At Jim Bridger squirreltail bottlebrush was the main grass sampled and alkali sacaton (Sporobolus airoides) and Indian ricegrass (Oryzopsis hymenoides) were collected at Four Corners.

Figure 1. Diagram of soil, vegetation, and animal tissue sampling transect lines at INEL, Jim Bridger Thermal-Electrical Generation Facility, Wyoming and Four Corners Power Plant, New Mexico.

To determine whether elemental concentrations of vegetation were due to surficial contamination or uptake processes, some shrub and grass samples were split and one-half washed in an ultrasound bath for at least 30 minutes. Student's t-test procedures will be used to evaluate elemental concentrations between washed and unwashed samples.

Tissue samples (muscle, bone, hair, and liver) were taken from all mammals collected. Black-tailed jack rabbits (Lepus californicus) were collected at stations along transect lines at the INEL and at the two control areas in Idaho. Pronghorn antelope (Antilocapra americana), badger (Taxidea taxus), cottontail rabbit (Sylvilagus spp.), white tailed jack rabbits (Lepus townsendii), white tailed prairie dog (Cynomys ludovicianus), and Richardson's ground squirrel (Spermophilus richardsonii) tissue samples were collected opportunistically, but as close to transect lines and stations as possible. Tissue samples consisted of: a 70 ml hair sample collected from the dorsal area, 400 ml each of leg muscle and liver tissue, and a bone sample (femur or metacarpus).

Fresh coyote (Canis latrans) feces were collected opportunistically but were mainly sought along transect lines at each study location. Raptor nests were sought near transect lines at all locations except Four Corners. Any castings (regurgitated hair and bone), egg shells or addled eggs found in or around each nest site were collected. Feathers found around and in nests, most of which were molted feathers from adult nesting birds were also collected.

All coyote scats, raptor castings egg shells muscle, liver, bone and hair samples were ultrasound washed in a demineralized water bath, and were oven-dried at 65°C for 72 hours.

Trace element analyses were conducted at a commercial laboratory. Samples were ground and blended, digested with nitric and perchloric acids and analyzed for Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P (PO₄), K, Si (SiO₂), Ag, Na, Sr, Sn, V, Zn by an inductively coupled argon plasma spectrograph. Mercury was analyzed by vapor analysis, Se by hydride atomic absorption, and F by electrode analysis.

To determine gamma-emitting radionuclide concentrations in different ecosystem components near the ICPP, soil, vegetation, jack rabbit tissue and coyote scat samples from the INEL were analyzed for gamma-emitting radionuclides on a 65 cm³ germanium-lithium crystal coupled to a computerized multichannel analyzer. A similar analysis was performed on soil samples collected around the Jim Bridger and Four Corners study areas.

Where several tissue samples were collected from the same animal, multiple linear regression techniques will be used to determine statistical differences in trace element concentrations among the

tissues. In addition, two-way analysis of variance will be used to detect significant changes in concentrations as functions of varying distances and directions from the coal-fired facilities.

RESULTS

Soil, vegetation and raptor nest site samples were collected by July 1981. Material from one golden eagle (Aquila chrysaetos), three ferruginous hawk (Buteo regalis) and three prairie falcon (Falco mexicanus) nests were collected in the vicinity of the Jim Bridger Facility. In the Lemhi Valley, material from one golden eagle nest, two red-tailed hawk (Buteo jamaicensis) nests and one great horned owl (Bubo virginianus) nest was collected. At the Twin Falls control area, material was collected from three great horned owl roosts and from one nest of each of the following species: Swainson's hawk (Buteo swainsoni), red-tailed hawk, ferruginous hawk, long-eared owl (Asio otus), marsh hawk (Circus cyaneus) and golden eagle. At the INEL, samples were collected from two golden eagle, three ferruginous hawk, two red-tailed hawk, three Swainson's hawk, one prairie falcon and one great horned owl nest.

In fall 1981, tissue samples from hunter harvested or road-killed pronghorn antelope were collected at the Jim Bridger Facility (n = 6), the INEL (n = 10) and near the control lines in Lemhi, Idaho (n = 7). Muscle, liver, hair and bone samples from two road-killed badgers were also collected on the INEL. In addition, muscle, liver, bone and feather samples from road-killed raptors (two American rough-legged hawks (Buteo lagopus), eight golden eagles, and one red-tailed hawk) on the INEL were collected throughout the following winter.

Many of the samples collected have already been analyzed for trace elements and the results logged into a computer. To date, 700 different samples have been analyzed and placed on computer file. Upon completion of the remaining sample analyses and statistical treatment of data, final results of this project will be published in the open literature and in Idaho Operations Office technical documents.

LITERATURE CITED

- Anderson, B.M., J.R. Keith and J.J. Connor. 1975. Antimony, arsenic, germanium, lithium, mercury, selenium, tin and zinc in soils of the Powder River Basin. P. 50-57. In Geochemical Survey of the Western Coal Regions, Second Annual Progress Report, U.S.G.S. Report No. 75-436.
- Bolton, N.E., R.I. VanHook, W. Fulkerson, W.S. Lyon, A.W. Andren, J.A. Carter and J.F. Enery. 1973. Trace element measurements at the coal-fired Allen Steam Plant, Progress Report, June 1971-January 1973 USAEC Report ORNL-NSF-EP-43, Oak Ridge National Laboratory, National Technical Information Service, 80 p.

- Bradford, G.R., A.L. Page, I.R. Straughan and H.T. Phung. 1978. A study of the deposition of fly ash on desert soils and vegetation adjacent to a coal-fired generating station. P. 383-393. In D.C. Adriano and I.L. Brisbin (eds.) Environmental Chemistry and Cycling Processes, ERDA Symposium Series, CONF-760429.
- Cannon, H.L. and V.E. Swanson. 1975. Contributions of major and minor elements to soils and vegetation by the coal-fired Four Corners Power Plant, San Juan County, New Mexico, U.S.G.S. p. 75-110.
- Connor, J.J., J.R. Keith and B.M. Anderson. 1976. Trace-metal variation in soils and sagebrush in the Powder River Basin, Wyoming and Montana. Jour. Res. U.S. Geol. Survey 4:49-59.
- Crockett, A.B. and R.R. Kinnison. 1979. Mercury residues in soil around a large coal-fired power plant. Environ. Sci. Technol. 13:712-715.
- Davison, R.L., D.F.S. Natusch, J.R. Wallace and C.A. Evans. 1974. Trace elements in fly ash: dependence of concentration on particle size. Environ. Sci. Technol. 8:1107-1113.
- Horton, J.H., R.S. Dorsett and R.E. Cooper. 1977. Trace elements in the terrestrial environment of a coal-fired powerhouse. DP-1475 Savannah River Laboratory, Aiken, S.C. 49 p.
- Klein, D.H., A.W. Andren and N.E. Bolton. 1975. Trace element discharges from coal combustion for power production. Water, Air, Soil Pollut. 5:71-77.
- Klein, D.H. and P. Russell. 1973. Heavy metals: fallout around a power plant. Environ. Sci. Technol. 7:357-358.
- Lee, R.E., H.L. Crist, A.E. Riley and K.E. MacLeod. 1975. Concentration and size of trace metal emissions from a power plant, a steel plant, and a cotton gin. Environ. Sci. Technol. 9:643-647.
- Natusch, D.F.S., J.R. Wallace and C.A. Evans. 1974. Toxic trace elements: preferential concentration in respirable particles. Science 183:202-204.
- Phung, H.T., L. J. Lund, A. L. Page and G.R. Bradford. 1979. Trace elements in fly ash and their release in water and treated soils. J. Environ. Qual. 8:171-175.
- Schulz, E.J., R.B. Engdahl and T.T. Frankenberg. 1975. Submicron particles from a pulverized coal-fired boiler. Atmos. Environ. 9:111-119.
- Turner, F.B. and C.L. Strojan. 1978. Coal combustion, trace element emissions, and mineral cycles. P. 34-58. In D.C. Adriano and I.L. Brisbin (eds.) Environmental Chemistry and Cycling Processes, ERDA Symposium Series, CONF-760429.

United States Department of Interior, Bureau of Land Management. 1972. Final environmental statement for the Jim Bridger thermal-electric generation plant.

United States Fish and Wildlife Service. 1978. Impacts of coal-fired power plants on fish, wildlife and their habitats. Biological Services Program, Wash., D.C. FWS/OBS-78/29. 260 p.

Vaughan, B.E., K.H. Abel, D.A. Cataldo, J.M. Hales, C.E. Hane, L.A. Rancitelli, R.C. Routson, R.E. Wildung and E.G. Wolf. 1975. Review of potential impact on health and environmental quality from metals entering the environment as a result of coal utilization. Report NP-20585, Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA. 75 p.

Wangen, L.E. and F.B. Turner. 1980. Trace elements in vegetation downwind of a coal-fired power plant. Water Air and Soil Pollut. 13:100-108.

Wangen, L.E. and M.D. Williams. 1978. Elemental deposition downwind of a coal-fired power plant. Water, Air, Soil Pollut. 10:33-44.

PUBLICATIONS

IDAHO NATIONAL ENGINEERING LABORATORY RADIOECOLOGY AND ECOLOGY PROGRAMS

- Markham, O. D. 1973. National Reactor Testing Station environmentally related publications. IDO-12078. Idaho Operations Office. 11 p.
- Markham, O. D. 1974. Radioecology of Idaho National Engineering Laboratory - radioecology and the ecology programs at Idaho National Engineering Laboratory. P. 33-34. In National Environmental Research Park Symposium. Idaho Falls, ID.
- Johnson, D. W. 1974. Fisheries research at Idaho National Engineering Laboratory. P. 44. ibid.
- Rucker, R. L. 1974. The home range of the coyote on the Idaho National Engineering Laboratory. P. 49. ibid.
- Markham, O. D. 1974. Environmental and radiological monitoring at the National Reactor Testing Station during FY-1973. Rad. Data and Reports 15:227-246.
- Markham, O. D. (Ed.). 1976. Summaries of the Idaho National Engineering Laboratory Site Ecological Information Meeting July 10-11, 1975. IDO-12079. National Technical Information Service, Springfield, VA. 68 p.
- Powers, L. R. and T. H. Craig. 1976. Notes on the status of nesting ferruginous hawks (Buteo regalis) in Little Lost River Valley and vicinity, southeastern Idaho. Murrelet 57:46.
- Markham, O. D. (Ed.). 1976. 1975 Progress report Idaho National Engineering Laboratory Site radioecology-ecology programs. IDO-12080. Idaho Operations Office. National Technical Information Service, Springfield, VA. 205 p.
- Markham, O. D., R. Autenrieth and R. Hoskinson. 1976. Concentration of radionuclides in tissue of antelope on and near the Idaho National Engineering Laboratory Site. P. 63-64. In Proc. 7th Biennial Pronghorn Antelope Workshop. Twin Falls, ID.
- Craig, T. H. and F. Renn. 1977. Recent nesting of the Merlin in Idaho. Condor 57:392.
- Johnson, W. C. 1977. Examination of censusing techniques for small mammals in a high desert ecosystem. M.S. Thesis. Idaho State Univ., Pocatello, ID. 95 p.
- Johnson, M. K. and R. M. Hansen. 1977. Comparison of point frame and hand separation of coyote scats. J. Wildl. Manage. 41:319-320.

- Sehman, R. W. 1977. Hibernaculum dynamics of the great basin rattlesnake (Crotalus viridis lutosus). M.S. Thesis. Idaho State Univ., Pocatello, ID. 66 p.
- Overton, C. K. 1977. Description, distribution, and density of Big Lost River salmonid populations. M.S. Thesis. Idaho State Univ., Pocatello, ID. 51 p.
- Craig, T. H. 1977. Raptors of the Idaho National Engineering Laboratory Site. M.S. Thesis. Idaho State Univ., Pocatello, ID. 102 p.
- Johnson, M. K. and R. M. Hansen. 1977. Progress report - Seasonal diets of coyotes on the Idaho National Engineering Laboratory Site 1975-1977. Idaho National Engineering Site Radioecology-ecology progress report. 258 p.
- Woodruff, R. A. 1977. Annual dispersal, daily activity pattern and home range of Canis latrans on the Idaho National Engineering Laboratory Site. M.S. Thesis. Idaho State Univ., Pocatello, ID. 125 p.
- Hoskinson, R. L. 1977. Migration behavior of pronghorn antelope and summer movements and fall migrations of pronghorn fawns in south-eastern Idaho. Ph.D. Thesis, Univ. of Minnesota, Minneapolis, MN. 125 p.
- Seal, U. S. and R. L. Hoskinson. 1978. Metabolic indicators of habitat condition and capture stress in pronghorns. J. Wildl. Manage. 42:755-763.
- Millard, J. B., T. H. Craig and O. D. Markham. 1978. Cannibalism in adult great-horned owls. Wilson Bull. 90:449.
- Gleason, R. S. 1978. Aspects of the breeding biology of burrowing owls in southeastern Idaho. M.S. Thesis. Univ. of Idaho, Moscow, ID. 47 p.
- Johnson, M. K. and R. M. Hansen. 1978. Estimating dry weight per occurrence for taxa in coyote scat. J. Wildl. Manage. 42:913-915.
- Guyer, C. 1978. Home range and homing ability in Sceloporus graciosus and Phrynosoma douglassi. M.S. Thesis. Idaho State Univ., Pocatello, ID. 130 p.
- Halford, D. K. and J. B. Millard. 1978. Vertebrate fauna of a radio-active leaching pond complex in southeastern Idaho. Great Basin Natur. 38:64-70.
- Markham, O. D. 1978. Activation and fission products in the environment near the Idaho National Engineering Laboratory Radioactive Waste Management Complex. IDO-12085. Idaho Operations Office. National Technical Information Service, Springfield, VA. 19 p.
- McBride, R., N. R. French, A. H. Dahl and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084. National Technical Information Service, Springfield, VA. 29 p.

- Sehman, R. W. and A. D. Linder. 1978. Amphibian and reptilian fauna of the Idaho National Engineering Laboratory Site. IDO-12086. National Technical Information Service. Springfield, VA. 26 p.
- Overton, C. K., D. A. Cannamela and D. W. Johnson. 1978. Assessing environmental effects of river fluctuations on the INEL National Environmental Research Park. P. 68-82. In Kitchings, J. T. and N. E. Tarr (eds.) National Environmental Research Park Symposium: Natural Resource Inventory, Characterization and Analysis. ORNL-5304. Oak Ridge National Laboratory, Oak Ridge, TN.
- Laundre, J. W., R. Davison, M. K. Johnson, B. L. Keller and D. B. Wilde. 1978. Coyote-prey assessment on a NERP Site in southeastern Idaho. P. 55-67. *ibid.*
- Reynolds, T. D. and C. H. Trost. 1978. Vertebrate population levels correlated with different land use practices on the INEL National Environmental Research Park. P. 45-54. *ibid.*
- Johnson, M. K. 1978. Food habits of coyotes in southcentral Idaho. Ph.D. Thesis. Colo. State Univ., Fort Collins, CO. 75 p.
- Markham, O. D., K. W. Puphal, and T. D. Filer. 1978. Plutonium and americium contamination near a transuranic storage area in southeastern Idaho. *J. Environ. Qual.* 7:422-428.
- Halford, D. K. and O. D. Markham. 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. *Ecology* 59:1047-1054.
- Wilde, D. B. 1978. A population analysis of the pygmy rabbit (Sylvilagus idahoensis) on the INEL Site. Ph.D. Thesis. Idaho State Univ., Pocatello, ID. 172 p.
- Linder, A. D. and R. W. Sehman. 1978. The herptofauna of the Idaho National Engineering Laboratory Site. *J. Idaho Acad. Sci.* 13:47-50.
- Reynolds, T. D. and T. D. Rich. 1978. Reproductive ecology of the sage thrasher (Oreoscoptes montanus) on the Snake River Plain in south-central Idaho. *Auk* 95:580-582.
- Craig, T. H. 1978. A car survey for raptors in southeastern Idaho. *Raptor Res.* 12:40-45.
- Johnson, M. K. and J. G. MacCracken. 1978. Similarity between pronghorn and mule deer fecal pellets. *Great Basin Natur.* 38:222-224.
- Johnson, M. K. 1978. What do coyotes eat? *Idaho Wildl.* 1:25-26.
- Reynolds, T. D. 1978. The response of native vertebrate populations to different land management practices on the Idaho National Engineering Laboratory Site. Ph.D. Thesis. Idaho State Univ., Pocatello, ID. 105 p.

- Markham, O. D. (Ed.). 1978. Ecological studies on the Idaho National Engineering Laboratory Site. 1978 Progress Report. IDO-12087. National Technical Information Service, Springfield, VA. 370 p.
- Reynolds, T. D. 1979. Response of the reptile populations to different land management practices on the Idaho National Engineering Laboratory Site. Great Basin Natur. 39:255-262.
- Gleason, R. and T. H. Craig. 1979. Food habits of burrowing owls in southeastern Idaho. Great Basin Natur. 39:274-276.
- Craig, T. H., D. K. Halford and O. D. Markham. 1979. Radionuclide concentrations in nestling raptors near nuclear facilities. Wilson Bull. 91:72-77.
- Markham, O. D. and W. J. Arthur (Eds.). 1979. Proceedings of the Symposium on the Idaho National Engineering Laboratory Ecology Programs. IDO-12088. Grand Teton National Park, September 10-12, 1978. National Technical Information Service, Springfield, VA. 72 p.
- Markham, O. D. and W. J. Arthur. 1979. Desert Island (article featuring Idaho's National Environmental Research Park). Idaho Wildl. 1:14-17.
- Craig, T. H. and C. H. Trost. 1979. The biology and nesting density of breeding American kestrels and long-eared owls on the Big Lost River, southeastern Idaho. Wilson Bull. 91:50-61.
- Craig, T. H. 1979. Raptors of the Idaho National Engineering Laboratory Site. Idaho Operations Report IDO-12089. U. S. Department of Energy. National Technical Information Service, Springfield, VA. 27 p.
- Laundre, J. W. 1979. A behavioral study of home range utilization by coyotes on the INEL site in southeastern Idaho. Ph.D. Thesis. Idaho State Univ., Pocatello, ID. 70 p.
- Reynolds, T. D. 1979. Impact of loggerhead shrikes on nesting birds in a sagebrush environment. Auk 96:798-800.
- Reynolds, T. D. and C. H. Trost. 1979. The effect of crested wheatgrass plantings on wildlife on the Idaho National Engineering Laboratory Site. P. 665-666. In G. A. Swanson (Tech. Coordinator). The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats. General Tech. Report Rm-65, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
- Johnson, M. K. 1979. Foods of primary consumers on cold desert shrub-steppe of southcentral Idaho. J. Range Manage. 32:365-368.
- Johnson, M. K. and R. M. Hansen. 1979. Coyote food habits on the Idaho National Engineering Laboratory. J. Wildl. Manage. 43:951-956.
- Fisher, J. S. 1979. Reproduction in the pygmy rabbit in southeastern Idaho. M.S. Thesis. Idaho State Univ., Pocatello, ID. 33 p.
- Connelly, J. W. 1979. A preliminary report on sage grouse studies on the Idaho National Engineering Laboratory. Trans. West. States Sage Grouse Workshop 11:11-12.

- Connelly, J. W. 1979. Ecology of sage grouse on the INEL site. P. 43-49
In Antelope-Sage Grouse Ecology, Idaho Department of Fish and Game Job
Progress Report W-160-R-6. Idaho Department of Fish and Game, Boise.
- Johnson, M. K. and R. M. Hansen. 1979. Estimating coyote food intake
from indigested residues in scats. *Amer. Midl. Natur.* 102:363-367.
- Markham, O. D., R. E. Autenrieth, and R. L. Dickson. 1979. Plutonium in
pronghorn antelope lungs near a nuclear fuel reprocessing plant.
Health Physics 37:398-400.
- Johnson, M. K. and R. M. Hansen. 1979. Food habits of cottontails and
woodrats in southcentral Idaho. *J. Mammal.* 60:213-215.
- Autenrieth, R. E., G. L. Copeland, J. W. Connelly and T. D. Reynolds.
1980. Job Progress Report, Project W-160-R-7, Antelope-Sage Grouse
Ecology. Idaho Department of Fish and Game. Boise, ID. 45 p.
- Markham, O. D., D. K. Halford, D. E. Bihl and R. E. Autenrieth. 1980.
Iodine-131 concentrations in air, milk, and antelope thyroids in
southeastern Idaho. *Health Physics* 38:321-326.
- Wilkosz, R. J. 1980. Coyote habitat preferences on the Idaho National
Engineering Laboratory Site in southeastern Idaho. M.S. Thesis,
Idaho State Univ., Pocatello, ID. 111 p.
- Markham, O. D., D. K. Halford and R. E. Autenrieth. 1980. Strontium-90
concentrations in pronghorn antelope bones near a nuclear fuel
reprocessing plant. *Health Physics* 38:811-816.
- Hoskinson, R. L. and J. R. Tester. 1980. Migration behavior of pronghorn
antelope in southeastern Idaho. *J. Wildl. Manage.* 44:132-144.
- Fazio, J. R. 1980. The conceptual design of interpretive exhibits for
Idaho National Environmental Research Park. Forest, Wildlife and
Range Experiment Station. Report No. 192. Univ. of Idaho, Moscow,
ID. 63 p.
- Morton, J. S., D. K. Halford and D. Parker. 1980. A confinement device
for the determination of radionuclide concentrations in live ducks.
Health Physics 38:234-236.
- Reynolds, T. D. 1980. The effects of some different land management
practices on small mammal populations. *J. Mammal.* 61:558-561.
- Stauber, E. H., R. E. Autenrieth and O. D. Markham. 1980. A
seroepidemiologic survey of three southeastern Idaho pronghorn
populations, 1975-1977. *J. Wildl. Dis.* 16:109-115.
- Reynolds, T. D. and C. H. Trost. 1980. The response of native vertebrate
populations to crested wheatgrass planting and grazing by sheep.
J. Range Manage. 33:122-125.
- Reynolds, T. D.. 1980. Nesting of the sage thrasher, sage sparrow, and
Brewer's sparrow in southeastern Idaho. *Condor* 83:61-64.

- Davison, R. P. 1980. The effect of exploitation on some parameters of coyote populations. PhD. Thesis. Utah State University, Logan, UT. 139 p.
- MacCracken, J. G. 1980. Feeding ecology of coyotes on the upper Snake River Plain, Idaho. M.S. Thesis. Colo. State Univ., Fort Collins, CO. 85 p.
- Reynolds, T. 1980. Save some sage. Idaho Wildl. 2:10-13.
- Reynolds, T. D. and R. E. Autenreith. 1980. Dexamethasone and its effect on the natality of preparturiant pronghorn antelope does. J. Am. Vetr. Med. Assoc. 177:943-945.
- Connelly, J. W. 1980. Ecology of sage grouse on the INEL Site. P. 29-45. In Job Progress Report, Antelope-Sage Grouse Ecology. Idaho Department of Fish and Game Job Progress Report. Federal Aid Project W-160-R-7. Idaho Dept. of Fish and Game, Boise, ID.
- Reynolds, T. D. 1980. Seasonal ranges and migration of antelope in southeastern Idaho. P. 9-13. *ibid.*
- Halford, D. K. 1981. Repopulation and food habits of Peromyscus maniculatus on a burned sagebrush desert in southeastern Idaho. Northwest Sci. 55:44-49.
- Halford, D. K., J. B. Millard and O. D. Markham. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. Health Physics 40:173-181.
- Fuller, R. K. 1981. Habitat utilization, invertebrate consumption, and movement by salmonid fishes under fluctuating flow conditions in the Big Lost River, Idaho. M.S. Thesis. Idaho State Univ., Pocatello, ID. 76 p.
- Connelly, J. W., W. J. Arthur and O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. J. Range Manage. 34:153-154.
- Anderson, J. E. and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. J. Range Manage. 34:25-29.
- Groves, C. R. and J. E. Anderson. 1981. Allelopathic effects of Artemisia tridentata leaves on germination and growth of two grass species. Amer. Midl. Natur. 106: 73-79.
- Laundre, J. W. and B. L. Keller. 1981. Home-range use by coyotes in Idaho. Anim. Behav. 29:449-461.
- Gates, R. J. 1981. Summer use by sage grouse of irrigated agriculture in southeastern Idaho. Trans. West. States Sage Grouse Workshop. 12:7-8.
- Griffith, J. S. 1981. Water bodies should be managed to maintain a balanced and indigenous community. P. 47-53 In L. D. Jensen (ed) Proceedings, Fifth National Workshop on Entrainment and Impingement. May 5-7, 1980, San Francisco, CA. E. A. Communications, Sparks, MD.

- Wilde, D. B. 1981. Pygmy rabbit reproduction: possible modification by drought conditions. p. 559-571 In K. Myers and C. D. MacInnes (eds.) Proceedings of the World Lagomorph Conference held at Guelph, Ontario, August 1979. U. of Guelph, Canada.
- Gasser, K. W., D. A. Cannamela and D. W. Johnson. 1981. Contributions to the life history of the shorthead sculpin, Cottus confusus, in the Big Lost River, Idaho: age, growth and fecundity. Northwest Sci. 55:174-181.
- Connelly, J. W. 1981. Winter flocking behavior and habitat use by sage grouse in southeastern Idaho. Trans. West. States Sage Grouse Workshop 12:8-9.
- Laundre, J. W. 1981. Temporal variation in coyote vocalization rates. J. Wildl. Manage. 45:767-769.
- Reynolds, T. D. and C. H. Trost. 1981. Grazing, crested wheatgrass, and bird populations in southeastern Idaho. Northwest Sci. 55:225-234.
- Johnson, M. K. 1981. Estimating coyote diet: a validation. Amer. Midl. Natur. 106:399-400.
- Connelly, J. W. and R. J. Gates. 1981. First record of a black-legged kittiwake in Idaho. Condor 83:272-273.
- Browers, H., Jr. 1981. Dispersal of sage grouse from the Test Reactor Area of the Idaho National Engineering Laboratory. Trans. West. States Sage Grouse Workshop 12:11-12.
- Autenrieth, R. E., G. L. Copeland and T. D. Reynolds. 1981. Capturing pronghorn antelope using a helicopter and M-99. Wildl. Soc. Bull. 9:314-319.
- Evenson, L. M. 1981. Systemic effects of radiation exposure on rodents inhabiting liquid and solid waste disposal areas. MS Thesis. Univ. of Idaho, Moscow. 91 p.
- Groves, C. R. 1981. The ecology of small mammals on the Subsurface Disposal Area, Idaho National Engineering Laboratory Site. M. S. Thesis, Idaho State Univ., Pocatello. 87 p.
- Griffith, J. S. 1981. Estimation of the length of stream-dwelling trout by underwater observation. Progr. Fish-Cult. 43:51-53.
- Shumar, M. L., J. E. Anderson and T. D. Reynolds. 1982. Identification of big sagebrush by ultraviolet spectrophotometry. J. Range Manage. 35:60-62.
- Markham, O. D., D. K. Halford, R. E. Autenrieth and R. L. Dickson. 1982. Radionuclides in pronghorn resulting from nuclear fuel reprocessing and worldwide fallout. J. Wildl. Manage. 46:30-42.
- Johnson, R. D. 1982. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. M.S. Thesis. Idaho State University, Pocatello. 86 p.
- Halford, D. K., O. D. Markham and R. L. Dickson. 1982. Radiation doses to waterfowl using a liquid radioactive waste disposal area. J. Wildl. Manage. 46:905-914.

- Halford, D. K., W. J. Arthur and O. D. Markham. 1982. Biotic transport of radioactive materials at the INEL site. Trans. of the American Nuclear Society 41:63.
- Connelly, J. W. 1982. An ecological study of sage grouse in southeastern Idaho. Ph.D. Dissertation, Washington State Univ., Pullman. 84 p.
- MacCracken, J. G. and R. M. Hansen. 1982. Herbaceous vegetation of habitat used by black-tailed jackrabbits and Nuttall cottontails in southeastern Idaho. Amer. Midl. Nat. 107:180-184.
- Johnson, M. K. 1982. Response of small mammals to livestock grazing in southcentral Idaho. J. Range Manage. 35:51-53.
- Stafford, M. P. 1982. A window pane trap. Idaho Entomol. Group Newsletter 9:11-12.
- Markham, O. D. and D. K. Halford. 1982. Radionuclides in mourning doves near a nuclear facility complex in southeastern Idaho. Wilson Bull. 94:185-197.
- Floyd, D. A. 1982. A comparison of three methods used for estimating vegetal cover on a controlled burn site in southeastern Idaho. M.S. Thesis. Idaho State Univ., Pocatello, ID 178 p.
- MacCracken, J. G. and R. M. Hansen. 1982. Seasonal foods of coyotes in southeastern Idaho: a multivariate analysis. Great Basin Natur. 42:45-49.
- Keller, B. L., C. R. Groves, E. J. Pitcher and M. J. Smolen. 1982. A method to trap rodents in snow, sleet or rain. Can. J. Zool. 60:1104-1106.
- Bright, R. C. and O. K. Davis. 1982. Quaternary paleoecology of the Idaho National Engineering Laboratory, Snake River Plain, Idaho. Amer. Midl. Natur. 108:21-33.
- U. S. Depart. Energy. 1982. Idaho National Engineering Laboratory, Hanford Site and Los Alamos National Laboratory Symposium on Radioecology and Ecology Symp. on Aug. 24-27, 1982 at Grand Teton National Park. IDO-12095. Idaho Operations Office. Nat. Tech. Infor. Ser., Springfield, VA. 63 p.
- Arthur, W. J. and O. D. Markham. 1982. Ecological vectors of radio-nuclide transport at a solid radioactive waste disposal facility in southeastern Idaho. p. 574-580. In M. A. Feraday (ed), Proceedings of International Conference on Radioactive Waste Management held at Winnipeg, Manitoba on Sept. 12-15, 1982. Canadian Nuclear Society, Toronto, Ontario. ISBN:0-919784-01-1.
- Woodruff, R. A. and B. L. Keller. 1982. Dispersal, daily activity, and home range of coyotes in southeastern Idaho. Northwest Sci. 56:199-207
- Petersen, K. L. 1982. Breeding ecology of passerine birds in a sagebrush-dominated community. M.S. Thesis. Iowa State Univ., Ames, IA. 66 p.

- Arthur, W. J. and O. D. Markham. 1982. Radionuclide export and elimination by coyotes at two radioactive waste disposal areas in southeastern Idaho. *Health Physics* 43:493-500.
- Arthur, W. J. 1982. Radionuclide concentrations in vegetation at a solid radioactive waste disposal area in southeastern Idaho. *J. Envir. Qual.* 11:394-399.
- Fraley, L. Jr., G. C. Bowman and O. D. Markham. 1982. Iodine-129 in rabbit thyroids near a nuclear fuel reprocessing plant in Idaho. *Health Physics* 43:251-258.
- Connelly, J. W. and O. D. Markham. 1982. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. *J. Wildl. Manage.* 47:169-177.
- Best, L. B. and K. L. Petersen. 1982. Effects of stage of the breeding cycle on sage sparrow detectability. *Auk* 99:788-791.
- Floyd, D. A. and J. E. Anderson. 1982. A new point, interception frame for estimating cover of vegetation. *Vegetatio* 50:185-186.
- Markham, O. D. (Ed.). 1983. Idaho National Engineering Laboratory Radioecological and Ecological Studies 1983 Progress Report. DOE/ID-12098. Idaho Operations Office, U. S. Department of Energy. Nat. Tech. Infor. Ser., Springfield, VA. 434 p.
- Halford, D. K., O. D. Markham and G. C. White. In Press. Biological elimination of radioisotopes by mallards contaminated at a liquid radioactive waste disposal area. *Health Physics*.
- Arthur, W. J. and O. D. Markham. 1983. Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. *J. Envir. Qual.* 12:117-122.
- Cholewa, A. F. and D. Henderson. 1983. Noteworthy collections-Idaho: Lesquerilla kingii S. Wats. var. cobrenses Roll. and Shaw, Astragalus kentrophyta Gray var. jessiae (Peck) Barneby, Gilia polycladon Torrey. *Madrono* 30:63-64.
- Goodrich, S., A. Cholewa and D. Henderson. 1983. Noteworthy collections: Idaho, Astragalus gilviflorus Sheld. *Madrono* 30:63.
- Johnson, W. C. and B. L. Keller. In Press. An examination of snap-trapping techniques for estimating rodent density in high desert. *Northwest Sci.*
- Groves, C. R. and B. L. Keller. In Press. Ecological characteristics of small mammals on a radioactive waste disposal area in southeastern Idaho. *Amer. Midl. Natur.*
- Fisher, G. S. and B. L. Keller. Submitted. Reproduction in the pygmy rabbit in Idaho. *J. Wildl. Manage.*
- White, J. A., H. G. McDonald, E. Anderson and J. M. Soiset. In Press. Lava blisters as carnivore traps. *Ann. Carnegie Mus.*

- Connelly, J. W. In Press. Sage grouse: their new look. Idaho Wildl.
- Millard, G. C., L. Fraley, Jr. and O. D. Markham In Press. Deposition and retention of ¹⁴¹Ce and ¹³⁴Cs aerosols on cool desert vegetation. Health Physics.
- Markham, O. D., T. E. Hakonson, F. W. Whicker and J. S. Morton. In Press. ¹²⁹I in mule deer thyroids from Rocky Mountain States. Health Physics
- Reynolds, T. D. 1983. Pronghorn responses to hunting coyotes. Great Basin Natur. 43:88-92.
- Laundre, J. W. and B. L. Keller. Submitted. Trap locations relative to home range boundaries of coyotes. Can. J. Zool.
- Connelly, J. W. and I. J. Ball. Submitted. Seasonal flocking characteristics and habitat use by sage grouse in southeastern Idaho. J. Wildl. Manage.
- Peterson, K. L. and L. B. Best. Submitted. Nest-site selection by sage sparrows and Brewer's sparrows. Condor
- Connelly, J. W., H. W. Browsers and R. J. Gates. Completed manuscript. Capturing sage grouse with mist nets. Murrelet
- Keller, B. L. Submitted. Employment of a continuous catch trap to assess dispersal. Can. J. Zool.
- Laundre, J. W. and B. L. Keller. Submitted. Home range size of coyotes - a critical review. J. Wildl. Manage.
- Craig, T. H., E. H. Craig and L. R. Powers. Submitted. The effects of increased jack rabbit populations on raptor densities in southeastern Idaho. Condor.
- Reynolds, T. D. and W. Wakkinen. Completed manuscript. Burrow analysis of four cool desert mammal species. J. Mammal.
- Johnson, R. D. and J. E. Anderson. In press. Diets of black-tailed jack rabbits in relation to population density and vegetation. J. Range Manage.
- Groves, C. R. and B. L. Keller. Completed manuscript. Estimating the density of rodents on a radioactive waste disposal area.
- Reynolds, T. D. Submitted. Daily summer movements, activity patterns, and home range of pronghorn antelope. Can. J. Zool.
- Kuzo, G. B., L. Fraley, F. W. Whicker and O. D. Markham. Completed manuscript. Transuranic concentrations in pelagic components of a test reactor leaching pond. Health Physics.
- Connelly, J. W. and I. J. Ball. Completed manuscript. Seasonal movements of sage grouse in southeastern Idaho.
- Peterson, K. L. and L. B. Best. Completed manuscript. Nestling diets and growth rates of sage sparrows and Brewer's sparrows.

- Kuzo, G. B., O. D. Markham and L. Fraley. Completed manuscript. Uptake of gamma-emitting radionuclides by soils placed in a test reactor leaching pond. J. Envir. Qual.
- Griffith, J. S., D. A. Andrews and R. K. Fuller. Completed manuscript. Rapid recolonization of some invertebrate taxa in an ephemeral portion of the Big Lost River on the Idaho National Engineering Laboratory.
- French, N. R. and J. E. Mitchell. Completed manuscript. Long-term vegetation changes in permanent quadrats at the Idaho National Engineering Laboratory Site, Univ. of Idaho Forest and Range Exper. Station Bull.
- Connelly, J. W. and I. J. Ball. Completed Manuscript. Sage grouse census methods and populations in southeastern Idaho.
- Arthur, W. J., O. D. Markham, C. R. Groves and B. L. Keller. Completed manuscript. Radionuclide export by Peromyscus maniculatus at a solid radioactive waste disposal area in southeastern Idaho.
- Janke, D. H. and W. J. Arthur. Completed Manuscript. Radionuclide transport by cottontail rabbits at a solid radioactive waste disposal in southeastern Idaho.
- Craig, T. H. and E. H. Craig. Submitted. A large concentration of roosting eagles in southeastern Idaho. Auk
- Arthur, W. J. and O. D. Markham. In press. Polonium-210 concentrations in soil, vegetation and small mammals in southeastern Idaho. Health Physics.
- Connelly, J. W. and I. J. Ball. Completed manuscript. Sage grouse on Idaho's National Environmental Research Park.
- Arthur, W. J., J. W. Connelly and D. K. Halford. Completed manuscript. Vertebrates of the Idaho National Engineering Laboratory. U. S. Department of Energy (Idaho Operations Office) technical report.
- Johnson, W. C. and B. L. Keller. In Press. An examination of the area of affect of snap-traps transects in Idaho desert. Can. J. Zool.
- Connelly, J. W., W. J. Arthur and O. D. Markham. Completed manuscript. Characteristics of sage grouse leks in southeastern Idaho.
- Arthur, W. J., C. R. Groves, D. K. Halford, B. L. Keller and O. D. Markham. Completed Manuscript. Radiation doses received by small mammals inhabiting a solid radioactive waste disposal area in southeastern Idaho.
- Laundre, J. W., and B. L. Keller. Submitted. Trap locations relative to home range boundaries of coyotes. Can. J. Zool.
- Halford, D. K. Completed manuscript. Effects of cooking on radionuclide concentrations in waterfowl tissues.
- Groves, C. R. and B. L. Keller. Submitted. Hip glands in a natural population of montane voles (Microtus montanus). Great Basin Natur.

- Groves, C. R. and B. L. Keller. Completed manuscript. Estimating the density of small mammals with the assessment line technique.
- Cholewa, A. F. and D. M. Henderson. Submitted. A survey and assessment of the rare vascular plants of the INEL. Great Basin Natur.
- Halford, D. K. and O. D. Markham. Submitted. Iodine-129 concentrations in muscle from waterfowl using a liquid radioactive waste pond. Health Physics.
- Markham, O. D. and D. K. Halford. Peer Review. Effects of additional HEPA filtration of atmospheric effluents at a nuclear fuel reprocessing plant on radionuclide concentrations in wildlife. Health Physics.
- Wilkosz, R. J. and J. E. Anderson. Submitted. Relationships of coyote activity to vegetal and topographic habitat components. J. Wildl. Manage.
- MacCracken, J. G. and R. M. Hansen. Submitted. Seasonal food of sympatric blacktail jack rabbits and Nuttall cottontails in southeastern Idaho. J. Range Manage.
- Reynolds, T. D. and F. L. Rose. Completed manuscript. Pronghorn antelope use of the Idaho National Environmental Research Park.

ORAL PRESENTATIONS

IDAHO NATIONAL ENGINEERING LABORATORY RADIOECOLOGY AND ECOLOGY PROGRAM

1979 - Present

- Sehman, R. W., L. M. Sehman and F. L. Rose. Population dynamics of the Great Basin rattlesnake (Crotalus viridis) at a den in southeastern Idaho. Presented at Southwestern Association of Naturalists, 26th Annual Meeting. April 19-21, 1979. Sherman, TX.
- Wilkosz, R. and J. E. Anderson. Habitat preferences of coyotes on the Idaho National Engineering Laboratory Site, southeastern Idaho. Idaho Academy of Science. April 19-21, 1979. Univ. of Idaho, Lewiston, ID.
- Laundre, J. W. Home range utilization of coyotes in Idaho. *ibid.*
- Anderson, J. E. Long-term trends in vegetation development on protected portions of the Idaho National Engineering Laboratory Site, southeastern Idaho. *ibid.*
- Halford, D. K. Radioecology of organisms near nuclear facilities. Presented at Mississippi State University. April 20, 1979. Starkville, MS.
- Connelly, J. W. A review of sage grouse research on the Idaho National Engineering Laboratory. Presented to Region 6 meeting of the Idaho Department of Fish and Game. June 1979. Idaho Falls, ID.
- Wilkosz, R. J. and J. E. Anderson. Coyote habitat preferences on the INEL Site in southeastern Idaho. Paper presented American Soc. Mammal., June 17-21, 1979. Corvallis, OR.
- Laundre, J. W. and B. L. Keller. Activity behavior of coyotes in Idaho. *ibid.*
- Wilde, D. B. Pygmy rabbit (Sylvilagus idahoensis) burrows in southeastern Idaho. *ibid.*
- Kuzo, G. B., L. Fraley, Jr. and O. D. Markham. Transuranics in selected components of a radioactive leaching pond ecosystem at the Idaho National Engineering Laboratory. Presented at 24th Annual Meeting of the Health Physics Society, July 8-13, 1979. Philadelphia. PA.
- McGiff, T. J., L. Fraley, Jr. and O. D. Markham. ¹²⁹I concentrations in vegetation near a nuclear fuel reprocessing plant in southeastern Idaho. *ibid.*
- Halford, D. K., J. B. Millard and O. D. Markham. Radionuclide concentrations in waterfowl using radioactive leaching ponds and the potential of internal radiation dose to man. *ibid.*

- Reynolds, T. D. The effect of crested wheatgrass plantings on wildlife on the Idaho National Engineering Laboratory Site. Poster presentation at the Mitigation Symposium. July 17-19, 1979. Ft. Collins, CO.
- Wilde, D. B. Ecology of the Idaho pygmy rabbit, Brachylagus idahoensis. World Lagomorph Conference. August 13-17, 1979. Univ. of Guelph, Ontario, Canada.
- Connelly, J. W. A preliminary on sage grouse studies on the INEL. Presented at the Eleventh Western States Sage Grouse Workshop. September 5-6, 1979. Twin Falls, ID.
- MacCracken, J. G. and R. M. Hansen. Feeding ecology of coyotes in south-central Idaho. Presented at the Annual Meeting, Society for Range Management. February 10-14, 1980. San Diego, CA.
- Anderson, J. E. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *ibid.*
- McGiff, T. J., L. Fraley, Jr., and O. D. Markham. ¹²⁹I concentrations in vegetation near a nuclear fuel reprocessing plant in southeastern Idaho. Presented at the Central Rocky Mountain Chapter, Health Physics Society Symposium. March 27, 1980. Colorado State Univ., Fort Collins, CO.
- Shumar, M. L. and J. E. Anderson. Identification of subspecies of big sagebrush by ultraviolet spectrophotometry. Presented at the 22nd Annual Meeting, Idaho Academy of Science. April 11-12, 1980. Boise State Univ., Boise, ID.
- Groves, C. R. and B. L. Keller. Ecology of small mammals on the Radioactive Waste Management Complex, INEL Site. *ibid.*
- Connelly, J. W., Jr. Sage grouse studies on Idaho's National Environmental Research Park. Presented at the Blackfoot Kiwanis Club weekly meeting. April 17, 1980. Blackfoot, ID.
- Griffith, J. S. Water bodies should be managed to maintain a balanced and indigenous community. Presented at the Fifth National Workshop on Entrainment and Impingement. May 5-7, 1980. San Francisco, CA.
- Groves, C. R. and B. L. Keller. On the use of the assessment line technique. Presented at the American Society of Mammalogists Meeting. June 8-12, 1980. Kingston, RI.
- Kuzo, G. B., O. D. Markham, G. White and L. Fraley, Jr. In situ uptake of alpha-emitting radionuclides by soil size fractions conducted at the Idaho National Engineering Laboratory. Presented at the Health Physics Society Annual Meeting. July 20-25, 1980. Seattle, WA.
- Evenson, L. M., D. P. Olson, D. K. Halford and O. D. Markham. Systemic effects of radiation exposure on rodents inhabiting liquid and solid radioactive waste disposal areas. *ibid.*

- McGiff, T., L. Fraley, Jr. and O. D. Markham. Concentrations of ¹²⁹I in vegetation near a nuclear fuel reprocessing facility in south-eastern Idaho. Presented at the Annual Meeting of the Ecological Society of America. August 3-8, 1980. Univ. of Arizona, Tucson, AZ.
- Davis, O. K. Continuum and typal models for vegetation paleoecology in the northern Great Basin. *ibid.*
- Gates, R. J., J. W. Connelly and H. W. Browsers, Jr. Capture and marking techniques used in sage grouse research on the Idaho National Engineering Laboratory Site. Presented at the Fifth Annual Meeting of the Idaho Ornithological Council. October 3-5, 1980. Pocatello, ID.
- Connelly, J. W. Jr. Sage grouse summer habitat and reproduction on the Idaho National Engineering Laboratory Site. *ibid.*
- Anderson, J. E. Succession and the nature of plant communities. Presented at the Annual Meeting. R. N. Irving Chapter, Soil Conservation Society of America. October 10-11, 1980. Pocatello, ID.
- Reynolds, T. D. and C. H. Trost. Effects of some different land use practices on native vertebrate populations. Invited paper, 3rd Annual Pacific Ecology Conference. April 3-5, 1981. Malheur National Wildlife Refuge Field Station, OR.
- Reynolds, T. D. A comparison of native vertebrate populations in sagebrush and crested wheatgrass habitats. Poster presentation. *ibid.*
- Connelly, J. W. The life history and ecology of sage grouse in south-eastern Idaho. Monthly Meeting Snake River Audubon Society, April 16, 1981. Idaho Falls, ID.
- Floyd, D. A. and J. E. Anderson. A new tool for collecting point interception data (for measuring vegetation cover). Idaho Academy of Science Annual Meeting, April 17-18, 1981. Twin Falls, ID.
- Shumar, M. L. Sagebrush distribution on the Idaho National Engineering Laboratory Site. *ibid.*
- Marlette, G. M. and J. E. Anderson. Plant succession in crested wheatgrass stands on the Idaho National Engineering Laboratory Site. *ibid.*
- Johnson, R. and J. E. Anderson. Relationships of black-tailed jack rabbit diets to population density and vegetal components of habitat. *ibid.*
- Arthur, W. J. Energy development and related impacts on wildlife in the western United States. Northwest Section of the Wildlife Society Annual Meeting, April 22-25, 1981. Coeur d'Alene, ID.
- Reynolds, T. D. The effect of some different land use practices on native fauna populations. *ibid.*

- Reynolds, T. D. Daily summer movement and activity patterns of pronghorn antelope. American Society of Mammologists 61st Annual Meeting, June 7-11, 1981. Oxford, OH.
- Kuzo, G. B., L. Fraley, Jr. and O. D. Markham. Transuranic concentrations in pelagic components of a test reactor leaching pond. Health Physics Society Annual Meeting, June 21-26, 1981. Louisville, KY.
- Reynolds, T. D. The usefulness of radio-telemetry data in wildlife studies. Invited paper, Park Naturalist's Seminar Series. July 6, 1981. Yellowstone National Park, WY.
- Marlette, G. M. Population dynamics and succession in crested wheatgrass stands on the Idaho National Engineering Laboratory. Annual Meeting Soil Conservation Society of America, August 3-7, 1981. Spokane, WA.
- Connelly, J. W. Winter flocking behavior and habitat use by sage grouse in southeastern Idaho. Twelfth Western States Sage Grouse Workshop, September 1-3, 1981. Bowman, ND.
- Browers, H. W. Jr. Dispersal of sage grouse from the Test Reactor Area of the Idaho National Engineering Laboratory. *ibid.*
- Gates, R. Summer use by sage grouse of irrigated agriculture in southeastern Idaho. *ibid.*
- Floyd, D. and J. Anderson. A comparison of three techniques for measuring vegetation cover. Presented at 35th Annual Meeting of Society for Range Management. February 1982. Calgary, Alberta.
- Arthur, W. J. and O. D. Markham. Ecological research at a solid radioactive waste disposal area in southeastern Idaho. Symposium on Energy and Environmental Processes in Terrestrial System. Sponsored by U. S. Department of Energy Ecological Research Division. March 4, 1982. Washington, D.C.
- Floyd, D. and J. E. Anderson. A comparison of three techniques for measuring vegetal cover. Presented at Idaho Academy of Science 24th Annual Meeting. March 26, 1982. Ricks College, ID.
- Petersen, K. L. and L. B. Best. Differential nest placement by sage sparrows and Brewer's sparrows. Annual Meeting of Cooper Ornithological Society. April 1982. Logan, UT.
- Knick, S. Ecology of bobcats in southeastern Idaho. Idaho Falls Chapter of Audubon Society. April 1982. Idaho Falls, ID.
- Arthur, W. J. and O. D. Markham. Small mammals as a radionuclide transport vector at a solid radioactive waste disposal area. Poster session at Ecological Society of American Annual Meeting. August 8-12, 1982. University Park, PA.
- Halford, D. K., W. J. Arthur and O. D. Markham. Biotic transport of radioactive materials at the Idaho National Engineering Laboratory. Annual Meeting of the American Nuclear Society. June 6-10, 1982. Los Angeles, CA.

- Groves, C. R. and B. L. Keller. Ecological characteristics of small mammals on a radioactive waste disposal area. *ibid.*
- Halford, D. K., O. D. Markham and G. C. White. Biological elimination of radioisotopes by mallards. *ibid.*
- Fraley, L. Jr. Early recovery of an Artemisia tridentata dominated plant community following a fire. Ecological Society of America Annual Meeting. August 8-12, 1982. University Park, PA.
- Marlette, G. M. and J. Anderson. Soil seed banks and seed disposal across an interface between crested wheatgrass seedings and native sagebrush type communities. *ibid.*
- Idaho National Engineering Laboratory, Hanford Site and Los Alamos National Laboratory Symposium on Radioecology and Ecology. Ecology and Radioecology related papers presented. August 24-27, 1982. Jackson Lake Lodge. Grand Teton National Park, WY.
- Arthur, W. J. and O. D. Markham. Ecological vectors of radionuclide transport at a solid radioactive waste disposal facility in southeastern Idaho. Canadian Nuclear Society International Conference on Radioactive Waste Management. September 13-16, 1982. Winnipeg, Manitoba, Canada.
- Petersen, K. L. and L. B. Best. Nest site selection by sparrows of a shrub steppe community: A three level approach. One-Hundredth Stated Meeting of the American Ornithologists. Union. October 1982. Chicago, IL.
- Craig, E. H., T. H. Craig and L. Powers. Activity patterns and home range of long-eared owls (Asio otus) on the Idaho National Engineering Laboratory. Raptor Research Foundation Annual Meeting. November 18-21, 1982. Salt Lake City, UT.
- Craig, T. H., E. H. Craig and L. Powers. Density of raptors on the Idaho National Engineering Laboratory. *Ibid.*
- Powers, L., T. H. Craig and E. H. Craig. A large concentration of roosting eagles in southeastern Idaho. *Ibid.*
- Craig, E. H. and T. H. Craig. Raptor studies on the Idaho National Engineering Laboratory Site. Pocatello Chapter of the Audubon Society. October 1982. Pocatello, ID.
- Keller, B. L. and C. R. Groves. Dispersal of small mammals as a vector for interred radioactive waste. Northwest Scientific Association Annual Meeting. March 1983. Olympia, WA.
- Filipovich, M. and B. L. Keller. Density, movement, and food habits of small mammals on a radioactive waste disposal area in southeastern Idaho. *ibid.*
- Veith, R. D. and B. L. Keller. Ecological studies of carrion beetles (Nicrophorus spp. in southeastern Idaho. *ibid.*

Anderson J. E. Impacts of black-tailed jack rabbits on sagebrush steppe vegetation. *ibid.*

Shumar, M. L. Factors affecting the distributions of two subspecies of big sagebrush and associated species. *ibid.*

Cole, N. K. and J. E. Anderson. Diurnal patterns of water potential of the perennial bunchgrass, Elymus cinereus. *ibid.*

Reynolds, T. D. Making ecological sense of remote sensing data. Idaho Section, the Wildlife Society. Annual Meeting. March 11-12, 1983. Boise, ID.

Wakkinen, W. L. and T. D. Reynolds. Burrow systems of four rodent species. *Ibid.*

Reynolds, T. D. Pronghorn use of the Idaho National Engineering Laboratory. Northwest Section, The Wildlife Society, Annual Meeting. April, 14-18, 1983. Spokane, WA.

Reynolds, T. D. and W. L. Wakkinen. Quantitative determination of the burrow systems of four small mammal species. *ibid.*