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Ecological Research Series

THE BIOENVIRONMENTAL IMPACT OF A COAL-FIRED POWER PLANT
First Interim Report
Colstrip, Montana – December 1974

Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

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THE BIOENVIRONMENTAL IMPACT OF A COAL-FIRED POWER PLANT

First Interim Report, Colstrip, Montana

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Edited by

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ABSTRACT

In June 1974, the National Ecological Research Laboratory initiated a field program in southeastern Montana. The purpose of this program is to assess the effects of a coal-fired power plant on a terrestrial environment. Numerous investigators have worked together on this project to establish a baseline investigation to characterize the environment around the plant prior to operation. This report is a summary of activities from June through October, 1974. The overall objectives, rationale, and design of the project are outlined. Recommendations regarding further actions on any of the components of this program are also included. The paper serves primarily as a status report to the scientists and managers who have been following the project since its inception in March, 1973.

ACKNOWLEDGEMENTS

In addition to the authors and their respective institutions, a very large number of persons have contributed to the development of the Colstrip, Montana Coal-fired Power Plant Project and to the preparation of this document. We would like to express our warmest thanks to all. Members of the following agencies and institutions have been particularly helpful: The Custer National Forest; Office of the Lieutenant Governor, State of Montana; the Montana State Air Quality Bureau.

Our work could not proceed without the help and support of the people of southeastern Montana, especially the ranchers on whose land we are working and the personnel and persons residing at and near Fort Howes Ranger Station. Critical contributions or review of the present document were provided by Drs. Carolyn W. Lewis and John Reuss. Editorial assistance was provided by Ms. Susan Jones and Mr. Larry Doe.

CONTENTS

TABLES

FIGURES

SECTION I
INTRODUCTION AND PERSPECTIVES

by
Robert A. Lewis,
Allen S. Lefohn, and
Norman R. Glass

INTRODUCTION

The nation is presently faced with a series of problems concerning the production, distribution, and consumption of fossil fuel energy. Because of great abundance at relatively low cost, the Administration's commitment to energy self-sufficiency by 1980 and other factors, it is clear that the United States is moving toward an economy based on coal as the primary fossil fuel resource. The rush toward energy self-sufficiency will result in new pressures on the environment. The decisions that will ultimately resolve the environmental and economic issues we face must be made with full knowledge of the constraints imposed by the need to minimize environmental impacts associated with energy production and utilization.

Currently, over 95 percent of the primary energy in the United States is produced through the combustion of fossil fuels (the remainder is derived from hydro power and nuclear energy). By the year 2000, the fossil fuel contribution to the total energy demand is estimated to be approximately 70 percent, but total usage of fossil fuels is estimated to increase over 100 percent. During the same period, nuclear energy is expected to grow ten-fold.

There is a clear relationship between research conducted on energy related problems and research which has been carried out for the purpose of setting or revising air and water quality standards designed to maintain environmental quality. This is due to the fact that environmental research designed to determine the effects on biota and ecological processes is concerned with the same types of pollutants or residuals for standard setting purposes as for purposes of identifying the effects of energy extraction, conversion, or generation. For example, ambient air quality standards have been established under the Clean Air Act Amendments of 1970 for the major, but not all, pollutants generated by fossil fuels. National Ambient Air Quality Standards (NAAQS) have been established for sulfur oxides, particulates, carbon monoxide, nitrogen oxides, hydrocarbons, and oxidants and were based upon the best information available at the time of their promulgation. New source performance standards (NSPS) have been established for several industries, including electric utilities, which place restrictions on the emissions of SO_x, NO_x, particulates, and other pollutants. They apply to the operation of fossil fueled generating plants, the construction or modification of which started after August 1971.

The Clean Air Act states that "...air quality criteria for an air pollutant shall accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutants in the ambient air, in varying quantities" [section 108(a)]. The Act further states that national primary ambient air quality standards are regulations which "in the judgment of the administrator, based on such criteria, and allowing for an adequate margin of safety, are requisite to protect the public health" [section 109(b)]. Air quality criteria, then reflect scientific knowledge, while primary air quality standards involve a judgement as to how this knowledge must be used in a regulatory action to protect public health. Secondary air quality standards determine the level of air quality required to protect the public welfare. Public welfare as defined in the Clean Air Act "includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate..." [section 302(h)]. These considerations also apply and become focal points for energy related environmental research. It is clear that the research experience gained in furtherance of the Clean Air Act is valuable in pursuing energy related research - in fact, the objectives of research programs are so similar that clear separation is not straight forward.

The major air pollutants emanating from fossil fuel energy systems are sulfur oxides, nitrogen oxides and particulate matter. Fossil fuel systems also contribute, to a lesser degree, to the carbon monoxide and oxidant burden. Primary ambient air standards, based on health effects have been established for these pollutants. Secondary standards have been established for SO_2, particulates, CO, oxidants, hydrocarbons, and NO_2. These standards were based on the best scientific information available at the time of their creation. However, at the time they were set, significant gaps in knowledge existed; even now important gaps in knowledge still exist for each pollutant. Accordingly, under the Clean Air Act, EPA is required to continually examine and update the criteria upon which these standards are based. In addition to the above pollutants, numerous trace metals such as copper, cadmium, zinc, lead, arsenic, mercury, and others, are emitted from fossil fueled power generating plants. In addition to trace metals, numerous other trace contaminants in the form of hydrocarbons and various aerosols are also emitted from power plants. In general, trace metals are emitted as particles adsorbed to fly ash or other particulate matter coming from the stack of the coal-fired power plant.

The following discussion represents an overview of the National Ecological Research Laboratory's recently initiated coal-fired power plant project. The broad objective of this program is to measure and predict change in a grassland ecosystem as a function of meaningful environmental parameters including air pollutants. This study is concerned not only with the stability of ecosystem organization in relation to ambient conditions, but also with the predictability and reproducability of changes that do occur. Insight into the mechanisms of dynamic-structural responses of ecosystem components to air pollution challenge is also sought. It is particularly important to identify the subsystem functions that contribute to ecosystem regulation and mechanisms whereby such regulation is effected.

This investigation thus represents an attempt to characterize the impact of air pollutants on a total ecosystem. It is the first attempt to generate methods to predict bioenvironmental effects of air pollution before damage is sustained. Historically, most terrestrial air pollution field research has dealt almost exclusively with direct, usually acute, effects on vegetation. We expect to observe complex changes in ecosystem dynamics as a function of relatively long term, chronic pollution challenge. By studying a rather broad range of interacting variables, we hope to isolate some of these as sensitive and reliable measures of air pollution impact.

The approach envisioned requires (1) the use of reasonably comprehensive models of component populations of the ecosystems; (2) the use of appropriately structured field and laboratory experiments; and (3) an evaluation of physiological and biochemical functions that may serve as specific indicators or predictors of air pollution stress.

Even in a comprehensive investigation, extensive studies of a large array of species or processes is not possible. Considerable research is required to identify the specific parameters that will give an adequate, sensitive measure of air pollution to a grassland ecosystem or components thereof. Broad categories of important functions that should be investigated include (1) changes in productivity or biomass of ecosystem compartments; (2) changes in life-cycle and population dynamic functions of "key" taxa; (3) changes in community structure or diversity; (4) changes in nutrient cycling; (5) sublethal biochemical or physiological changes in individuals or compartments; (6) behavioral changes in mobile organisms; and (7) changes in reproductive patterns.

If we are to assess and interpret the effects of air quality on natural ecosystems, it is essential that we understand the wide range of abiotic factors (e.g., weather, geography, insolation, hydrology, etc.) that influence the dynamics of the living components of the ecosystem. Optimum production, the maintenance of stability and diversity, and other desirable properties of ecosystems all depend upon a variety of these abiotic factors.

RATIONALE

In addition to the "simple" direct effects of air pollutants that have been reported from experimental studies of natural systems, we may expect to observe complex changes in ecosystem dynamics as a function of pollution challenge. We know that insults to the environment from rather diverse sources (toxic substances, pesticides, radiation, disease, and adverse climate) produce a similar array of effects at the community level in spite of very different effects on individual organisms studied under experimental conditions. The response mechanisms may vary, but results are often similar: (1) a "reversal" of succession or simplification of ecosystem structure; (2) a reduction in the ratio of photosynthesis to respiration; and (3) a reduction in species diversity at more than one trophic level, which may include the elimination of certain species (e.g., in grassland, usually rare, but characteristic species). Effects may be temporary and reversible (i.e., the system adapts) or chronic and cumulative. In any case, if a coal-fired power plant has a measurable impact on the environment, there is every reason to believe that it will be registered as a diminution of community structure.

Both plant and animal diversity and energy transfer between and within trophic levels are measures of community structure. Furthermore, these functions may be regarded as important ecosystem resources. We hypothesize that the immediate population-level effects from environmental stress may result from differential impairment of competitive ability. At the relatively low pollution levels anticipated in the investigation, we may expect to find predisposing and subclinical effects that will be impossible to detect in the absence of appropriate population dynamic, biochemical, and physiologic information.

Effects need not be mediated by alterations in food chains or energy flow. Certainly food chains and mass and energy flow patterns will be affected (although possibly secondarily) whenever population adjustments occur. For example, a pollutant may alter the physiology or behavior of the individuals that comprise a population. These alterations are ultimately reflected in altered survival, reproduction and/or emigration rates. Such effects may be subtle and difficult to relate to the specific stressor. In the real world, numerous stressors are operating in complex ways with various lag times; these tend to confound the results of any field evaluation of a single stressor. The end result of the response of the community to a continued environmental stress is a readjustment of the component populations (plant and animal) at a new state of dynamic equilibrium. It is not possible to predict with any confidence, either the adjustments and mechanisms most importantly involved or the final population levels that will be reached. By studying a rather broad range of interacting variables and, in particular, by an intensive study of certain populations, some may be isolated as sensitive and reliable measures of air pollution.

Table 1 outlines the existing research plan.

BASIS FOR SITING THE INVESTIGATION IN SOUTHEASTERN MONTANA

The selection of an appropriate study area was deemed to be essential to structuring the entire investigation. Colstrip was selected on the basis of our initial literature review and several field trips to Montana and Wyoming. The principal criteria employed in the selection of the study area are detailed below:

1. The region is climatically and ecologically representative of a relatively large portion of the North Central Great Plains.

2. The Colstrip area of the Fort Union Basin is a relatively pristine pine savanna area which has never had a stationary source of [toxic] gaseous or particulate emissions. Thus the vegetation and non-migratory animals in the area, while being stressed by various environmental factors such as drought, adverse temperatures, nutrient deficiencies, etc. have never been subjected to the added stress of air pollutants. Previous air pollution studies around power plants (e.g., the Environmental Protection Agency's Mount Storm studies; the Tennessee Valley Authority's pre- and post-operational studies; Large Power Plant Effluent Study (LAPPES) [APTD 70-2, 0589, and 0735] and others [EPA 660/3-74-011] have occurred <u>after</u> the power plants are on line, or in areas already so polluted prior to operation of the power plant that one has never been able to adequately assess the very first introduction of toxic emissions of power plants to an essentially pristine ecosystem.

Table 1. Outline of The Research Plan for the Montana Coal-Fired Power Plant Project

I. Field Investigation

A. Temporal and spatial quantitative inventory of components of the study area, with particular focus on the annual cycle phenomena of key species.
B. Meteorological measurements to support the modeling and experimental air pollution research efforts.
C. Development of remote sensing as a tool for detecting effects of air pollutant challenge on the ecosystem.
D. Measurement of loss of inventory attributed to strip mining, power lines, human activity, water use, and other potentially confounding influences, e.g., pesticides, disease, population cycling.

II. Air Pollution Experiments

A. Experimentally controlled air pollution of spatial segments of an ecosystem.
B. Detailed measurement of biological structure and function, including energy flow, nutrient cycling and species condition, composition and diversity during and following air pollution stress.

III. Laboratory Experiments

A. Measurement and evaluation of physiologic, biochemical and behavioral mechanisms of response to air pollution challenge.
B. Precise measurement of parameters that support dynamic models.
C. Experiments designed to test whether changes observed in experimental study plots can be attributed to air pollutant stress.
D. Secondary stresser experiments (e.g., disease, temperature stress, water stress, non-specific stress).
E. Experiments designed to test field-generated hypotheses.

IV. Modeling

A. Use of an ecosystem level model to describe and predict effects of air pollutant challenge.
B. Use of models to help design experiments.
C. Use of models to help disentangle pollutant effects from natural variation and system dynamics.
D. Meteorlogical and dispersion modeling to describe the mode of entry of pollutant into the ecosystem and its time and space distribution and concentration.

3. Montana laws favor rational development of resources.

4. According to current assessments, Montana contains nearly a third of the strippable coal reserves in the northern central Great Plains. It is possible that some 120,000 acres will be stripped during the next two decades.

5. Southeastern Montana constitutes a rich rangeland resource.

6. Existing data, while extremely scarce, indicate that air quality in Eastern Montana is well above the national average.

7. Local-regional emission sources (see Regional Profile Report on Atmospheric Aspects, Northern Great Plains Resource Program, April 1974 [draft copy]) other than the coal-fired power plant at Colstrip are unlikely to contribute importantly to the air pollution burden of the Rosebud Creek Watershed during the period of investigation.

8. The projected sites and schedules of strip-mining and power plant development are known.

9. The history of human disturbance is reasonably well-documented.

10. We expect human disturbance (except that associated with coal mining and coal-conversion) to be relatively low throughout the period of investigation. We feel reasonably assured that sample sites, including buffer zones and reference sites, will remain substantially free of confounding disturbance.

11. Other investigations are underway at Colstrip that are complementary to our investigation. Our investigation will thus broaden and extend an existing data base.

SCOPE AND PURPOSE

Summaries of the progress of the individual studies contained within the National Ecological Research Laboratory's Colstrip, Montana Coal-fired Power Plant Project are presented in the sections that follow. Most of these research activities were initiated in July 1974 and this document represents a summary of the progress to date. The overall investigation as presently planned is a three-year field effort with a fourth year devoted to data analysis and evaluation. Most of the field activities during each sampling year will take place from April through October, although some components will continue through the entire annual cycle. We expect the evaluation and synthesis of our results to generate a protocol that will allow planning managers to assess the impact of energy conversion activities on grasslands in the Northern Great Plains prior to the initiation of site selection activities. Achievement of this objective would greatly enhance our ability to make valid siting and regulatory decisions. The full realization of this objective within the time frame that has been projected will require a synthesis of the National Ecological Research Laboratory's effects research data and the coordination of these with the results of socio-economic and transport/fate research projects. This will be difficult to accomplish, but the rewards are potentially great.

SECTION II

SITE DESCRIPTIONS AND EFFECTS OF COAL-FIRED POWER PLANT EMISSIONS ON PLANT COMMUNITY STRUCTURE

by John E. Taylor, Wayne Leininger, and Ronald Fuchs

INTRODUCTION

This investigation was activated on 15 July 1974 as part of the larger project to study the bioenvironmental effects of air pollution from fossil fuel power plants on a grassland ecosystem.

Our particular project objectives were to describe pre-treatment native plant communities in areas likely to be affected by fossil fuel power plants and on areas to be stressed artificially with pollutants; to develop measurement techniques to monitor changes in plant community structure, diversity, phenology, and speciation; and to provide data for simulation models which can be used to predict bioenvironmental changes following fossil fuel power generation in other areas.

Because of the seasonally late initiation of the project, priorities had to be realigned to conform with the growing season. In particular, many of the early ephemeral plants had completed their annual cycles and were essentially gone from the scene by the time field work was initiated. This affected estimates of plant species diversity, community structure, and phenology. Also, infrared photographic procedures were hindered by the absence of green plant material; consequently, infrared signatures to aid in aerial photo interpretation were not obtained. The data served a most useful purpose, however, since they constitute a trial of procedures to be refined and used in future years. Some of the field techniques will be rejected or modified as the data analyses are completed this winter.

A good part of the first field season was devoted to developing procedures and techniques which will be used in subsequent years.

RESEARCH ACTIVITIES

A field station was established at the Environmental Protection Agency site at the Fort Howes Ranger Station. Studies in the vicinities of Ft. Howes and Colstrip were conducted from that location.

The project activities for the report period may be classified as follows:

Description and Characterization of Study Areas
Plant Community Structure Studies
Aerial Photography
Miscellaneous Service Functions

Each of these activities is discussed in detail below. Plants encountered at each of the study sites are listed in Table 2.

Description and Characterization of Study Areas

The first season's work was concentrated on the principal sites which were established for the overall EPA project (Figure 1) and on the proposed experimental site at Ash Creek.

Site Descriptions are:

1. Ash Creek: This site is located on the Custer National Forest (Ft. Howes Ranger District), southeast of Ashland, Montana. The 27 acre

Table 2. Species Encountered on Eight Study Sites, Summer 1974

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
GRAMINOIDS								
<u>Agropyron cristatum</u>					X			
<u>Agropyron smithii</u>	X	X	X	X	X	X	X	X
<u>Agropyron spicatum</u>	X	X				X	X	X
<u>Aristida longiseta</u>	X		X	X	X	X	X	
<u>Bouteloua curtipendula</u>								X
<u>Bouteloua gracilis</u>	X	X	X	X	X	X	X	X
<u>Bromus japonicus</u>	X	X	X	X	X	X	X	X
<u>Bromus tectorum</u>	X	X	X	X	X	X	X	X
<u>Calamovilfa longifolia</u>		X				X	X	X
<u>Calamagrostis montanensis</u>	X							
<u>Carex filifolia</u>		X	X	X	X	X	X	X
<u>Carex pennsylvanica</u>	X							
<u>Festuca idahoensis</u>	X							
<u>Koeleria cristata</u>	X	X	X	X	X	X	X	X
<u>Muhlenbergia cuspidata</u>							X	
<u>Poa secunda</u>	X	X	X	X	X	X	X	
<u>Poa pratensis</u>	X	X			X	X	X	
<u>Schedonnardus paniculatus</u>		X			X			
<u>Schizachyrium scoparium</u>			X	X				X
<u>Sporobolus cryptandrus</u>					X			
<u>Stipa comata</u>	X	X	X	X	X	X	X	X
<u>Stipa viridula</u>	X	X					X	
<u>Vulpia octoflora</u>	X	X	X	X	X	X	X	X
FORBS								
<u>Achillea lanulosa</u>	X	X	X	X	X		X	
<u>Ambrosia psilostachya</u>						X		

Table 2. (Continued)

Species	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
FORBS (Continued)								
Linum perenne		X			X	X	X	
Linum rigidum		X	X					X
Mammillaria missouriensis	X		X			X	X	
Melilotus officinale							X	X
Mirabilis linearis				X				
Opunta fragilis	X	X	X	X	X	X	X	X
Opuntia polyacantha		X	X	X	X	X	X	X
Orthocarpus luteus	X			X				
Oxytropis spp.		X					X	X
Petalostemon purpureum							X	
Phlox hoodii	X	X	X		X		X	
Plantago purshii	X	X	X	X	X	X	X	
Polygala alba		X						
Psoralea argophylla	X	X	X	X	X		X	X
Ratibida columnaris	X		X		X			
Sisymbrium altissimum					X	X		
Solidago missouriensis		X	X					X
Solidago occidentalis			X					
Solidago spp.	X							X
Sphaeralcea coccinea	X	X	X	X	X		X	
Taraxacum officinale	X	X	X	X	X	X		
Tragopogon dubius	X	X	X	X	X	X	X	X
Yucca glauca						X	X	
Unknown forbs	X	X	X	X	X	X	X	X
SHRUBS								
Artemisia cana	X	X		X	X	X	X	X

Table 2. (Continued)

Species	Site: Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
Forbs (continued)								
Androsace occidentalis	X	X	X	X	X	X	X	X
Antennaria parvifolia	X	X	X					
Antennaria spp.							X	
Artemisia ludoviciana	X	X						
Aster spp.				X				
Astragalus crassicarpus	X	X		X			X	X
Astragalus gilviflorus		X						
Astragalus striatus		X						
Cerastium arvese		X						
Chrysopsis villosa				X				X
Cirsium arvense	X							
Cirsium undulatum	X		X	X	X	X		
Conyza canadensis	X	X	X	X	X			X
Echinacea pallida	X		X				X	X
Eriogonum annuum								X
Erigeron divergens	X		X	X	X			
Erigeron spp.							X	X
Erysimum asperum			X	X	X			X
Evolvus pilosus			X	X	X			
Gaura coccinea	X	X	X	X	X	X	X	X
Grindelia squarrosa	X	X	X	X			X	
Haplopappus spinulosus	X							
Hedeoma hispida	X	X	X	X	X	X	X	
Hymenopappus filifolius		X						
Lactuca spp.		X		X				X
Lepidium spp.		X	X	X	X	X		X
Liatris punctata					X			X

Table 2. (Continued)

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
SHRUBS (continued)								
Artemisia dracunculus	X	X	X	X	X	X	X	X
Artemisia frigida	X	X	X	X	X	X	X	X
Artemisia tridentata		X				X	X	
Atriplex gardneri		X					X	
Chrysothamnus nauseosus							X	
Eurotia lanata	X	X		X	X		X	
Gutierrezia sarothrae	X	X		X	X	X	X	
Juniperus scopulorum							X	
Prunus virginiana						X		X
Rhus trilobata						X	X	X
Rosa arkansana	X	X						
Rosa spp.		X						

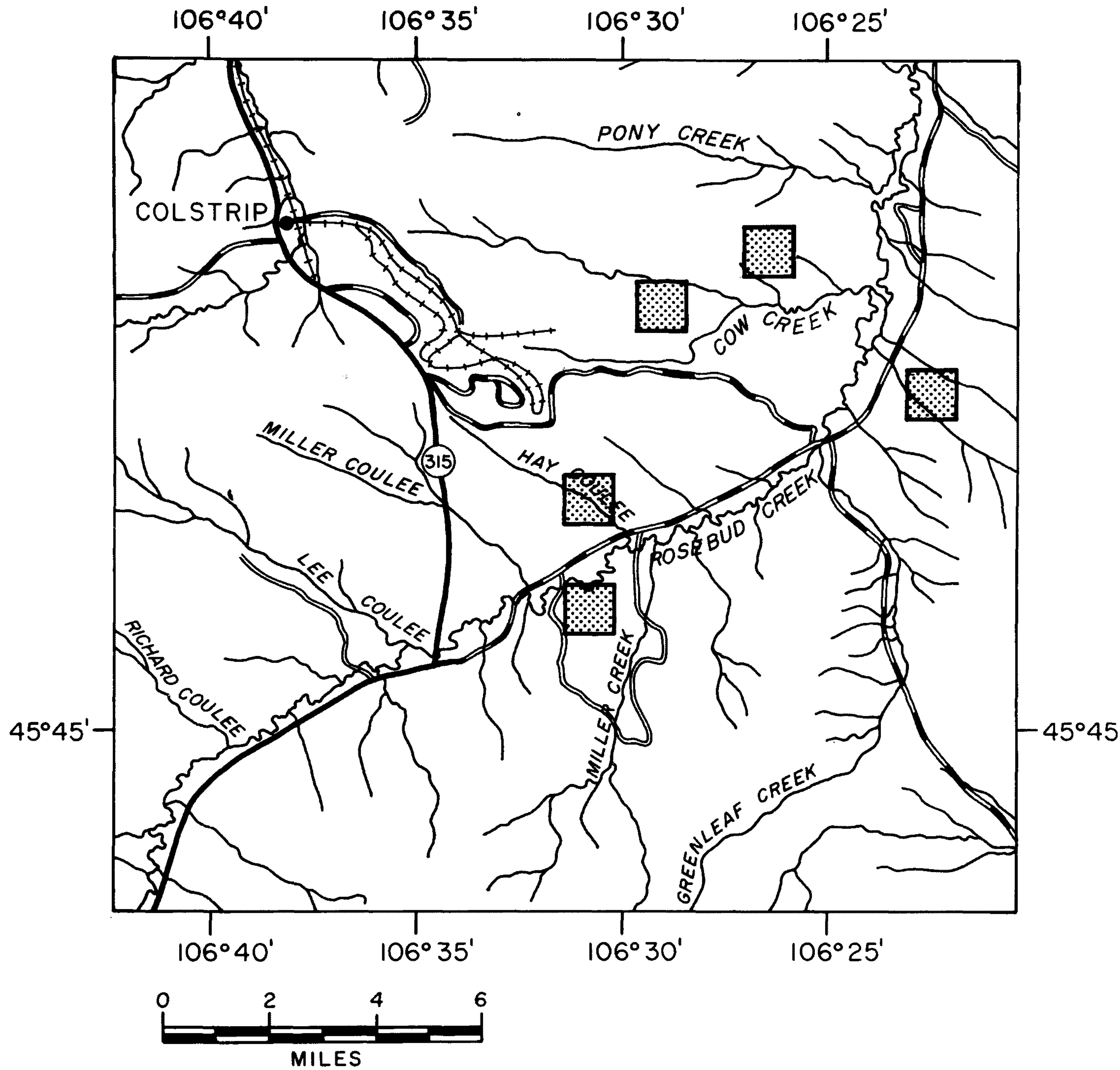

Figure 1. Location of Principal Study Sites in the Vicinity of Colstrip, Montana

exclosure is situated on a broad upland bench at an elevation of about 3850 feet. There is a slight (four to five percent) slope to the NE. Soils are silt loams, derived in place from decomposition of parent material. The site is estimated to be in low good range condition, according to the method of the Soil Conservation Service (1971). Dominant vegetation is western wheatgrass (Agropyron smithii) and prairie junegrass (Koeleria cristata), associated with Japanese brome (Bromus japonicus) and silver sage (Artemisia cana).

2. Hay Coulee: This site is the location of the air quality monitoring station, and is situated on private land, seven miles southeast of Colstrip, Montana. Topography is a sloping hillside above a coulee bottom, with a four percent slope to the south-southwest. Elevation is 3050 feet. The clay loam soils are derived from alluvium from surrounding uplands. Range condition is estimated to be good. Western wheatgrass and big sagebrush (Artemisia tridentata) dominate the site, in association with prairie junegrass and Japanese brome.

3. Kluver West (Cow Creek): This site is on private land about eight miles east-southeast of Colstrip at an elevation of approximately 3070 feet. The exclosure is on an outwash terrace and slopes about six percent toward the north. The predominant soils are sandy loams which have been washed down from the higher slopes. Range condition is good. The dominant vegetation is needle-and-thread (Stipa comata) and annual bromes [cheatgrass (Bromus tectorum) and Japanese brome]. Major plant associates are western wheatgrass, wooly indianwheat (Plantago purshii), six weeks fescue (Vulpia octoflora), and scarlet globemallow (Sphaeralcea coccinea).

4. Kluver North: This location is on private land about nine miles east of Colstrip. The exclosure is near a coulee bottom at an elevation of 3000 feet. The topography is fairly flat, with a five

percent slope to the northeast. Soils are alluvial sandy loams. Range condition is good, with needle-and-thread and fringed sagewort (*Artemisia frigida*) the most conspicuous plants. Other important species include western wheatgrass, Japanese and cheatgrass bromes, threadleaf sedge (*Carex filifolia*), Sandberg bluegrass (*Poa secunda*) and meadow salsify (*Tragopogon dubius*).

5. Kluver East (School Section, Bull Pasture): The exclosure is about 11 1/2 miles east-southeast of Colstrip on a state section. The site is a gently sloping (three and one-half percent) coulee bottom with a southwest exposure. Elevation is 3000 feet. Soils are clay loams, formed in place from weathered parent material and alluvium. Range condition is good. Western wheatgrass, cheatgrass and Japanese bromes are associated with fringed sagewort, meadow salsify, and needle-and-thread grass.

6. McRae Knolls.

6a. McRae Knoll "A": This is one of three adjacent sites, essentially undisturbed by domestic animals, located on private land nine miles southeast of Colstrip. The site is on a relatively flat-topped knoll at 3030 feet elevation. There is a slight (two percent) slope to the east-southeast. The sandy loam soils are derived from alluvium and parent materials weathered in place. Range condition is good. The knoll top is dominated by needle-and-thread grass and Japanese brome, with western wheatgrass and scattered silver sagebrush. Several desirable native range species are found along the knoll slopes. These include prairie sandreed (*Calamovilfa longifolia*), little bluestem (*Schizachyrium scoparium*), and bluebunch wheatgrass (*Agropyron spicatum*).

6b. McRae Knoll "B": This site lies between Knolls "A" and "C" and is about 20 feet lower in elevation. Soils are similar to those of

Knoll "A". This knoll slopes up toward Knoll "A" (northeast) and slopes downward in the other directions. Range condition here is estimated to be excellent. Bluebunch wheatgrass and needle-and-threadgrass dominate the vegetation, associated with big sagebrush and Japanese brome. Prairie sandreed is found on the slopes.

6c. McRae Knoll "C": Adjacent to the previous site, this area is considerably smaller than "A" and about the same size as "B". It breaks off abruptly to the west side. Soils and topography are generally similar to those of Knolls "A" and "B". Range condition is high good, with needle-and-thread and threadleaf sedge predominating. Major associates include western wheatgrass, Japanese brome, prairie sandreed, and little bluestem.

Further possible sites were examined for future use, including areas near Pony Creek (east of Colstrip), Poker Jim Flat (west of Ft. Howes), the Ashland Division, Custer National Forest (Ashland and Ft. Howes Districts), and several study areas established and described by Steve Knapp, Biologist, Montana Fish and Game Department (pers. comm.).

Plant Community Structure

Canopy Cover Determinations --

Canopy cover estimates were made on all intensively studied locations and on all three of the McRae knolls. The technique used was that of Daubenmire (1959), which employs a two by five dm plot in which each species' canopy cover is classified into one of six categories. Fifty frames were examined on each sampling date on each site. The data from the first sampling date are shown in Table 3. It can be seen that there is a substantial difference among sites, and that Ash Creek is by far the richest floristically.

Table 3. Average Percent Canopy Cover on Eight Study Sites (averages of two lines of 25 frames each)

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
GRAMINOIDS								
Agropyron cristatum					10.9			
A. smithii	22.65	14.45	10.65	11.7	17.35	1.55	3.4	1.7
A. spicatum		.3					.4	
Bouteloua gracilis	.05	9.0	6.0	16.8	5.95	2.1	14.15	7.15
Bromus japonicus	7.1	16.0	32.65	15.1	13.2	24.85	4.75	9.4
B. tectorum		7.8	9.8	3.85	12.15	2.15	.8	1.1
Calamovilfa longifolia								1.85
Calamagrostis montanensis	.25							
Carex filifolia			3.95	.4		10.9	6.35	16.8
C. pennsylvanica	.05							
Koeleria cristata	19.9	9.6	.1	.3	.05	2.55	10.55	
Poa secunda	3.65	2.35	2.95	2.2	.75	.75	.15	
Schedonnardus paniculatus					.3			
Stipa comata	1.05	.4	38.1	14.8	5.05	13.15	3.4	20.0
S. viridula	.05						.05	
Vulpia octoflora	1.6	2.9	8.45	.65	.2	.35		1.05
Aristida longiseta			.3	1.25	.05			
FORBS								
Achillea lanulosa	1.5		.15		.6			
Androsace occidentalis	.9	.3	.35	.55	.1	.05	1.0	.1
Antennaria parvifolia	.65							
Antennaria species							.05	
Artemisia ludoviciana	3.45							
Astragalus crassicarpus	.4			.35				
A. striatus	.15							
Cerastium arvense	.75							
Conyza canadensis	1.45		.1	.15	.05			
Erysimum asperum			.05		.3			

Table 3. (Continued)

Species	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
	Site							
FORBS (Continued)								
Gaura coccinea	.75						.05	.1
Grindelia squarrosa				.3				
Haplopappus spinulosus	.05							
Hedeoma hispida	2.0	3.4	1.8	1.2	.45	.1	.1	
Lepidium spp.		.1	.1	.2	.1	.1		
Lygodesmia juncea			.1			.8	3.05	.15
Linum rigidum		.05						.05
Mamillaria missouriensis			.15					
Opuntia fragilis		.05	.3	.1	.9	1.1	.65	.05
O. polyacantha				.3				
Phlox hoodii	3.5	.75					.05	
Plantago purshii	2.15	2.95	3.75	1.5	1.95	.4	.65	
Psoralea argophylla	4.5		.25		.75		.1	.05
Sphaeralcea coccinea	1.1	.05	1.05				.4	
Taraxacum officinale	.75	.5		2.9	.5			
Tragopogon dubius	3.25	1.3	1.2	13.7	3.4	.4	.4	.2
Unknown forbs		.05		.45	.35			
SHRUBS								
Artemisia cana	1.1	1.4			1.25	1.55	1.1	.3
A. frigida	5.15	5.2	.4	12.8	16.95	2.35	2.85	2.55
A. tridentata		5.5					.75	
Eurotia lanata	.05	.35						
Gutierrezia sarothrae	3.15	.3		.3			.05	
Rosa arkansana	.8							

Table 3. (Continued)

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
OTHERS								
Moss	1.45	.05	.05	.05		1.75	2.8	5.45
Bare ground	22.85	11.05	5.25	16.4	14.9	8.45	11.15	15.8
Rocks and erosion pavement			.05		.1	.25	.85	.15
Lichens	4.35	12.3	29.35	16.2	15.8	12.85	10.65	3.5
Litter	56.4	68.5	78.25	60.95	53.4	37.2	42.85	50.25

Diversity Studies

Procedure -- Numerical data for index of diversity studies (species and individuals per species) were recorded for each Daubenmire plot concurrently with canopy cover. These data are presented in Table 4.

Indices used --

(1) Shannon-Weaver Function

$$H' = \sum_{i=1}^{S} P_i \text{Log } P_i$$

Where H' = the index of diversity

S = the number of species present

P_i = the number of individuals per species divided by the total number of individuals sampled.

H' is an estimation of Brillouin's H, the true population diversity. At large sample sizes the value for H' is almost exactly that for H. In addition, since log P_i is used rarer species aren't discriminated against (Pielou, 1966; Shannon and Weaver, 1963).

Table 4. Number of Plants per Species on Eight Study Sites (total of two lines of 25 frames each).

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
GRAMINOIDS								
Agropyron cristatum					96			
A. smithii	1324	1362	418	467	956	92	251	123
A. spicatum		2					11	
Aristida longiseta			1	7	1			
Bouteloua gracilis	1	101	63	104	22	22	203	116
Bromus japonicus	576	1141	1905	803	797	2700	1124	855
B. tectorum		388	556	243	710	201	123	553
Calamovilfa longifolia								12
Calamagrostis montanensis	7							
Carex filifolia			91	10		352	249	535
C. pennsylvanica	2							
Koeleria cristata	563	302	2	5	1	40	143	
Poa secunda	157	124	36	48	10	29	5	
Schedonnardus paniculatus					1			
Stipa comata	12	2	260	137	37	169	126	129
S. viridula							1	
Vulpia octoflora	128	386	803	30	14	18		68
FORBS								
Achillea lanulosa	106		3		7			
Androsace occidentalis	89	9	14	18	2	2	82	4
Antennaria parvifolia	7							
Antennaria species							1	
Artemisia ludoviciana	112							
Astragalus crassicarpus	1			1				
A. striatus	4							
Cerastium arvense	11							
Conyza canadensis	59		1	3	1			
Erysimum asperum			1		5			

Table 4. (Continued)

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
FORBS (Continued)								
Gaura coccinea	35						1	2
Grindelia squarrosa				1				
Hedeoma hispida	156	498	94	51	11	2	1	
Lepidium spp.		3	3	11	2	2		
Lygodesmia juncea			2			18	28	3
Linum rigidum		1						1
Mamillaria missouriensis			4					
Opuntia fragilis		3	6	6	19	10	2	2
O. polyacantha				4				
Phlox hoodii	44	15					3	
Plantago purshii	374	377	225	141	124	9	40	
Psoralea argophylla	61		5		14		3	5
Sphaeralcea coccinea	66	1	32				8	
Taraxacum officinale	9	6		48	11			
Tragopogon dubius	39	24	22	291	47	9	10	4
Unknown forbs		1		5	1			
SHRUBS								
Artemisia cana	7	3			1	5	8	1
A. frigida	49	47	4	125	140	4	25	2
A. tridentata		4					1	
Eurotia lanata		2						
Gutierrezia sarothrae	13	1		1			1	
Rosa arkansana	6							

Table 4. (Continued)

Species	Site							
	Ash Creek	Hay Coulee	Kluver West	Kluver North	Kluver East	McRae Knoll A	McRae Knoll B	McRae Knoll C
OTHERS								
Moss	6	1	1	2		32	90	74
Bare ground								
Lichens	101	235	285	197	264	279	451	101

(2) Simpson's D

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

Where D = the index of diversity

S = the number of species present

P_i = the number of individuals per species divided by the total number of individuals sampled.

While values for D agree closely with values for H', the expression p_i^2 used in the formula discriminates against the rarer species (Simpson, 1949).

(3) Redundancy

$$R = (H'max-H') \quad (H'max-H'min)$$

Where R = redundancy

H' = Shannon's H'

H'max+H'min = are the maximum and minimum possible values, respectively, for H' based on the species and total number of individuals recorded.

Redundancy is a measure of evenness or equitability which relates the observed H' to the maximum and minimum possible values of H' given the number of species and total number of individuals present (Hamilton, 1974).

(4) Probability of Interspecific Encounter (P.I.E.)

$$\Delta_1 = \left(\frac{N}{N-1}\right) 1 - \sum_{i=1}^{s} P_i^2 = \left(\frac{N}{N-1}\right) D$$

Where Δ_1 = the probability of interspecific encounter (P.I.E.)

D = Simpson's D

N = the total number of individuals sampled.

P.I.E. is an index of diversity based on Simpson's D. It is the probability an individual has of encountering an individual of another species (Hurlbert, 1971).

(5) Probability of Intraspecific Encounter (Pa)

$$Pa = 1 - \Delta_1$$

Where Pa = the probability of intraspecific encounters

Δ_1 = P.I.E.

Pa is the complement to P.I.E. (Hurlbert, 1971). It measures the probability of one individual encountering another individual of the same species in the sample population.

(6) P.I.E. Transformation (Δ_3)

$$\Delta_3 \quad = \quad 1 \sum_{i=1}^{s} P_i^2$$

Where Δ_3 = P.I.E. transformation

$\sum_{i=1}^{s} P_i^2$ = the expression from Simpson's D.

The P.I.E. transformation is used to increase the spread between values for Simpson's D at the upper portion of its range (Hurlbert, 1971).

(7) Fisher's α

$$\alpha = \frac{N(1-X)}{X}; \; N = \frac{n}{1-X}$$

Where α = the index of diversity

N = the total number of individuals sampled

n' = number of species with just one individual

Fisher's α is based on the number of species in the sample containing only one individual (Fisher, Cobert and Williams, 1943).

Results and discussion -- A comparison of the various indices is given in Table 5. Statistical tests of correlation appear in Tables 6 and 7.

Table 5. Comparison of Various Indexes of Diversity, Based on Plant Numbers

Site	Fisher's α	Simpson's D	H'	Redundancy	P.I.E.	Pa	Δ3	Range Condition
Kluver North	3.0382	.8765	1.0506	.2808	.8768	.1232	8.0972	60%
Hay Coulee	5.0052	.8585	.9804	.3275	.8587	.1413	7.0671	60%
Kluver West	5.0053	.8433	.9464	.3516	.8435	.1565	6.3816	55%
Ash Creek	2.0010	.8423	1.0590	.3547	.8425	.1575	6.3412	50%
Kluver East	6.0112	.8194	.8886	.3948	.8196	.1804	5.5371	50%

Table 6. Spearman Rank Correlation Coefficients, Based on Plant Numbers

	D	H'	R	P.I.E.	Pa	Δ3	R.C.
D	-	0.4	-1.0	1.0	-1.0	1.0	1.0
H'	0.4	-	-0.4	0.4	-0.4	0.4	0.4
R	-1.0	-0.4	-	-1.0	1.0	-1.0	-1.0
P.I.E.	1.0	0.4	-1.0	-	-1.0	1.0	1.0
Pa	-1.0	-0.4	1.0	-1.0	-	-1.0	-1.0
Δ3	1.0	0.4	-1.0	1.0	-1.0	-	1.0
R.C.	1.0	0.4	-1.0	1.0	-1.0	1.0	-

Table 7. Pearson's Product of Moments Correlation Coefficients, Based on Plant Numbers

	D	H'	R	P.I.E.	Pa	Δ3	R.C.
D	-	0.4	-1.0	1.0	-1.0	1.0	1.0
H'	0.4	-	-0.4	0.4	-0.4	0.4	0.4
R	-1.0	-0.4	-	-1.0	1.0	-1.0	-1.0
P.I.E.	1.0	0.4	-1.0	-	-1.0	1.0	1.0
Pa	-1.0	-0.4	1.0	-1.0	-	-1.0	-1.0
Δ3	1.0	0.4	-1.0	1.0	-1.0	-	1.0
R.C.	1.0	0.4	-1.0	1.0	-1.0	1.0	-

As can be seen from Tables 5, 6 and 7, the various indexes correlated quite closely except for Fisher's α. The high value for H' for the Ash Creek control site is probably due to a greater number of forbs, reflecting the more favorable plant habitat.

Future studies -- Additional data are needed to see if the various indexes used are sensitive enough to show variations in diversity through the growing season. Once enough background data have been gathered and analyzed, it will be seen if the indexes can monitor changes in diversity due to air pollution stresses on the ecosystem.

Also, we will calculate another set of diversity indexes based on Colorado State University's biomass data. These indexes will be compared with the results gained using individuals per species. Modifications in methods, procedures, and calculations of indices may follow if biomass rather than individuals per species yields more promising results.

Phenology studies -- Initial observations were made to test a phenological scorecard which was developed for this project. The lateness of the season precluded the development of an annual phenologic profile for the study areas, but it was felt that the system will be useful in subsequent seasons.

The phenological stages recognized and the field form used are shown in Tables 8 and 9, respectively.

Pattern analysis -- Some preliminary pattern studies were initiated on several of the locations using the approach of Kershaw (1957). These data will be analyzed this winter. The purpose of this study is to evaluate pattern analysis procedures in terms of their sensitivity to plant community changes which may result from the initiation of power generation.

Table 8. Classification of Phenological Stages

Code	Stages
1	Cotyledon (newly germinated)
2	Seedling
3	Basal Rosette
4	Early greenup, veg. buds swelling
5	Vegetative growth, twig elongation
6	Boat stage, flower buds appearing
7	Shooting seed stalk, floral buds opening
8	Flowering, anthesis
9	Late flowering
10	Fruit formed
11	Seed shatter, dehiscence
12	Vegetative maturity, summer dormancy, leaf drop
13	Fall greenup
14	Winter dormancy
15	Dead

Table 9. Plant Scorecard

LOCATION ______________________

DATE ______________________

WORKER(S) ______________________

Species	Phenology Code	Comments

Plant Collection -- The field crew attempted to collect all plant species on each study site as they came into flower. This included only the late flowering species of this year. Future collections will obtain specimens of the early flora. This material will constitute a local reference herbarium for consultation by field workers. Specimens also will be submitted to the Montana State University Herbarium for taxonomic verification and voucher purposes.

Seed Collection -- Seeds of common plant species were collected as time permitted. This material will be used by the bird research personnel in examining food habits. This work will continue in future years.

Soil Sampling -- Soil samples were collected from the McRae Knoll sites to be used in further characterization of plant habitats. Additional collections will be made on all sites, following the methods of Passey and Hugie (1962). Soil analysis will be conducted by the Soil Testing Laboratory, Montana State University.

Permanent Ground Photo Plots -- Initial photo plots were established and photographed at all locations. At Ash Creek, two plots were placed in each of the proposed stressing plots. At Hay Coulee and the three Kluver sites, two photo plots were established in each enclosure, and one photo plot was placed on each of the three McRae knolls.

The photo plots were three by three feet, and were marked for relocation. Each was photographed in color from a high oblique angle (25° from vertical). Stereoscopic photography was used for ease of plant identification. Most of the plots also were photographed with infrared color film. After the oblique photographs were made, the camera was tilted up so that the field of view included the horizon, and an aspect picture was taken. At the same time as the plot photography, a rough chart was prepared of the plot, showing locations and identifications of the various species present. This was done to aid in the interpretation of the photographs this winter.

The ground level photographs will be analyzed during the coming months to evaluate potential usefulness in recording detailed vegetational changes.

Aerial Photography

On 24 and 25 September, initial aerial photography of the study areas was contracted to Aerial Survey, Inc. of Miles City. The purpose of this activity was to obtain imagery in various emulsion types and at different scales for evaluation as future operational procedures. Color, IR color, and black-and-white imagery were obtained in 35 mm and 70 mm formats. Flying elevations ranged from 500 to 7200 feet above ground level, yielding image scales from 1/3000 to 1/44,500.

Black-and-white index mosaics were prepared for each of the study areas as aids to future aerial photography. The color imagery will be examined further in terms of its use as a monitoring technique.

FUTURE ACTIVITIES

No substantial changes are anticipated in this research, with the exception of the procedural modifications mentioned above. The winter season will be used to identify the most useful and meaningful data and to refine field procedures. Photographic interpretation will be completed and base maps drawn of each experimental area. Decisions about future aerial photographic support requests will be made in consultation with Robert A. Lewis and Thomas Osburg. Other principal investigators will be contacted about their photographic support requirements and their data sharing possibilities.

No field work is planned for the next quarter, except for the possibility of some more aerial photo scale experiments if conditions are favorable. This will be accomplished locally. The bulk of research activities for the next quarter will be centered on data analysis and interpretation and planning for the next field season.

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SECTION III

EFFECTS OF SO_2 AND OTHER COAL-FIRED POWER PLANT EMISSIONS ON PRODUCER, INVERTEBRATE CONSUMER, AND DECOMPOSER STRUCTURE AND FUNCTION IN A SOUTHEASTERN MONTANA GRASSLAND

By J. L. Dodd, R. G. Woodmansee, and W. K. Lauenroth

INTRODUCTION

The overall objective of our task is to determine the effects of coal-fired power plant emissions on the structure and function of a southeastern Montana grassland ecosystem and to represent these effects in a total system simulation model.

One set of objectives relates to baseline monitoring of four grassland study sites (Hay Coulee, Kluver West, Kluver North, and Kluver East) near the coal-fired power plant at Colstrip, Montana. These sites are expected to be exposed to differing intensities of atmospheric pollution following completion of the plant during midsummer 1975. The objectives for 1974 were to characterize decomposition rates and seasonal biomass dynamics of the producer and invertebrate consumer components of each of these ecosystems in the season prior to their first exposure to emissions from the coal-fired plant. Objectives for 1975 are to determine the effects of the anticipated atmospheric pollution on these and other ecosystem attributes.

A second array of objectives relates to the field experimental study to be located near the Ash Creek reservoir seven miles northeast of the Ft. Howes Ranger Station in the Custer National Forest. Our objectives are to determine the effects of SO_2, a major component of power plant emissions, on the seasonal biomass dynamics of the producers and invertebrate consumers and on decomposition rates. Our objectives for 1974 were to test pre-treatment homogeneity of the four sites to be used in the field experimental study.

A final set of objectives pertain to the adaptation of the Natural Resource Ecology Laboratory ecosystem level simulation model to the grassland type mentioned in the previous objectives. The objectives for this year were to secure the field information necessary to adapt the model and to consider modifications of the model that will allow it to be used to simulate the dynamics of the Montana grassland under challenge from atmospheric pollution.

PROGRESS FOR THE 1974 FIELD SEASON

Primary Producer Biomass

Seasonal Biomass Dynamics --

Colstrip sites -- Six sample dates (10 May, 15 June, 1 July, 24 July, 12 August, and 26 September) were completed for the 1974 season. Ten 0.5-m^2 quadrats were clipped for each of the four exclosures on each sample date. Aerial plant biomass was separated by species and categories (viz. live, recent dead, old dead). The data have been summarized ($\overline{X}$'s, SE's) for five of the dates. Below-ground biomass and plant bases (crowns) were sampled in conjunction with above-ground biomass. Thirty cores, 7.5 cm in diameter x 10 cm deep, were collected on each sample date on each site. In addition to this, on 27 July an extra set of 10 cores 5 cm in diameter x 60 cm deep was collected per exclosure.

The cores were washed with water to remove soil and the crowns and roots were separated and weighed. These data also are summarized for five dates. Litter was collected from each quadrat clipped for above ground biomass with a vacuum. These data are also summarized for five dates.

Ash Creek experimental site -- Sampling was done in a similar manner here. Two sample dates (3 June and 10 July) were completed at this site in 1974.

Phenology --

No phenology data were collected in 1974 due to a late starting date.

Species Lists --

Species lists compiled in 1974 included only those species occurring in the 0.5-m^2 quadrats clipped for above ground biomass.

Chemical Analyses --

Table 10 summarizes the chemical analyses planned for both above- and below ground biomass. In addition, all above-ground plant material is being saved for future analyses. No results are available at this time.

Soil Respiration

No soil respiration data were collected in 1974 due to a late starting date.

Decomposition Bags

Litter --

No litter bag samples were collected in 1974 due to a late starting date.

Table 10. Chemical Analyses Planned for Above and Below Ground Biomass

	Components	Average Number of Categories	Dates	Treatment	Replicate	Types of Analysis	Total Number of Analyses
Colstrip (treatment E, F, G, H)[a]	KOCR[b]	2	3	4	2	N,P,S,Ash	192
	AGSM	2	3	4	2	N,P,S,Ash	192
	STCO	2	3	4	2	N,P,S,Ash	192
	BRJA	1[d]	3	4	2	N,P,S,Ash	96
	BOGR	2	3	4	2	N,P,S,Ash	192
	Belowground[c]	1	1	4	2	N,P,S,Ash,TAC[j]	40
						Sub	904
Ft. Howes (treatment A, B, C, D)	KOCR	2	1[f]	1[i]	2	N,P,S,Ash	16
	AGSM	2	2[g]	4	2	N,P,S,Ash	128
	STCO	2	1[f]	4	2	N,P,S,Ash	64
	BRJA	1[d]	1[h]	4	2	N,P,S,Ash	32
	Belowground	1	1	4	2	N,P,S,Ash,TAC	32
						Sub	272
						Total[k]	1176

a/ Treatment: A, control, Ash Creek; B, low level SO_2, Ash Creek; C, moderate level SO_2, Ash Creek; D, high level SO_2, Ash Creek; E, Hay Coulee; F, Kluver West; G, Kluver North; and H, Kluver East.
b/ Plant species code names, see Table 11.
c/ Belowground sample is dry separated from 0-10 cm layer.
d/ Use live or dead, not both, for each date.
e/ Dates are 10 May, 1 July, late August, or early September.
f/ Use samples from 1 July.
g/ All dates since this set treatments will be sampled only two times.
h/ Use material from earliest date (maximum live).
i/ Use treatment A.
j/ Nitrogen, phosphorus, sulfur, ash, total available carbohydrates.
k/ Total number is approximate.

Cellulose

Sixteen cellulose bags were placed in the field per treatment (exclosure) in the spring of 1974. Three collections of four bags per treatment (exclosure) were completed in 1974. These data are not yet summarized.

Invertebrates

Above-ground Invertebrates --

Samples were collected in conjunction with plant biomass samples. Six sample dates were completed for the Colstrip sites and two for Ash Creek. Each sample date included ten 1.5-m^2 samples per treatment (exclosure). Laboratory processing is complete for four Colstrip dates and one Ash Creek date. Preliminary statistical analysis is incomplete.

Below-ground Invertebrates --

Macroarthropods. Ten soil cores per treatment (exclosure) were collected on each of the aboveground invertebrate sample dates. Processing and statistical analysis status is the same as for above-ground macro-arthropods.

Microarthropods --

Ten soil cores per treatment were collected on each of the aboveground invertebrate sample dates. Laboratory processing and statistical analysis is incomplete at this time.

Soil Description

One soil pit was described in September at the Ash Creek site. Plans include describing several more pits at Ash Creek and at least one at each of the Colstrip sites in the spring of 1975.

FUTURE ACTIVITIES

We intend to complete all sample processing and preliminary data analysis of 1974 field information by 1 December. In addition, we hope to have preliminary tabular summaries on our first-season results by 1 January, 1975.

We intend to continue field efforts in 1975. Tentative plans have been made to monitor primary producer and invertebrate consumer biomass dynamics and decomposition rates (cellulose decay, standard litter decay, and soil respiration) on each of the four Colstrip sites and each of the four SO_2 fumigation sites on six sample dates in the growing season of 1975. Procedures will be as outlined in our original proposal to EPA with modifications as necessary. Following completion of preliminary analyses of our 1974 work and comprehensive discussions and plans with other investigators of the project at our January meeting, we will formulate specific plans for the 1975 season.

We are currently considering preparation of a manuscript to be submitted to the refereed literature by midspring of 1975. We intend this publication to be a formal presentation of much of the 1974 data from our portion of the study and make our data available to other investigators of the project in a summarized, evaluated, and citable form.

Table 11. List of Plant Species Encountered in Above-ground Biomass Samples

Soil Conservation Service Standard Code	Scientific Name
ACM12	*Achillea lanulosa*
AGCR	*Agropyron cristatum*
AGSM	*Agropyron smithii*
ANOC2	*Androsace occidentalis*
ANNE	*Antennaria neglecta*
ARLO3	*Aristida longiseta*
ARFU3	*Arnica fulgens*
ARCA13	*Artemisia cana*
ARDR4	*Artemisia dracunculoides*
ARFR4	*Artemisia frigida*
ARLU	*Artemisia ludoviciana*
ARTR2	*Artemisia tridentata*
ASTRA	*Astragalus* spp.
BOGR2	*Bouteloua gracilis*
BRJA	*Bromus japonicus*
CAMO	*Calamagrostis montanensis*
CALO	*Calamovilfa longifolia*
CAEL2	*Carex eleocharis*
CAFI	*Carex filifolia*
CAPE6	*Carex pennsylvanica*
CIUN	*Circium undulatum*
COCA5	*Conyza canadensis*
CYAC	*Cymopterus acaulis*
DRRE2	*Draba reptans*
ECVI2	*Echinocereus vicidiflorus*
ERIGE	*Erigeron* spp.
ERAS2	*Erysimum asperum*
EULA5	*Eurotia lanata*
FEOC2	*Vulpia octoflora* (=*Festuca*)
GACO5	*Gaura coccinea*
GRSQ	*Grindelia squarrosa*
GUSA2	*Gutierrezia sarothrae*
HEHI	*Hedeoma hispida*
KOCR	*Koeleria cristata*
LARE	*Lappula redowskii*

Table 11. (Continued)

LEDE	Lepidium densiflorum
LEMO4	Leucocrinum montanum
LIIN2	Lithospermum incisum
LOOR	Lomatium orientale
LYJU	Lygodesmia juncea
MAMM1	Mammillaria spp.
OPFR	Opuntia fragilis
OPPO	Opuntia polyacantha
ORLU2	Orthocarpus lutea
PACH	Parmelia chlorochroa
PHHO	Phlox hoodii
PLPAG	Plantago patagonia gnaphaloides
POSE	Poa secunda
PSAR2	Psoralea argophyla
PSES	Psoralea esculenta
PSTE3	Psoralea tenuiflora
RACO3	Ratibida columnifera
ROAR3	Rosa arkansana
SCPA	Schedonnardus paniculatus
SEDE2	Selaginella densa
SENIC	Senecio spp.
SPCO	Spaeralcea coccinea
SORI2	Solidago rigida
STCO4	Stipa comata
STVI4	Stipa viridula
TAOF	Taraxacum officinale
TRDU	Tragopogon dubius
VIAM	Vicia americana
ZYEL	Zygadenus elegans
CSFO	Miscellaneous cool season forbs
WSFO	Miscellaneous warm season forbs

SECTION IV

EFFECTS OF COAL-FIRED POWER PLANT EMISSIONS ON PLANT DISEASE AND ON PLANT-FUNGUS AND PLANT-INSECT SYSTEMS

by C. C. Gordon

INTRODUCTION

Our component of the Montana Coal-fired Power Plant Project was initiated on 1 August, 1974. Consequently, this report treats the progress of both the field and laboratory studies which have been undertaken during the first two and two-thirds months of work. There are five objectives for the first year of this study and each is discussed individually in the text that follows in terms of: (1) the field and laboratory work thus far accomplished; (2) results obtained to date; and (3) work plans for the fall and winter months.

DISCUSSION OF OBJECTIVE #1: A SURVEY OF THE INSECTS AND FUNGAL POPULATIONS, INFESTATIONS, AND DAMGE TO INDIGENOUS PLANT SPECIES AT THE STUDY SITES OUTSIDE AND INSIDE THE IMPACT AREA

Five of the primary sites as well as 14 other sites are employed in our preliminary surveys of fungal and insect populations. We are surveying and collecting at the following sites: Ash Creek, Hay Coulee, Kluver West, Kluver North and Kluver East. The other study sites which have been selected are presented in Figure 2 of this report and the range and township of each of these sites is given in Table 12.

Thus far we have collected vegetation samples from each of these sites twice since August 1. A check list of the plant species found at the sites is being prepared for each site. An herbarium sample has been prepared for each of the plant species collected, and those species thus far collected are now on deposit at the University of Montana Botanical

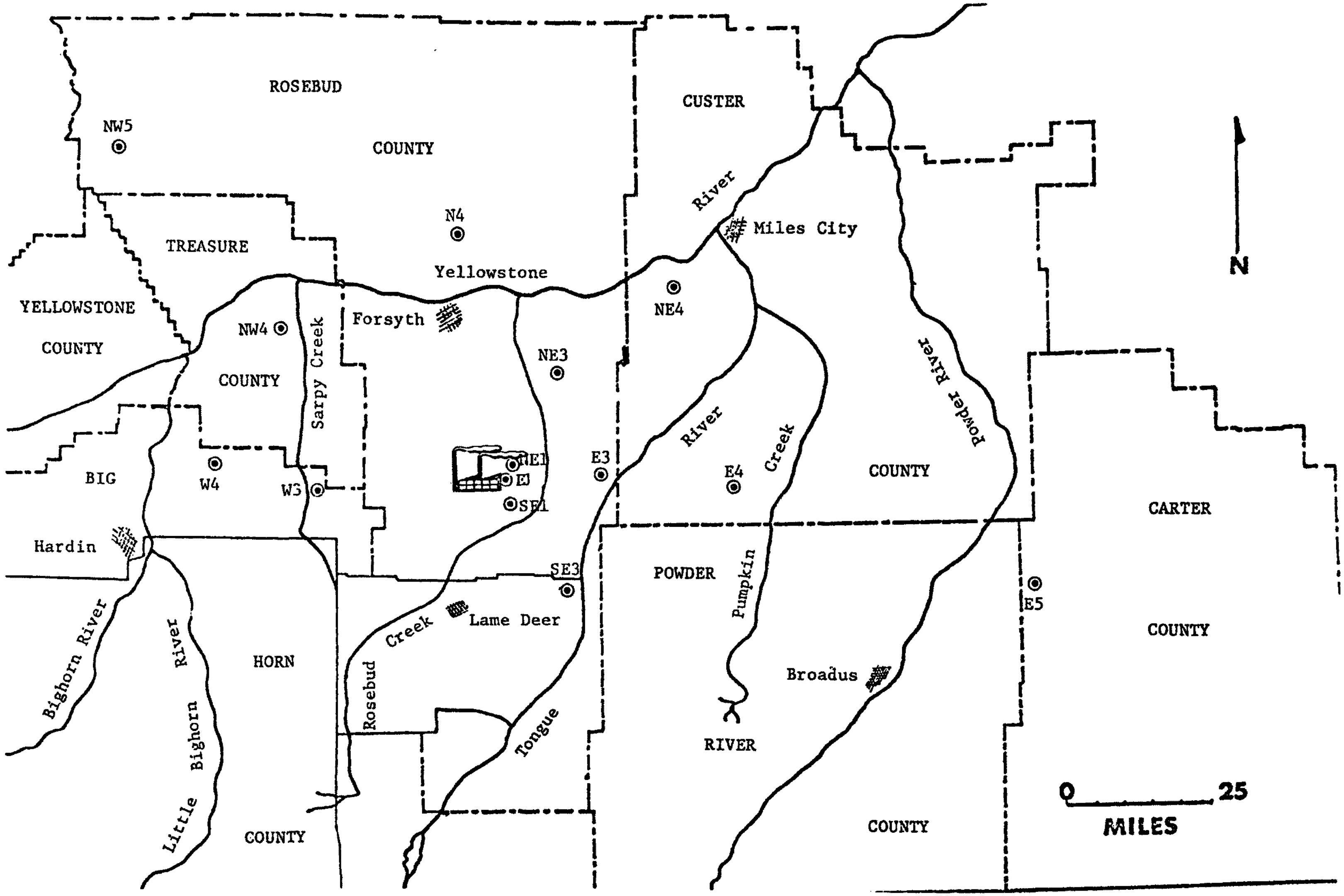

Figure 2. Map of Vegetation Collection Sites

Table 12. Vegetation Collection Sites in the Vicinity of Colstrip, Montana

Site No.	Location (section, township, range)
North #4	Sec. 36, T8N, R40E
Northeast #1	Sec. 16, T2N, R42E
Northeast #3	Sec. 10, T4N, R43E
Northeast #4	Sec. 17, T6N, R46E
East #1	Sec. 29, T2N, R42E
East #3	Sec. 27, T2N, R44E
East #4	Sec. 36, T2N, R47E
East #5	Sec. 18, T2S, R55E
Southeast #1	Sec. 16, T1N, R42E
Southeast #3	Sec. 17, T2S, R44E
West #3	Sec. 36, T2N, R37E
West #4	Sec. 8, T2N, R35E
Northwest #3	Sec. 16, T4N, R39E
Northwest #4	Sec. 2, T5N, R36E

Herbarium with a special herbarium label which was prepared for our study in the Colstrip area of the Fort Union Basin.

The identification of the insect fauna present on the vegetation collected from the sampling sites is being carried out by Dr. Jerry Bromenshenk, entomologist, while the identification of the fungal species is being done by Dr. C. C. Gordon, plant pathologist and mycologist.

The identification of fungi as well as insects is done almost entirely in the laboratory and not in the field. Those plant samples containing symptoms of fungal disease are treated in the following manner: a temporary microscope slide is prepared of the plant tissue manifesting the tissue necrosis caused by the fungus. If the fungus is not an obligate parasite (a rust or smut), an attempt to isolate the organisms by culturing on nutrient media is made. To date, 46 cultures have been obtained of fungal isolates utilizing this culturing method. A list of those isolates which have been identified appears in Table 13. The majority of isolates, several which have not produced spores at this time, have not as yet been identified. Culturing of these fungi and new isolates as plant collections are made throughout the late fall of this year will continue until we obtain an adequately diverse group of fungi to utilize at the stress sites next spring.

Samples of both obligate and saprophytic fungi have been prepared for histological studies, utilizing the normal procedures of fixing in a solution of 95 percent ethanol: glacial acetic acid: formalin: water (126:10:10:54), dehydrating in the tertiary butyl alcohol series, and mounting in paraffin. Thus far, 54 plant specimens damaged or have been prepared for microtoming in this manner. Sectioning of the materials has not commenced at the time of writing this report. It should be noted that special emphasis for histological studies has been given to the fungi parasitizing the grass species. The reason for this

Table 13. Checklist of Identified Fungal Cultures

Number	Fungus	Hosts obtained from:
1	Septoria avenae	Agropyron smithii A. spicatum
2	Ascohyta agropyrina	Agropyron smithii
3	Hendersonia sp.	Stipa comata
4	Fusarium solani	Koeleria cristata
5	Penicillium spp.	Stipa comata Agropyron spicatum Melilotus alba
6	Aspergillus spp.	Agropyron spicatum A. smithii Koeleria cristata etc.
7	Leptosphaeria artemisiae	Artemisia cana A. tridentata
8	Phyllosticta sp.	A. tridentata
9	Tubercularia vulgaris	Symphoricarpos occidentalis
10	Alternaria sp.	Rhus trilobata Chrysothamnus viscidiflorus
11	Cladosporium sp.	Petalostemon purpureum
12	Verticillium sp.	Artemisia frigida

is that at the principal study sites the grasses are the predominant species. With the completion of the histological studies as well as the isolation and cultural studies, a host-fungal checklist will be completed this winter.

Plant samples demonstrating symptoms of insect damage are processed in the following manner. The vegetation is sorted, dissected, and examined for insects and for insect damage. Insects are extracted from the plant material using a Berlese funnel. Pending identification, immature insects are preserved in 70 percent alcohol, while adult specimens are freeze-dried. Recognition of dominant insect-host plant relationships will be followed by collection of eggs and immature forms of specific insects and subsequent rearing in a greenhouse for use in studies with the Environmental Studies Laboratory's fumigation chamber. Since most insects at mid to high latitudes undergo an obligatory cold-induced diapause, it is anticipated that these laboratory populations will have to be treated to low temperatures for 50-80 days before hatching can be induced (January or February, 1975).

Sweep net surveys of Orthopterans were conducted during August, and identification of the prominent grasshopper populations is almost completed. An intensive survey of insect populations in the grassland ecosystem of the Colstrip area of the Fort Union Basin would be redundant, since Colorado State University is conducting a survey of the above- and below-ground invertebrates found on the principal study sites. Ponderosa pine trees, which occur on most of our study sites, do not occur on the principal sites. Therefore, we are conducting a more intensive survey of the insects associated with pines rather than of the insects of the grassland sites. To date, vegetation samples have been obtained from 70 trees at 14 sites. Additional samples will be obtained through the late fall of this year and early next spring. Pine samples are obtained from mid-crown using a pole pruner equipped with a basket below the cutting head to catch branch samples and insects dislodged during the cutting process. Four branches 18-20 inches in length are removed from each tree. Estimates of populations of pine insects are made in the laboratory based on the type and amount of insect damage and the relative amount of damage caused by each type of insect. Chemical analyses of the foliar concentrations of fluorides and sulfurs are partially completed. The relationships between damage caused by each species of insect and foliar concentrations of fluoride and sulfur will be analyzed statistically. Visual ratings of tree conditions are made at the time of foliage sampling and this information also will be analyzed with regard to insect, fluoride, and sulfur damage. Tree vigor descriptions are based on the degree of insect damage, crown thinning, and needle retention. The majority of the pines sampled to date displayed little or no insect damage, no apparent thinning of the crown, and good needle retention (four to eight years). At one site, some insect damage and thinning was apparent.

At the time of this report, insects have been separated and preserved from pines, shrubs and grasses. The majority of the specimens are immature forms, since many of the insect adults had begun to die off by early August.

DISCUSSION OF OBJECTIVE #2: ANALYSIS AND SELECTION OF INDIGENOUS PLANT SPECIES WHICH HAVE A DIVERSIFIED BUT UNDERSTANDABLE INTERRELATIONSHIP WITH THE INSECT AND FUNGAL POPULATIONS AT THE STUDY SITES

Until more pure culture isolations have been obtained from the grass and forb species which are dominant on the grassland sites, selection of the insect, fungus, and host species to be utilized on these sites next spring will not be accomplished. The fulfillment of this objective depends also on the host-parasite relationships which will be realized with the histological studies of the diseased and insect-infested materials prepared and being prepared for microtoming.

What we are primarily watching for, in our selection of both fungal parasites and host species, is that we have some fungi which carry out their entire life cycle within the host tissues as well as some that have a large percentage of their life cycle exogenously (outside) on the host species. Also, as previously stated, we are interested in selecting the forb and grass species which are predominant on the principal study sites. While fungal taxonomists have carried out their tasks of naming these species, very little data are available in the literature on the host-parasite relationships of the majority of these fungi. This objective will be fully realized when the isolation and histological studies are completed this winter.

DISCUSSION OF OBJECTIVE #3: SELECTION AND PRETESTING FOR EASE OF IN-VITRO GROWTH AND INOCCULATION STUDIES OF DISEASE AND INJURY-CAUSING FUNGAL AND INSECT SPECIES TO BE UTILIZED AT STUDY SITES INSIDE AND OUTSIDE THE IMPACT AREA

As previously mentioned, 46 fungal isolates have been obtained in pure culture thus far. This is considered by us a very small number since our goal is to have at least 150 fungal isolates to select from and work with during the National Ecological Research Laboratory's stressing program in the spring. The reason for the low success to date is possibly because the shrub, forb, and grass species at the sampling sites, as well as off the sampling sites, which have been collected have had very low populations of fungi. Currently it is not known if this is because of a normal low population of fungi in the Colstrip area of Fort Union Basin or whether this was a growing year in which the incidence of disease-causing fungi was extremely low. However, since field collections will continue throughout these fall and winter months, we still anticipate that at least 150 isolates can be obtained from the winter collections.

Of these species of fungi isolated into pure culture and identified so far, there is a predominance of species of Moniliales and Sphaeropsidales which belong to the class Fungi Imperfecti (Deuteromycetes). The species of Moniliales, especially the isolates of Fusarium, Penicillium, and Aspergillus, are not known to be strongly parasitic to any of the host plants from which they were isolated and, in fact, are likely to be soil contaminants on the plant samples as being saprophytic. However, several of these isolates of the Moniliales are being maintained for inocculation studies this winter. Species of the Sphaeropsidales isolated to date are known pathogens or saprogens of the hosts from which they were isolated. Three of the genera isolated (Septoria avenae, Phyllosticta sp. and Hendersonia) have been cited as common saprophytes and/or parasites of indigenous grasses of the Colstrip area. The isolation, culturing, identification, and inocculation pretesting of fungi is expected to take a large portion of time the remainder of this year and during January and February of 1975.

Several potential insect systems have been identified for further testing and selection. These include several grasshopper species (Melanoplus spp.) on grasses and forbs, the Western Harvester Ant (Pogonomyrmex occidentalis) which occurs on each of the principal study sites, and several pine insects including bark beetles (Ips and Dendroctonus spp.), needle miners, and scale insects. Preliminary studies of the Western Harvester Ant were initiated in August, 1974. A photographic record of each of the colonies (hills) as well as counts of colonies at each site were made. Population trends as indicated by the number of colonies per unit area, ant density per colony, and colony size will be followed at these sites. As mentioned before, laboratory populations of insects for studies of insect-plant relationships will be established this winter.

DISCUSSION OF OBJECTIVE #4: SELECTION AND PRETESTING OF BENEFICIAL FUNGAL AND INSECT SPECIES TO BE UTILIZED AT STUDY SITES INSIDE AND OUTSIDE THE IMPACT AREA

To date we have acquired seed and begun propogation of the plant species listed in Table 14. Also the fumigation chamber has been remodeled for better temperature and gas delivery controls and has been tested for three weeks on these two modifications. The chamber is working with excellent performance, and we are able to maintain continuous SO_2 concentrations as low as 0.1 ppm. After adequate numbers of parasites and saprophytic fungal species have been isolated for inocculation and pretesting, fumigation studies will commence which will help us in selecting the species of plants and fungi to be utilized at the National Ecological Research Laboratory's sites in the spring.

Preliminary studies of the Colstrip area indicate that the social bees best lend themselves to air pollution studies, not only because of their indispensible function of pollination, but because of their social nature and the very fact that they can be manipulated by man. Furthermore, such parameters as reproduction, honey production, pollen collection, flight activity, mortality and the like can be readily measured. Bees are particularly susceptible to population changes linked to airborne sulfur and fluoride. Samples of worker Honey Bees have been obtained from 11 sites (apiaries) near Colstrip. Thirty-four samples of approximately 1100 bees (100 gms) were collected, using an electric vacuum apparatus. Three samples were obtained at each site, consisting of specimens from at least four colonies. The samples from each site were distributed as follows: One sample is at our laboratory for fluoride and sulfur analyses; one sample has been sent to Dr. Robert A. Lewis (National Ecological Research Laboratory) for acetylcholinesterase determinations; and one sample was sent to Dr. Ronald Thomas (Environmental Protection Agency, Chemical and Biological Investigations Branch, Pesticides-Surveillance

Table 14. Plant Species Propogated in the Laboratory

Common Name	Scientific Name
Fairway crested wheatgrass	Agropyron cristatum
Thickspike wheatgrass	A. dasystachyum
Western wheatgrass	A. smithii
Tall wheatgrass	A. elongatum
Slender Wheatgrass	A. trachycaulum
Lincoln bromegrass	Bromus inermis
Orchardgrass	Dactylis glomerata
Green needlegrass	Stipa viridula
Alfalfa	Medicago sativa
Prairie sandreed grass	Calamovilfa longifolia
Basin wild rye	Elymus cinereus
Indian ricegrass	Oryzopsis hymenoides
Cicer milkvetch	Astragalus cicer
Sainfoin	Onobrychis vicialfolia
Rabbitbrush	Chrysothamnus nauseosus
Yellow sweetclover	Melilotus officinalis
Skunkbush sumac	Rhus trilobata
Nuttall saltbush	Atriplex nutallii
Woods rose	Rosa woodsii
Native snowberry	Symphoricarpos albus
Golden current	Ribes sp.
Blue grama grass	Bouteloua gracilis
Needle and thread grass	Stipa comata

Division, Beltsville, Maryland) for pesticide residue analyses. Pesticides have periodically been a source of severe environmental stress in the study area. The presence of pesticides in the environment tends to confound the results of evaluations of other environmental stressors, particularly if the types and quantities of pesticides present are unknown.

Honey Bees will be utilized next summer on the experimental plots for physiological and behavioral studies. Since the commercial beekeeper in the Colstrip area moves his colonies to California in early October, the removal of bee samples from apiaries in this area took precedence over other aspects of the insect investigations. Arrangements have been made for bee colonies to be left throughout the year at several locations near Colstrip so that permanent colonies are available for study. Wild bees such as Leaf-cutter Bees and Bumblebees will be utilized for comparative investigations.

DISCUSSION OF OBJECTIVE #5: CHEMICAL ANALYSIS OF INDIGENOUS PLANTS, INSECTS, AND FUNGI (WHEN POSSIBLE) WHICH ARE SELECTED FOR INTENSIVE INVESTIGATION DURING SECOND AND THIRD YEARS OF PROPOSED STUDY

Over 350 samples of vegetation have been collected and prepared for chemical analysis since August 1, 1974. Of these, 94 samples have been analyzed for sulfur content and 180 for fluoride levels. We collected data on the seasonal variation in fluoride and sulfur content in several of these species in the fall of 1973 (Set I) and the spring of 1974 (Set II). As regards F^- content, the means of all species for collection Sets I and II were below 5 ppm F^- except for the rice-grass *Oryzopsis hymenoides*, which was 7.27 ppm F^-. No difference between the F^- content of the grasses or shrubs could be detected, but both had significantly greater fluoride concentrations than Ponderosa Pine. There was a reduction in F^- concentration in the needles of ponderosa pine from Set II compared with Set I, and a significant increase in the F^- content as age of the needles increased (see Table 15).

The mean total sulfur content in Ponderosa Pine did not exceed 900 ppm at any sampling location. It was not possible to show a tendency of increase in sulfur content with increasing age of the needles, but there was a significant decrease in the mean total sulfur content in Set II when compared with Set I (see Table 15).

The amounts of "normal" sulfur accumulation as well as the possible seasonal fluctuation of baseline sulfur levels in the indigenous grasses growing at the principal study sites is not presently known. Also, the significance and consequence of excessive accumulation of sulfur into plant foliage from SO_2 fumigation to pathogenic and beneficial fungal and insect population are totally unknown. The analysis of vegetation will continue throughout this winter. The results of this analysis will provide a background data bank of sulfur and fluoride concentrations for use in future comparisons.

Also sulfur and fluoride analysis will be carried out this winter on Honey Bees which were collected this fall.

OTHER WORK IN PROGRESS

Precipitation Chemistry

Bulk rain collectors have been set out at each of the principal sites as well as at ten other sampling sites within a 20-mile radius of Colstrip. Automated Wong rain water collectors will also be placed at the sites where there is electricity and, where there is no electricity, in as close proximity to the study sites as possible. Monthly collections will be carried out throughout the fall, winter, and spring months.

Table 15. Chemical Analysis of Indigenous Plants

Sulfur Data for all locations combined
parts per million

Paired T tests among pine needle data from collection set 1 only

Years	Means		SEPD[1]	Sample T	DF[2]
1970 vs 1971	827.71	830.12	14.94	-0.16	82
1970 vs 1972	827.71	840.96	15.88	-0.83	82
1970 vs 1973	827.71	807.23	16.15	1.27	82
1971 vs 1972	830.12	840.96	14.95	-0.73	82
1971 vs 1973	830.12	807.23	22.07	1.04	82
1972 vs 1973	840.96	807.23	15.07	2.24	82

Paired T tests among pine needle data from collection set 2 only

Years	Means		SEPD[1]	Sample T	DF[2]
1970 vs 1971	762.50	756.25	11.44	0.55	79
1970 vs 1972	762.50	780.00	13.17	-1.33	79
1970 vs 1973	762.50	775.00	11.72	-1.07	79
1971 vs 1972	756.25	780.00	11.56	-2.05	79
1971 vs 1973	756.25	775.00	15.97	-1.17	79
1972 vs 1973	780.00	775.00	12.31	0.41	79

Paired T tests among pine needle data from collection set 1 & 2

Years	Means		SEPD[1]	Sample T	DF[2]
1970 vs 1971	795.71	793.87	9.43	0.20	162
1970 vs 1972	795.71	811.04	10.32	-1.49	162
1970 vs 1973	795.71	791.41	10.09	0.43	162
1971 vs 1972	793.87	811.04	9.48	-1.81	162
1971 vs 1973	793.87	791.41	13.76	0.18	162
1972 vs 1973	811.04	791.41	9.80	2.00	162

[1] Standard error of the paired difference

[2] Degrees of freedom

Table 15. (Continued)

Sulfur data for all locations combined
parts per million

Paired T tests, on pine needles, between collection sets 1 & 2

Years	Means		SEPD	Sample T	DF
Set 1 Set 2	Set 1	Set 2			
1970 vs 1970	823.08	755.13	20.60	3.30	77
1971 vs 1971	824.36	752.56	23.22	3.09	77
1972 vs 1972	839.74	775.64	22.12	2.90	77
1973 vs 1973	805.13	767.95	18.17	2.05	77
1970-73 vs 1970-73	823.08	762.82	10.53	5.72	311

Table 15. (Continued)

Fluoride Data
parts per million

Both collection dates

Group Name	# of Data	Mean	High	Low	SD	CV%	SEM	EEM%
All samples except Precip.	1982	2.32	18.40	0.00	1.85	79.68	0.04	1.79
All shrub samples	335	3.05	13.40	0.09	1.81	59.40	0.10	3.25
All grass samples	369	3.34	18.40	0.10	2.76	82.78	0.14	4.31
Chrysothamnus viscidiflorus	5	3.88	5.40	2.20	1.35	34.69	0.60	15.52
Rhus trilobata	50	3.09	8.90	0.40	2.13	69.16	0.30	9.78
Artemisia frigida	3	3.67	5.00	2.50	1.26	34.32	0.73	19.81
Chrysothamnus nauseosus	14	4.23	6.40	1.70	1.52	35.87	0.41	9.59
Artemesia cana	73	2.93	5.70	0.70	1.24	42.50	0.15	4.97
Oryzopsis hymenoides	3	7.27	13.50	3.20	5.48	75.43	3.16	43.55
Stipa comata	16	3.41	5.70	0.20	1.57	45.96	0.39	11.49
Andropogon scoparius	136	2.87	12.40	0.10	2.16	75.38	0.19	6.45
Calamovilfa longifolia	19	2.21	9.60	0.20	2.37	107.17	0.54	24.59
Aristida longiseta	6	3.10	4.50	0.90	1.37	44.28	0.56	18.08
Pinus ponderosa	1271	1.84	13.20	0.00	1.25	68.01	0.04	1.91
Artemesia tridentata	51	4.19	9.60	1.00	1.96	46.78	0.27	6.55
Juniperus scopulorum	129	2.52	13.40	0.09	1.74	69.10	0.15	6.08
Hiniperus horizontalis	1	2.70	2.70	2.70	--	--	--	--
Agropyron spicatum	185	3.75	18.40	0.10	3.16	84.41	0.23	6.21
Populus trichocarpa	1	2.00	2.00	2.00	--	--	--	--
Sarcoratus vermiculatus	1	4.10	4.10	4.10	--	--	--	--
Symphoriocarpus sp.	2	3.00	3.50	2.50	0.71	23.57	0.50	16.67
Poa protensis	2	2.85	2.90	2.80	0.07	2.48	0.05	1.75
Koeleria cristata	1	3.60	3.60	3.60	--	--	--	--
Prunus virginiana	5	1.84	3.30	0.60	1.04	56.30	0.46	25.18
Sheperdia argentea	1	4.50	4.50	4.50	--	--	--	--
Precipitation	68	0.00	0.00	0.00	0.00	--	0.00	--
Festuca idahoensiss	1	2.60	2.60	2.60	--	--	--	--
Yucca glauca	6	0.83	1.20	0.30	0.30	36.13	0.12	14.75
Pinus ponderosa: 1970 needles	315	2.05	7.50	0.10	1.24	60.81	0.07	3.43
Pinus ponderosa: 1971 needles	318	1.87	7.90	0.10	1.24	66.09	0.07	3.71
Pinus ponderosa: 1972 needles	319	1.81	13.20	0.00	1.38	75.88	0.08	4.25
Pinus ponderosa: 1973 needles	319	1.62	6.90	0.10	1.10	67.52	0.06	3.78

Table 15. (Continued)

Fluoride data** for all locations combined
parts per million

Paired T tests, on pine needles, between collection sets 1 & 2

Years		Means		SEPD	Sample T	DF
Set 1	Set 2	Set 1	Set 2			
1970 vs	1970	2.30	1.81	0.14	3.56	154
1971 vs	1971	2.02	1.71	0.14	2.21	154
1972 vs	1972	2.06	1.59	0.16	2.95	154
1973 vs	1973	1.72	1.53	0.12	1.64	154
1970-73 vs	1970-73	2.03	1.66	0.07	5.24	619

Table 15. (Continued)

Fluoride Data
Parts per million

First collection set only

Group Name	# of Data	Mean	High	Low	SD	CV %	SEM	EEM %
All samples except Precip.	1347	2.63	18.40	0.09	2.05	77.94	0.06	2.12
All shrub samples	335	3.05	13.40	0.09	1.81	59.40	0.10	3.25
All grass samples	369	3.34	18.40	0.10	2.76	82.78	0.14	4.31
Chrysothamnus viscidiflorus	5	3.88	5.40	2.20	1.35	34.69	0.60	15.52
Rhus trilobata	50	3.09	8.90	0.40	2.13	69.16	0.30	9.78
Artemisia frigida	3	3.67	5.00	2.50	1.26	34.32	0.73	19.81
Chrysothamnus nauseosus	14	4.23	6.40	1.70	1.52	35.87	0.41	9.59
Artemisia cama	73	2.93	5.70	0.70	1.24	42.50	0.15	4.97
Oryzopsis hymenoides	3	7.27	13.50	3.20	5.48	75.43	3.16	43.55
Stipa comata	16	3.41	5.70	0.20	1.57	45.96	0.39	11.49
Andropogon scoparius	136	2.87	12.40	0.10	2.16	75.38	0.19	6.48
Calamovilfa longifolia	19	2.21	9.60	0.20	2.37	107.17	0.54	24.59
Aristida longiseta	6	3.10	4.50	0.90	1.37	44.28	0.56	18.08
Pinus ponderosa	636	2.01	13.20	0.10	1.40	69.35	0.06	2.75
Artemisia tridentata	51	4.19	9.60	1.00	1.96	46.79	0.27	6.55
Juniperus scopulorum	129	2.52	13.40	0.09	1.74	69.10	0.15	6.08
Juniperus horizontalis	1	2.70	2.70	2.70	--	--	--	--
Agropyron spicatum	185	3.75	18.40	0.10	3.16	84.41	0.23	6.21
Populus trichocarpa	1	2.00	2.00	2.00	--	--	--	--
Sarcoratus vermiculatus	1	4.10	4.10	4.10	--	--	--	--
Symphoriocarpus sp.	2	3.00	3.50	2.50	0.71	23.57	0.50	16.67
Poa protensis	2	2.85	2.90	2.80	0.07	2.48	0.05	1.75
Koeleria cristata	1	3.60	3.60	3.60	--	--	--	--
Prunus virginiana	5	1.84	3.30	0.60	1.04	56.30	0.46	25.18
Sheperdia argentea	1	4.50	4.50	4.50	--	--	--	--
Festuca idahoensis	1	2.60	2.60	2.60	--	--	--	--
Yucca glauca	6	0.83	1.20	0.30	0.30	36.13	0.12	14.75
Pinus ponderosa: 1970 needles	157	2.28	7.50	0.10	1.36	59.37	0.11	4.74
Pinus ponderosa: 1971 needles	159	2.03	7.90	0.10	1.38	68.02	0.11	5.39
Pinus ponderosa: 1972 needles	160	2.03	13.20	0.12	1.57	77.51	0.12	6.13
Pinus ponderosa: 1973 needles	160	1.71	6.90	0.10	1.20	70.12	0.09	5.54

Table 15. (Continued)

Fluoride data, parts per million
First collection set only

T-Tests

	T Statistic	DF
Total pines vs total grasses	-8.60	1003
Total pines vs total shrubs	-9.17	969
Total grasses vs total shrubs	1.63	702

Flouride data ** for all locations combined
parts per million

Paired T tests among pine needle data from collection set 1 only

Years	Means		SEPD	Sample T	DF
1970 vs 1971	2.29	2.03	0.13	2.05	155
1970 vs 1972	2.29	2.06	0.13	1.72	155
1970 vs 1973	2.29	1.72	0.12	4.70	155
1971 vs 1972	2.03	2.06	0.15	-0.19	155
1971 vs 1973	2.03	1.72	0.13	2.37	155
1972 vs 1973	2.06	1.72	0.12	2.74	155

Paired T tests among pine needle data from collection set 2 only

1970 vs 1971	1.81	1.71	0.07	1.40	157
1970 vs 1972	1.81	1.59	0.08	2.63	157
1970 vs 1973	1.81	1.53	0.09	3.06	157
1971 vs 1972	1.71	1.59	0.08	1.37	157
1971 vs 1973	1.71	1.53	0.08	2.12	157
1972 vs 1973	1.59	1.53	0.09	0.73	157

Paired T tests among pine needle data from collection sets 1 & 2

1970 vs 1971	2.05	1.87	0.07	2.48	313
1970 vs 1972	2.05	1.82	0.08	2.86	313
1970 vs 1973	2.05	1.82	0.08	5.57	313
1971 vs 1972	1.87	1.82	0.09	0.50	313
1971 vs 1973	1.87	1.62	0.08	3.14	313
1972 vs 1973	1.82	1.62	0.07	2.65	313

Table 15. (Continued)

Fluoride data
parts per million
Both collection dates

	T-Tests	
	T Statistic	DF
Total pines vs total grasses	-10.14	1638
Total pines vs total shrubs	-11.57	1604
Total grasses vs total shrubs	1.63	702

Rain water samples thus far collected are being kept frozen in the Environmental Studies Laboratory until adequate numbers of samples (80-100) are available to carry out continuous analysis for one-week periods. The bulk precipitation collectors will continue to be used this winter even after the automated Wong collectors are located at or near the main study sites, to establish if there is a difference between the physical and chemical composition of precipitation collected by these two methods.

Annual Growth Increment, and Needle and Stem Growth of Ponderosa Pine

The incremental growth studies of Ponderosa Pine will begin by mid-November after several frost periods. Since Ponderosa Pine are not present on the grassland sites, we have selected, for annual growth increment studies, the ridge areas immediately adjacent to these sites where mixed-age stands of Ponderosa Pine are growing. Needle and stem growth measurements, and needle retention counts will be made concurrently with the incremental growth studies.

SECTION V

LICHENS AS PREDICTORS AND INDICATORS OF AIR POLLUTION FROM COAL-FIRED POWER PLANT EMISSIONS

By Sharon Eversman

INTRODUCTION AND OBJECTIVES

The primary objectives of this part of the Colstrip Coal-fired Power Plant Program are: 1) to identify those lichen species that can be used as air pollution indicators; 2) to monitor those species in the laboratory to determine specific effects of SO_2 pollution in a semi-arid grassland field situation; 3) to try to compare relative sensitivities of certain native grasses and crop plants, and lichen species; and, 4) to catalog the components of the lichen communities to detect any population changes as a result of the effluents from the coal-burning power plants. Control measurements are those measurements completed during the summer and fall of 1974, and those expected to be made during spring, 1975. SO_2 effects observed in lichens taken from the stress plot area at the Ash Creek site will be used as gauges in determining power plant effluent effects.

This part of the project is designed to detect changes, resulting from coal-burning, in two of the major categories -- community structure and sublethal biochemical or physiological changes -- outlined for the program as a whole. The lichens are the particular component of the biotic community being analyzed. Samples of all species of lichens that occur on the primary study sites were collected. Present laboratory work is concentrated on two species: Parmelia chlorochroa Tuck, and Usnea hirta (L.) Wigg.

Parmelia chlorochroa is a quite common and abundant terricolous foliose lichen of the Great Plains region that grows on fairly bare soil between grass, forb, and shrub clumps, usually in close proximity to the *Artemisia* species. It reproduces by fragmentation and subsequent growth of the fragments. Apothecia were observed on only two plants, both from the Kluver West site. It does not form soredia or isidia.

Parmelia was found on all of the primary sites, but not on the Ash Creek (experimental) site. Two slightly different growth forms occur at each site, one with wider lobes, the other with more finely dissected lobes.

Usnea hirta is a corticolous fruticose lichen, of the Rocky Mountains, Pacific Northwest, and the northeastern United States, that grows on the bark of the trunk and branches of *Pinus ponderosa* in the Colstrip area. It is sorediate; no apothecia or isidia were observed. The most notable observation about the *Usnea* in the study area is its complete absence from many Ponderosa stands (near Kluver sites, near McRae sites), and its low density at the Ash Creek site. This was disappointing, because fruticose lichens are the type of lichen most sensitive to air pollutants (according to all the literature) and because *Usnea* is the only fruticose lichen of any consequence present in the area. It was also somewhat unexpected because *Usnea* growth is abundant on the Ponderosa branches and trunks on the divide between Lame Deer and Ashland, Montana. Possibly due to aridity, *Usnea* has not become established on the trees on the ridges near the Kluver and McRae sites. Conversely, *Usnea* was established near Ash Creek and at Fort Howes, but was presumably destroyed by the forest fire in Custer National Forest in 1967. Presently it occurs in small tufts only on the shadiest trunks of the Ponderosa Pines.

Cladonia pyxidata commonly occurs on the soil at all of the primary sites, but will not be studied because of the minute size, doubtful vigor, and even closer association with soil particles than the *Parmelia*.

About ten different lichen species were found growing on the soil of the grassland study sites. Two fruticose species were found on the Ponderosa Pine. Several as-yet unidentified saxicolous species occur. The lichens other than Parmelia and Usnea occur in such sporadic and minute amounts that trying to use them for the laboratory tests is unreasonable.

DISCUSSION

Field work included:

1. Observations of presence and absence of lichen species on the primary sites and other selected areas.

2. Estimation of cover-classes of grasses, forbs, and lichens (lichens by species).

3. Collections of lichen samples for identification and laboratory tests:

    a. Parmelia chlorochroa from ground plots.

    b. Usnea hirta from certain Ponderosa Pine stands.

4. Staking of permanent collection areas on test sites. Further samples will be taken from a diameter of one meter from stakes.

5. Transplanting of Usnea from the lichen-rich area along the highway on the divide between Lame Deer and Ashland, to the Ponderosa Pine stand south of the Kluver North site and to Fort Howes Ranger Station south of Ashland. Both sites of transplanting are east-west ridges with Ponderosa Pine on north exposures. Transplantation was achieved by taking entire Usnea-covered branches from Ponderosa

pine on the Ashland-Lame Deer divide and tying them on comparable branches on Ponderosa Pine at Fort Howes and Kluver North site.

Parmelia had to be transplanted from the *Artemisia* stand north of the test site at Ash Creek to the Ash Creek stress plot, since *Parmelia* was absent from the latter site. Twelve plants were placed on bare spots at each of the four compass directions at the base of identified *Artemisia* shrubs on the site.

Laboratory work included:

1. Recording weights of individual *Parmelia* plants over 30 mg, and of available representative *Usnea* tufts.

2. Determination of absorption spectra of chlorophyll extracts from *Parmelia* and *Usnea*.

3. Determination of nitrogen content of samples sent to the Chemistry Analytical Laboratory for Kjeldahl analyses.

4. Determination of respiration rates (in $\mu l\ O_2$ consumed/gram of dry weight per hour at 20°C) in a Gilson Differential Respirometer.

Laboratory work to be completed fall and winter 1974-75, include:

1. Completion of spectrophotometric analyses of chlorophylls and sample weights from some sites.

2. Repetition of respirometer readings, and readings for air-dry samples, not moistened as the others have been.

3. Sulfur content determination by the Soils Testing Laboratory.

4. Nitrogen content determination of lichens from some sites.

5. Identification of collected specimens.

6. Preparation of microscope slides of lichen tissues.

Data obtained as of 20 October 1974, are summarized in Table 16.

Laboratory Methods

Lichen samples in the laboratory were washed with tap water, rinsed with distilled water, and air-dried for at least 48 hours before further processing. There was no separation or grouping into possible clones; all data are from randomly pooled samples (250 mg or one gram) of lichens from each site.

For spectrophotometer determinations of absorption spectra, one gram of *Parmelia* or 300 mg of *Usnea* was ground with 0.5 gram (or 150 mg) Na_2CO_3 in 20 ml of 80% acetone. The extract was filtered, mixed with 10 ml diethyl ether in a separatory funnel, and allowed to separate. The upper ether layer was transferred to vials and used for absorption spectrum determination in a Beckman DU spectrophotometer. The lower acetone layer was discarded.

Respiration rates were determined for 250 mg samples of *Parmelia* and *Usnea* in a Gilson Differential Respirometer. Air-dried specimens were moistened with one ml distilled water for 30 minutes; excess water was shaken off before placing specimens in the flasks. After 45 minutes of calibration in the respirometer, four consecutive one-hour readings were made to determine rates of oxygen consumption at 20°C.

Table 16. Summary of Lichen Data (as of 20 October 1974)

	% ground cover	Chlorophyll absorption peak um	Respiration rate*	Thallus weight mg	% nitrogen
Parmelia chlorochroa					
02 McRae Hay Coulee A	2.75	660	265.68 (56.92)	60.54 (32.45)	0.72
B			323.96 (109.28)		0.73
03 Kluver West A	3.00	660	211.88 (19.92)		0.82
B			221.12 (41.80)		0.75
04 Kluver North	2.50	660	288.36 (34.24)	34.19 (14.85)	0.73
05 Kluver East	2.50	660	230.00 (39.72)	77.98 (24.46)	0.77
01 Ash Creek A			345.80 (61.76)		
B			344.60 (48.60)		
07 Harvey A			274.24 (53.92)		
			280.13 (41.04)		
Usnea hirta					
01 Ash Creek Trees		660	595.28 (97.41)	166.32 (136.40)	1.52
06 Highway		660	779.88 (90.80)	122.73 (60.35)	1.70

*Respiration rate is given in microliters O_2 consumed per gram dry weight in one hour at 20°C. Mean values of respiration rates and thallus weights are followed by standard deviations in parentheses.

Each plant and plant fragment was weighed on a Mettler balance to the nearest hundredth mg. Weights over 30.00 mg were included for data analysis.

The Chemistry Analytical Laboratory is employed in the determination nitrogen content, and the Soils Testing Laboratory is determining total sulfur content.

Field work to be completed before coal-burning operations begin, probably spring, 1975, include:

1. Collection and laboratory analyses (respirometer, chlorophyll, weight, nitrogen and sulfur content) of the transplanted Usnea (from Ft. Howes and Kluver West) and Parmelia (from Ash Creek) to determine whether they have survived transplanting with no adverse effects.

2. Location and sample testing of some Usnea sites downwind from the stack.

FUTURE ACTIVITIES

Unless greater amounts of material (particularly Usnea) can be located in pertinent testable areas, expansion of this part of the Colstrip study is impractical. Ideally, Usnea samples could be correlated with Ponderosa Pine studies, and Parmelia could be correlated with grassland data, but the Usnea needs to be found in amounts adequate for large-scale repetitive laboratory testing.

1975 activies will include:

1. Collection of Usnea and Parmelia will be made from the same sites as in 1974 and the same laboratory measurements will be made to compare results from the two years.

2. Field measurements of cover classes by species will be repeated to detect possible changes after coal-burning begins.

3. Microscopic examination of tissue will continue.

4. Spring collection of some local grasses associated with the *Parmelia* (e.g., *Koeleria cristata*, *Bromus tectorum*) and immediate laboratory determination of respiration rates and nitrogen and sulfur concentrations would yield some bases with which to compare lichen sensitivity with that of associated vascular plants.

The field season of 1974 began in late June and early July when the driest season was underway. *Parmelia*, at every site and during every collection, was dry and crisp indicating dormant condition. Moistening them in the laboratory broke the dormancy. The grasses would be better examined from a more active growing period, especially spring.

The largest problem with *Usnea* is finding it -- very disappointing, since this is predicted to be more sensitive to pollution than *Parmelia*. The data obtained so far indicate that its mean respiratory rate at 20°C is about twice that of *Parmelia*. If the trial transplantations are found to be as viable as the source material at its source, data could be obtained from transplantations. (The source of *Usnea*, however, appears to be in the path of the new road, if it continues construction, between Lame Deer and Ashland, although other sources could be located.)

The precise effects of various SO_2 concentrations at the Ash Creek experimental site will have to be tested in 1975, using the parameters determined in 1974 as comparison standards.

No attention has yet been paid to clones versus averages of collections from test sites. Clone characteristics probably vary, and comparisons between clones, and between clones and population means would be an interesting topic for further investigation.

SECTION VI
PHYSIOLOGICAL RESPONSES OF PLANTS TO COAL-FIRED POWER PLANT EMISSIONS

by David T. Tingey

INTRODUCTION AND OBJECTIVES

This component of the Coal-fired Power Plant Project is designed to supply plant physiological support. This will be accomplished by (1) experimentally assessing the sensitivity of selected plant species to ozone, nitrogen dioxide alone, sulfur dioxide alone, and to mixtures of these three gases; (2) determining the influence of moisture stress on the sensitivity and growth of native plants exposed to sulfur dioxide, nitrogen dioxide and to mixtures of these; and (3) measuring rates of uptake of SO_2 and NO_2 by the plants. Other support activities may be instituted as indicated by results of the field investigations.

PROGRESS TO DATE

The selected plant species have been collected from the Montana site. These are (common names only): Western Wheat Grass, Blue Grama, Needle and Thread Grass, Fringed Sage Wort, and Prairie June Grass. Techniques for culturing and propagating the plants in the greenhouse are under development and we have started to develop a system to grow these plants at the defined levels of moisture stress.

PROBLEMS

It is necessary to develop a procedure in conjunction with the Chemistry Laboratory to quantitate the sulfur content of plant tissue to be used in the measurement of SO_2 uptake.

FUTURE ACTIVITIES

We plan to: (1) continue to develop and make operational a system to grow plants at the defined levels of moisture stress, (2) expose plants to determine their levels of sensitivity to air pollutants and the influence of various levels of moisture stress on sensitivity, (3) determine the sulfur dioxide and nitrogen dioxide content of plant tissue; and (4) measure the influence of airborne toxicants and soil stress on the nitrogen metabolism system in native plants. Ponderosa Pine exposed to chronic levels of SO_2 through the growing season at our Corvallis field site will be analyzed for nitrogen, sugar, starch and sulfur content of the needles, stems, and roots. This data will then be used to support the Montana study.

SECTION VII

EFFECTS OF COAL-FIRED POWER PLANT EMISSIONS ON ANIMALS: A SUMMARY

By Robert A. Lewis and Martin L. Morton

INTRODUCTION

In order to address the overall goals of the Colstrip, Montana Coal-fired Power Plant Project (see Lefohn, Lewis and Glass, 1974), the animal component attempts to (1) identify those populations (or taxa) of birds and mammals that are most sensitive to air pollution in the study area; (2) identify, if possible, species, systems, and functions that may serve as specific, "noise-free" indicators of pollution (e.g. pollination systems, physiologic control systems, etc.); (3) identify population components that may serve as a measure of impact in the sense that they themselves are ecosystem resources or are coupled to ecosystem resources; (4) to relate, if possible, functions of types (2) and (3) to evolve extrapolative or predictive models; (5) to determine the extent of pollution-related effects on small mammal and bird populations in the study area, and if possible, to distinguish between direct and indirect air pollution effects and the effects of other human activites that might tend to confound our results (e.g. effects of coal-mining, water use, increased human population density, use of herbicides and pesticides, etc.); and (6) determine the temporal relationships of observed changes in animal function to that of other ecosystem components so that predictive relationships can be established.

This strategy to be fully realized depends upon appropriate support from other elements of the Colstrip, Montana Coal-fired Power Plant Project.

OBJECTIVES

The objectives of the animal task are:

1. To measure and predict change in population structure and/or dynamics of selected species of birds and mammals as a function of air pollution, endogenous and exogenous cycles, and other environmental information including relevant biotic interactions and physical factors.

   a. To characterize both the population means and normal dispersion about the mean of descriptors so that deviations may be discriminated and assessed.

2. To evaluate physical and biotic factors that influence the dynamic-structural processes under investigation.

3. To identify, if possible, specific pollution effects on animal populations or systems.

4. To identify physiologic and population functions that contribute to the regulation of selected populations and to evaluate the mechanisms whereby such regulation is effected, so that we may better interpret the causes of changes that occur. We may thus increase our understanding of pollution-related effects and the confidence in our output.

5. To evaluate certain physiological, biochemical, and behavioral functions that we think have a potential for sensitive assay of pollution challenge. We thus hope to be able to identify low levels of pollution stress before serious or irreversible effects occur.

6. To estimate, by the use of demographic methods, the ability of the bird and mammal populations to recover from decimation or to withstand environmental disturbance, including air pollution challenge.

To satisfy these objectives, the animal program is comprised of five overlapping components:

I. Population biology

II. Reproductive biology

III. Measures of condition, physiologic stress, homeostasis, and adaptation

IV. Histological cycles of organ-systems of potential or probable concern

V. Indicators of pollution

The population portion of the investigation deals with population processes and at least some of the mechanisms that effect population adjustments (e.g. fecundity, mobility).

The investigation of reproductive biology broadly overlaps with the population component. This work will be focused on the description of the annual reproductive cycles of a small set of indigenous species together with the growth and development of young to include information on bioenergetics, productivity, and the regulation of reproductive processes and of postnuptial molt (birds).

The third, or physiological, phase of this investigation treats a number of types of functions, notably those that reflect condition and vigor of the animals and their responses to stress. The fourth component of the investigation, the evaluation of histological cycles, is designed to support the other components of the program. In addition, since it is impossible to fully anticipate which tissues or organ systems may be most affected by chronic pollution stress, we are establishing a tissue bank of the major organs that might be expected to show involvement. Laboratory experiments may be conducted to test field-generated or model-generated hypotheses and/or to identify specific pollution effects suggested by observed field responses.

For the present, the fifth phase of the study is restricted to an assessment of brain acetylcholinesterase depression of Honey Bees as a function of air pollution in the study area. We hope, of course, that other sensitive indicators of air pollution challenge will be discovered as a function of our approach to the animal task.

POPULATION BIOLOGY

The objectives of this component of the animal task are to:

1. Predict changes in population size and structure as a function of mortality, recruitment rates and life cycle functions.

2. Predict changes in any of all of the above as a function of pollution intensity.

    a. Comparative (i.e. across sites; across species).
    b. Annual (i.e. between and within years).

3. Determine the growth potential of the populations of concern. That is, we would like to establish the capacity of the populations of interest to tolerate (or to recover from) challenge (especially air pollution) or perturbations that alter life functions and thereby tend to reduce the population or alter its composition.

The major characteristics of a population that allow us to make predictions about that population are:

1. natality
2. mortality
3. mobility
4. density
5. sex and age structure
6. genetic composition

We must know something about all of these if we are to understand mechanisms of population regulation and change and to relate observed changes to environmental information (e.g., air pollution). Nevertheless, some of these functions are very difficult to assess.

Because of the relatively low signal-to-noise ratio in many population dynamic functions, we may expect the short-term chronic effects of air pollutants on population parameters to be small relative to natural and/or random variation. Thus appropriate sensitive analysis requires:

a. A pollution gradient across study sites (mammals and perhaps birds).
b. Employment of reference sites that will allow us to estimate variations both between and within years (birds and mammals).
c. Investigation and characterization of responses that may be pollution specific (birds and mammals).
d. Investigation of associated functions that may represent deviations from the normal pattern or the phase-shifting or uncoupling of normally coupled phenomena.
e. Evaluation of changes in population structure rooted in a study of annual cycle and life cycle components (e.g. time-based changes in sex and age structure; breeding success, etc.).

Standard mark and release methods are employed in the assessment of population dynamics. Assessments of life table functions will be made in order to help us to determine the mechanisms of population changes that may occur. Field methods to be employed in the acquisition of such information will be adapted from published methods (see for example Henny, 1972; Manly and Parr, 1968). The functions that form the basic life equation of small birds and mammals are:

1. Number of eggs laid per clutch or young formed per litter.
2. The frequency at which clutches are laid or young are born.
3. Survivorship (eggs, young) to the age of first breeding.
4. Survivorship of adults during their reproductive lifetime.
5. Age of sexual maturity.

These kinds of data will be employed in models to allow us (in combination with behavioral and physiological data) to evaluate population sensitivity to selected pollutants or to generate hypotheses to be tested by laboratory experiments.

In addition to intensive studies of a few abundant indigenous species at fixed study sites we are conducting infrequent surveys using standard census techniques (e.g. Emlen, 1971; Robbins and Van Velzen, 1970) to assess changes in diversity and relative abundance of vertebrates in the study area.

REPRODUCTION AND ONTOGENY

The reproduction component of this investigation is inseparable from and supports the population-dynamic component. In addition, the reproductive and life cycles are of special and independent concern. We feel that significant impairment of animals at the population level will be reflected in altered reproductive performance and/or in ontogenetic cycles.

The reproductive cycle of North Temperate Zone vertebrates is, in general, the best characterized of the annual subcycles. Furthermore, regulatory mechanisms are fairly well known (Farner and Lewis, 1971; Lewis and Orcutt, 1971; Sadlier, 1969). We are thus in an excellent position to assess the effects of air pollution on reproductive functions.

Lowered growth rates of altricial birds and rodents, by whatever agency (e.g. air pollution), would increase the period of time that the young remain in the nest and their period of dependence upon parental care. They would thus be exposed to relatively high predation rates for a longer than normal period and both parents and young might suffer a competitive disadvantage following departure of the young from the nest.

CONDITION, STRESS, ADAPTATION AND DISEASE

In addition to reproduction, ontogeny, and the development of a tissue-banking system, the physiological phase of the animal task is directed to the evaluation of a number of functions and systems that may be expected to reflect the condition of the animals under investigation. Of particular interest are the following:

1. Bioenergetics (to include body weights, body composition [water, lipid, etc.], growth rates) and nutritional biology.
2. Adrenocortical system and responses to stress (e.g. general adaptation syndrome of mammals).
3. Immunobiologic responses (e.g. hematologic change, reticulo-endothelial system responses).
4. Disease histopathology.
5. Behavior patterns (e.g. mobility, territorial behavior, habitat selection, etc.).

In general the measures of condition that we intend to employ are regulated functions. That is, these functions tend to be maintained within relatively narrow limits at any given stage of the annual cycle. Such functions are, of course, frequently age and sex-dependent. We may thus expect that some of these functions will provide relatively stable frames of reference against which environmental impacts can be measured.

We are employing standard biometric methods and whole carcass and organ analysis of selected species of rodents and birds to evaluate compositional and biometric changes as a function of age, sex, season and physiologic state in relation to the physical and biotic enviroment. The main purpose of this type of analysis is to better assess condition, vigor, nutritional state, and net energy balance as a function of air quality and other environmental gradients.

Major body and organ components to be measured and evaluated include live wet weight, lean wet weight, lean dry weight, lipids, allometry of feather growth (birds) and of related functions, stomach and crop (birds) contents and weights, caloric density of the diet, parasite burdens (e.g., of intestinal tract and perhaps of blood). If possible, dietary and tissue protein levels will be assayed.

HISTOLOGICAL CYCLES OF ORGAN-SYSTEMS OF POTENTIAL OR PROBABLE CONCERN

It is not possible to predict with confidence the organ-systems or species of animals that deserve intensive histological evaluation. Consequently, a system of tissue banking has been initiated whereby several tissues and organs of animals collected in the field will be fixed and routinely embedded. As pollution-sensitive species and tissues are identified, appropriate specimens will be stained and examined histologically.

Organ-systems of probable importance include the respiratory system, blood, adrenocortical system, reticuloendothelial system, liver, and the reproductive system. Elements of these systems will definitely come under study.

BEES AS INDICATORS OF AIR POLLUTION

In collaboration with Professor C. C. Gordon and Dr. J. Bromenshenk of the University of Montana, we are investigating the effects of air pollution on the physiology, production and behavior of bees. Samples of worker Honey Bees are being collected from eleven sites (apiaries) in the study area and from two reference sites outside the study area. Samples are undergoing analysis for acetylcholinesterase pesticide residues, fluorides and sulfur. As a result of this study we hope to establish a gradient response analysis of air pollution effects and to evaluate pesticides as a potentially confounding factor (NOTE: pesticides effects tend to be episodic, whereas the air pollution effects will tend to be chronic).

We will also conduct field experiments in one acre fenced enclosures to evaluate physiological and behavioral responses of free-living bees to controlled exposures of sulfur dioxide (four concentrations). We hope thereby to establish the lower levels of sulfur dioxide to which bees respond and to learn something about the character and specificity of the responses.

Beginning April 1, 1975, we may also initiate a study of acetylcholinesterase levels in bird and mammal tissues as a function of air pollution gradients.

PROGRESS TO DATE

Collections of small mammals and birds employing standard mark and release methods, were initiated in the vicinity of four of the primary sites (Hay Coulee, Kluver West, Kluver North, and Kluver East). An additional mammal station is situated on Pony Creek, and a bird trapping station is operated at the McRae Knolls site. In additon, bird specimens are collected via shotgun at various locations both within the study area and in reference areas in Rosebud and Powder River counties.

Mammals are collected by means of two trapping systems, one for collection of specimens and another for mark-release data. Live traps are used in both cases.

1. Collections. Rodents are livetrapped one day per week and returned to the laboratory for work-up. Body weight and length measurements (body, ear, hindfoot and tail) are taken. Following ether anesthesia, blood is taken from the orbital sinus in a capillary tube. From this is determined hematocrit (via centrifugation) and plasma protein concentration (via diffraction meter). Heart, lungs, kidneys, adrenals, spleen, liver, gonads and oviducts are preserved in Bouins, weighed after one week, and transferred to 70% ethanol for subsequent embedding. Carcasses are saved frozen for analysis of components. More than 200 small mammal specimens have been collected thus far. Femurs from 80 animals have been frozen and mailed to C. Gordon for determination of fluoride content.

2. Mark-release. Grids with outside dimensions of 150 m x 150 m have been established at five locations. Trapping stations within each grid are 15 m apart; thus there are 121 stations/grid. Two traps are set at each station; a total of 242 traps/grid. The grids are trapped in regular rotation following three or four nights of prebaiting with rolled oats.

All animals trapped are toe-clipped according to a standard numerical scheme, weighed, measured, and examined for external signs of sexual activity and other factors such as ectoparasites and pelage changes. Releases are made at the station of capture. At this time 232 individuals have been marked and released. A total of 238 recaptures have occurred. The species captured in descending order of frequency, are *Peromyscus maniculatus*, *Microtus ochrogaster*, *Perognathus fasciatus*, *Reithrodontomys megalotis*, and *Onychomys leucogaster*. In addition we have caught a few specimens of *Peromyscus leucopus*, *Citellus tridecemlineatus* and *Sylvilagus auduboni*. Mammalian species that were trapped or observed in the study area are listed in Table 17.

Birds are trapped at fixed stations by the use of four 12 meter mist nets that are set at dawn and usually operated until noon. Birds captured in this way are banded with U. S. Fish and Wildlife Service numbered bands, weighed, examined for sex, breeding condition (degree of development of the brood patch; cloacal protuberance) molt, ectoparasites, and then released at the site of capture. A total of 317 birds, representing 32 species were banded and released. Of these, only six percent (two species) occurred at all of the netting stations and only 30 percent were present at more than one site.

A standard roadside census of birds, to be conducted from April through September at bimonthly intervals, was instituted. This census is patterned after that of the North American Breeding Bird Survey (see Robbins and Van Velzen, 1970). This census should provide us with fairly sensitive data on significant changes in species diversity; changes in relative and absolute abundance; changes in dispersion in relation to the coal-fired power plant at Colstrip; and supplemental information on sex and age ratios, productivity, and the annual calendar of some species. Based upon the combined results of netting and censusing, the most abundant and widely-distributed grassland bird species in the study area are the Western Meadowlark, Vesper Sparrow and Lark Sparrow.

Table 17. Taxonomic List of Wild Mammals Observed in the Colstrip Study Area, 1974 (May through September)

Common Name	Scientific Name
Masked Shrew	*Sorex cinereus*
Little Brown Bat	*Myotis lucifugus*
White-tailed Jackrabbit	*Lepus townsendi*
Desert Cottontail	*Sylvilagus audoboni*
Black-tailed Prairie Dog	*Cynomys ludovicianus*
13-lined Ground Squirrel	*Citellus tridecemlineatus*
Least Chipmunk	*Eutamias minimus*
Northern Pocket Gopher	*Thomomys talpoides*
Wyoming Pocket Mouse	*Perognathus fasciatus*
Desert Harvest Mouse	*Reithrodontomys megalotis*
Deer Mouse	*Peromyscus maniculatus*
Wood Mouse	*Peromyscus leucopus*
Grasshopper Mouse	*Onychomys leucogaster*
Prairie Vole	*Microtus ochrogaster*
Porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Red Fox	*Vulpes fulva*
Raccoon	*Procyon lotor*
Long-tailed Weasel	*Mustela frenata*
Mink	*Mustela vison*
Badger	*Taxidea taxus*
Striped Skunk	*Mephitis mephitis*
Bobcat	*Lynx rufus*
White-tailed Deer	*Odocoileus virginianus*
Mule Deer	*Odocoileus hemionus*
Pronghorn	*Antilocapra americana*

More than 300 birds have been collected by shooting. These are frozen and transmitted to the Animal Physiology Laboratory in Corvallis. Five species are specifically sought. These are the Vesper Sparrow, Lark Sparrow, Western Meadowlark, Mourning Dove, and Lark Bunting.

Avian species that were captured or observed in the study area are listed in Table 18.

Samples of Honey Bees from the eleven study sites have been frozen whole and await assay for acetylcholinesterase in our laboratory. In addition, we are supporting this study by the deployment of corrosion plates. Plates (four per site) have been placed at all of the bee collecting sites, at all of the primary study sites, and at the mammal-trapping station on Pony Creek. The plates were cleaned using a standard method, initial weights were taken and the plates were set out on 4 October 1974. These plates will be changed at intervals of three months.

When the acetylcholinesterase assay on bees is operational, we may begin to study acetylcholinesterase levels in birds and mammals as a function of air pollution gradients.

FUTURE ACTIVITIES

We hope to complete the laboratory processing of the 1974 field collections and data reduction by May, 1975. We will prepare data summaries and preliminary data evaluations before the end of the fiscal year. Field and laboratory efforts will continue.

Small mammal trapping will continue throughout the winter or until it is no longer feasible. Intensive studies of the reproductive biology of several selected species of birds will begin in April. In most cases, breeding will terminate by about the time the Colstrip power plant becomes operational.

Table 18. Taxonomic List of Wild Birds Observed in the Colstrip Study Area, 1974 (July through September)

Common Name	Scientific Name
Great Blue Heron	Ardea herodias
Turkey Vulture	Cathartes aura
Cooper's Hawk	Accipiter cooperii
Red-tailed Hawk	Buteo jamaicensis
Rough-legged Hawk	Buteo lagopus
Golden Eagle	Aquila chrysaetos
Marsh Hawk	Circus cyaneus
Pigeon Hawk	Falco columbarius
Kestrel	Falco sparverius
Sharp-Tailed Grouse	Pedioecetes phasianellus
Sage Grouse	Centrocercus urophasianus
Ring-necked Pheasant	Phasianus colchicus
Killdeer	Charadrius vociferus
Spotted Sandpiper	Actitus macularia
Rock Dove	Columba livia
Mourning Dove	Zenaidura macroura
Great Horned Owl	Bubo virginianus
Poor-will	Phalaenoptilus nuttallii
Common Nighthawk	Chordeiles minor
Belted Kingfisher	Megaceryle alcyon
Red-shafted Flicker	Colaptes cafer
Red-headed Woodpecker	Melanerpes erythrocephalus
Hairy Woodpecker	Dendrocopus villosus
Eastern Kingbird	Tyrannus tyrannus
Western Kingbird	Tyrannus verticalis
Cassin's Kingbird	Tyrannus vociferans
Say's Phoebe	Sayornis saya
Western Flycatcher	Empidonax difficilis
Horned Lark	Eremophila alpestris
Tree Swallow	Iridoprocne bicolor
Barn Swallow	Hirundo rustica
Black-billed Magpie	Pica pica
Black-capped Chickadee	Parus atricapillus
House Wren	Troglodytes aedon

Table 18. (Continued)

Common Name	Scientific Name
Winter Wren	Troglodytes troglodytes
Catbird	Dumetella carolinensis
Brown Thrasher	Toxostoma rufum
Robin	Turdus migratorius
Mountain Bluebird	Sialia currucoides
Loggerhead Shrike	Lanius ludovicianus
Starling	Sturnus vulgaris
Red-eyed Vireo	Vireo olivaceus
Yellow Warbler	Dendroica petchia
Audubon's Warbler	Dendroica auduboni
Ovenbird	Seiurus aurocapillus
Yellow-breasted Chat	Icteria virens
American Redstart	Setophaga ruticilla
Western Meadowlark	Sturnella neglecta
Red-winged Blackbird	Agelaius phoeniceus
Bullock's Oriole	Icterus bullockii
Brewer's Blackbird	Euphagus cyanocephalus
Common Grackle	Quiscalus quisculas
Brown-headed Cowbird	Molothrus ater
Black-headed Grosbeak	Pheucticus melanocephalus
Dickcissel	Spiza americana
American Goldfinch	Spinus tristis
Red Crossbill	Loxia curvirostra
Rufous-sided Towhee	Pipilo erythrophthalmus
Lark Bunting	Calamospiza melanocorys
Savannah Sparrow	Passerculus sandwichensis
Vesper Sparrow	Pooecetes gramineus
Lark Sparrow	Chondestes grammacus
Harris' Sparrow	Zonotrichia querula
White-crowned Sparrow	Zonotrichia leucophrys
Song Sparrow	Melospiza melodia
McCown's Longspur	Rhynchophanes mccownii

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SECTION VIII

FIELD EXPERIMENTAL COMPONENT: THE BIOENVIRONMENTAL EFFECTS OF SULFUR DIOXIDE

By Jeffrey Lee
and Robert A. Lewis

INTRODUCTION

The Montana Coal-fired Power Plant Project has, as a major objective, the generation of a protocol that will allow planning managers to assess the impact of energy producing activities on the environment prior to the initiation of construction activities. The field experimental component of this project is expected to provide data essential to the construction of such a protocol. In particular, we hope to establish both the specificity and threshold of the effects of sulfur dioxide on well-defined components of a grassland ecosystem. We hope also, by correlation of results of the field experimental stressing at the Ash Creek site with those in the Colstrip study area, to evaluate the site-specificity of these responses. Finally, during the three years of the investigation, we hope to generate predictive or extrapolative models that will link short-term low threshold effects to those that occur only after prolonged exposure.

This investigation will take place at the Ash Creek site located in Custer National Forest. Experimental stressing of four one-acre plots will be initiated in April, 1975. These plots are situated within a 27 acre exclosure that was fenced one year in advance of the study to reduce the effects of succession resulting from removal of the plots from grazing by cattle.

Our plan is to maintain different levels of sulfur dioxide on each of these plots. The system is designed to allow us to maintain a constant 30 day mean concentration on each plot during the entire growing season (circa 1 April-30 September). A log-normal distribution of concentrations about this mean is expected. Preliminary testing of a prototype system at Ash Creek during September 1974, indicates that this type of control is feasible. A log-normal distribution is desirable because this type of distribution occurs frequently.

DESCRIPTION OF SYSTEM

This zonal air pollution system will consist of a separate SO_2 delivery system for each of the four one acre plots at the stress site, a common monitoring system, and a common electric power system. Spatial geometry of the delivery system is depicted in Figure 4. The four plots will be located along a line and will be separated by 200 foot buffer zones. System components include: (1) an electric power system; (2) a sulfur dioxide delivery system; and (3) sulfur dioxide monitoring system.

Power will be provided by a 6.5 kw diesel generator, located approximately 1100 feet from the nearest study plot. The generator will be positioned downwind from the stress plots and will be shielded by terrain to minimize air and noise pollution effects. Power will be transmitted via three conductor, buriable copper wire.

The sulfur dioxide delivery system for each plot will provide coverage to at least a 210 feet x 210 feet area. The source will consist of (1)a helical compressor that provides a continuous flow of air, at a pressure gauge of about one pound per square inch and (2) a bank of sulfur dioxide cylinders housed in a heated six by eight foot fiberglass shed. The sulfur dioxide bank will consist of three pairs of cylinders, each pair equipped with a pressure regulator. By setting the regulators differentially it will be possible to replace empty cyclinders without interrupting gas flow. Gas delivery lines will consist of one inch aluminum pipe with 1/32 inch exit holes situated at intervals of ten feet. A series of one inch aluminum poles will support the delivery lines at a height of two and one-half feet above the ground. Sulfur dioxide will be monitored by a sulfur dioxide analyzer in the logarithmic output mode. The output will be put onto a stripchart recorder. Sample lines (1/4" aluminum tubing) from the four stress plots and from four areas outside the plots will lead to a time-share system that has single line that leads from the time-share to the analyzer. Each line will be analyzed approximately once per hour. The recorder, time-share, and analyzer will all be housed in a heated fiberglass shed.

The exact concentrations of SO_2 to be maintained on each test plot have yet to be determined. However, these will range from the normal ambient level on the control plot to a level of about 15 to 20 pphm on one of the experimental plots.

When the first system is complete, the sulfur dioxide monitoring component will be used to map in detail the spatial pattern of sulfur dioxide under various meterological conditions. This will be related to a particular type of sample and will serve as a calibration of the actual sampling configuration used. Although current plans call for four entry points yielding one pooled sample per sample area, the construction technique allows a large degree of flexibility in design. Different configurations can be easily tried.

Micrometeorological data to include air and soil temperatures, humidity, wind speed, solar radiation, and precipitation will be continuously recorded from each plot.

PROGRESS TO DATE

A full-size prototype system was constructed essentially following the description that was written last spring. The dimensions were modified somewhat, as shown in Figure 3, and steel pipe was used instead of aluminum. The system was run for more than three weeks and data on sulfur dioxide distribution were taken.

The prototype clearly demonstrated the feasibility of the field experimental plan. Although certain problems were identified during the start-up and testing phases, most were readily solved and none indicated that the air pollution system would not perform adequately.

Most of the materials necessary for the construction of the stressing system have been procured and are ready for transport to the experimental site. Construction of the delivery system was recently initiated.

RECOMMENDATIONS

Figure 4 represents an improved Zonal Air Pollution System geometry (Note: the plan is drawn to scale except for the shed and dispensing equipment). The earlier geometry resulted in "dead spots" located halfway between the sulfur dioxide pipes. The new design should eliminate these and should generally produce a more nearly uniform sulfur dioxide distribution. Superior features of the new design include

A. Main lines that are 50 feet apart (rather than 70 feet).

B. More point sources of gas (229 vs 152) per plot.

C. More dilute sulfur dioxide in lines and at sources, since air flow will be increased approximately 50 percent while sulfur dioxide flow will not be changed, for the same average concentration in the plot.

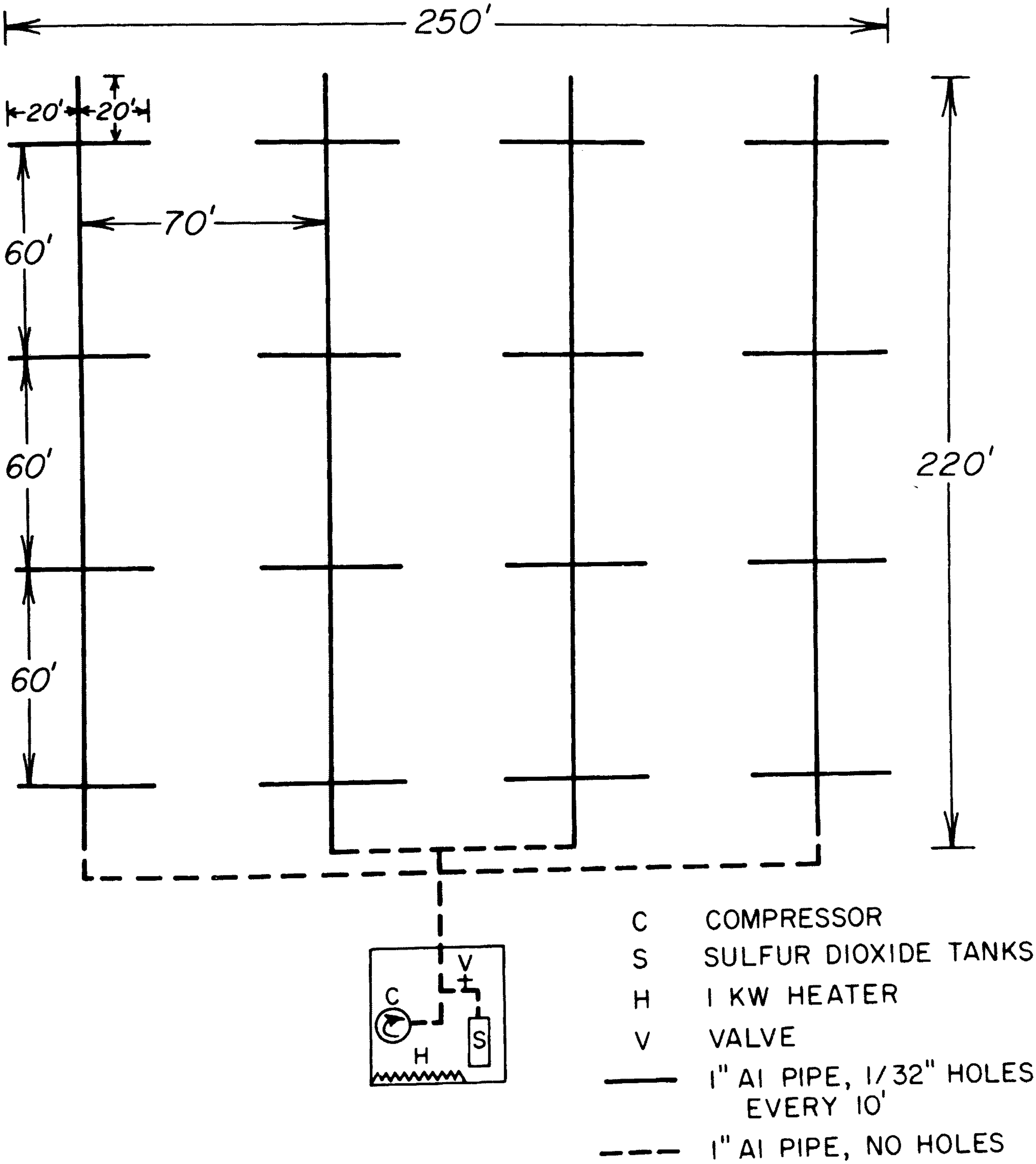

Figure 3. Zonal Air Pollution System

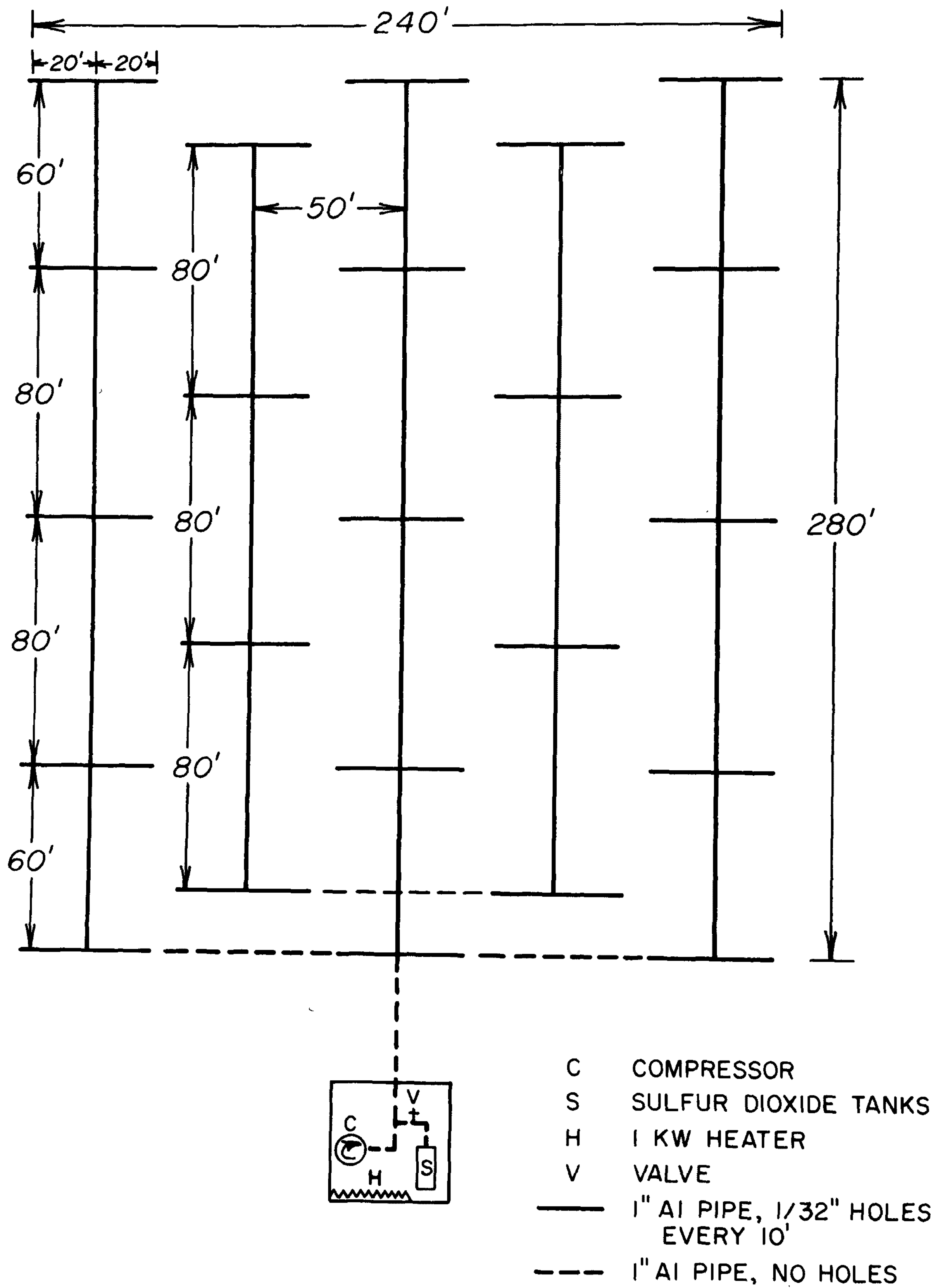

Figure 4. Modified Zonal Air Pollution System

D. Staggered arms from the main lines which will effectively produce intermediate lines with sources 40 feet apart.

E. Minimized pipe cutting because distances between fittings equal integer multiples of pipe length (20 feet).

At least one plot should be monitored for sulfur dioxide at several locations for the length of the experiment. The actual number of points monitored will depend upon empirical needs and available funding.

PROBLEM AREAS AND REQUIRED ACTION

The new design requires an additional 2,400' of aluminum pipe. If this should prove difficult to obtain, steel pipe (possibly from the prototype) should be considered as an alternative. Furthermore, any decision to monitor sulfur dioxide more closely must be made quickly in order to allow time for procurement of any additional equipment.

The data from the prototype show a pronounced daily pattern. Concentrations increased very sharply after dawn and less sharply after sunset. The sulfur dioxide flow must be reduced or stopped during these periods. The controlling parameter can either be time or some meteorological parameter, or sulfur dioxide concentration. In any case, meteorological information will be needed to maximize efficiency. The prototype data will be further, and more quantitatively, analyzed and if weather permits, further prototype testing may aid in perfecting control and maintenance protocols.

SECTION IX
AIR QUALITY COMPONENT MEASUREMENTS

By Tim Cail, Jim Miller, and Allen S. Lefohn

PROGRESS TO DATE

In July, 1974, the National Ecological Research Laboratory sited an air quality monitoring trailer near Colstrip, Montana. The exact location is at Hay Coulee, seven miles southeast of Colstrip, Montana.

Although the trailer is considered to be a mobile air quality laboratory, it is employed as a stationary laboratory facility. Table 19 summarizes the specific instrumentation that has been integrated into the air quality facility. Technicians are able to monitor on a continuous basis the amount of sulfur dioxide, nitrogen oxides, ozone, total hydrocarbons, carbon monoxide, methane, wind speed, humidity, and incident radiation that is present in the area surrounding the laboratory. To simplify data formating and analysis, a data acquisition system has been designed to retain the air quality information and provide teletype printouts at one hour and twenty-four hour periods. Data is also stored on a magnetic tape so that further analysis can occur after the data is returned from the field.

The air quality laboratory returned to Corvallis, Oregon, in late October 1974. The trailer and its equipment will be serviced and prepared for a return to the field in March 1975. The period of sampling will be from March through October so as to insure complete characterization of the ambient air quality in the area.

Table 19. Air Quality Laboratory Instrumentation

Instrument	Instrumentation in Minimum Measured Detectable Level	Precision	Minimum Detectable Level measured under Field Conditions
CO/CH_4/Total Hydrocarbon	.02 ppm	± 0.5 percent	.02 ppm (CO, CH_4, Total hydrocarbon)
$NO/NO_2/NO_x$	0.005 ppm	± 1 percent	.003-.005 ppm
Ozone	0.001 ppm	± 2 percent	0.003 ppm
SO_2	0.005 ppm	± 1 percent	0.01 ppm
Detailed Hydrocarbons	--	--	--
Temperature Sensor	0.5 °F	± 1 percent	0.5 °F
Humidity Sensor	0.2%RH	± 2 percent	1%RH
Solar Radiation	--	--	--
Wind Speed and Direction	∿1 mph	± 1 mph<25 mph	--
High Volume Particulate Sampler	--	± 3 percent	--
Data Acquisition System	--	--	--

PROBLEMS TO DATE

The main difficulty encountered this past year was the late date of the project's initiation. Because of the delay in getting approval for the project, plans for obtaining appropriate electrical service were delayed. Whereas the National Ecological Research Laboratory was prepared to locate the air quality laboratory in Montana as early as April 1974, it was unfortunately unable to obtain the necessary facility support until late June 1974. Electric service was not provided by the local rural electric company until July, 1974. Because all of the facility support work has already been completed, we anticipate no difficulty in gaining access to the area and being operational by March, 1975.

There have been several instances of instrumentation downtime. For example, the CO, CH_4, and total hydrocarbon analyzer was inoperable for a period of one month. In addition, the gas chromatograph system failed to operate satisfactorily for a period of two weeks. The sulfur dioxide, ozone, and nitrogen oxide analyzers performed continuously throughout the period of data taking. The computer system did have a small amount of downtime when a power transformer failed. This electrical failure was corrected within a week after the problem was identified.

In summary, there was a certain amount of instrumentation breakdown that did occur during this first year of sampling. However, this instrumentation downtime is normal and expected in this type of field operation. We anticipate that as the field personnel gain more experience with the equipment, instrumentation downtime will be reduced.

FUTURE ACTIVITIES

No substantial changes are anticipated with the mobile laboratory. More time will be spent this winter on gaining experience with the various components of a support laboratory which hopefully will result in less downtime during the actual operating time in the field. Wet chemical calibration techniques will be developed during the winter period so as to build up the calibration verification capability of the mobile laboratory. The bulk of research activities for this next quarter will be centered on further data analysis and interpretation and planning for the next field season. Table 20 is a summary of the air quality data that was obtained during the 1974 sampling season.

Ambient Air Quality Data

Table 20. Number of Days Daily Average Equal to or Greater Than Indicated Values

Parameter	≥5pphm	≥ 4 pphm	≥3 pphm	≥2 pphm	≥1 pphm	≥ .5 pphm	≥.1 pphm	Total Days	Highest Value-Date	Primary Standard	Secondary Std.
NO	0	0	0	5	18	32	42	43	2.8 pphm Aug. 28 - Sept. 1	--	--
NO_2	0	0	0	0	0	5	42	43	.7 pphm Sept. 26	5 pphm	5 pphm
NO_x	0	0	2	8	25	41	43	43	3.3 pphm Aug. 28	100 $\mu g/M^3$	100 $\mu g/M^3$
O_3	1	10	35	47	51	51	51	51	5.57 pphm Sept. 19	8 pphm	8 pphm
SO_x	0	0	0	0	0	3	12	42	.66 pphm Sept. 11	14 pphm	10 pphm 50 pphm
	≥ 2.00 ppm	≥ 1.5 ppm	≥ 1.0 ppm	≥ 0.5 ppm	≥ 0.1 ppm	≥ 0.5 ppm	≥ -.01 ppm				
CH_4	1	19	23	24	25	25	25	25	2.08 ppm Sept. 5	--	--
CO	0	0	0	0	15	22	24	25	0.46 ppm Oct. 5	9 ppm 35 ppm	9 ppm 35 ppm
THC Less CH_4	0	0	2	4	11	16	21	25	1.25 ppm Sept. 26	0.24 ppm	0.24 ppm
	≥ 125 $\mu g/m^3$	≥ 100 $\mu g/m^3$	≥ 75 $\mu g/m^3$	≥ 50 $\mu g/m^3$	≥ 25 $\mu g/m^3$	≥ 10 $\mu g/m^3$	≥ 5 $\mu g/m^3$				
Hi-Vol Particulate	0	0	1	7	34	58	60	61	93.2 $\mu g/m^3$ Sept. 26	75$\mu g/m^3$ 260$\mu g/m^3$	60$\mu g/m^3$ 150$\mu g/m^3$

SECTION X
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16. ABSTRACT

In June 1974, the National Ecological Research Laboratory initiated a field program in southeastern Montana. The purpose of this program is to assess the effects of a coal-fired power plant on the terrestrial environment. Numerous investigators have worked together on this project to establish a baseline investigation to characterize the environment around the plant prior to operation. This report is a summary of activities from June through October, 1974. The overall objectives, rationale, and design of the project are outlined. Recommendations regarding further actions on many of the components of this program are also included. The paper serves primarily as a status report to the scientists and managers who have been following the project since its inception in March, 1973.

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