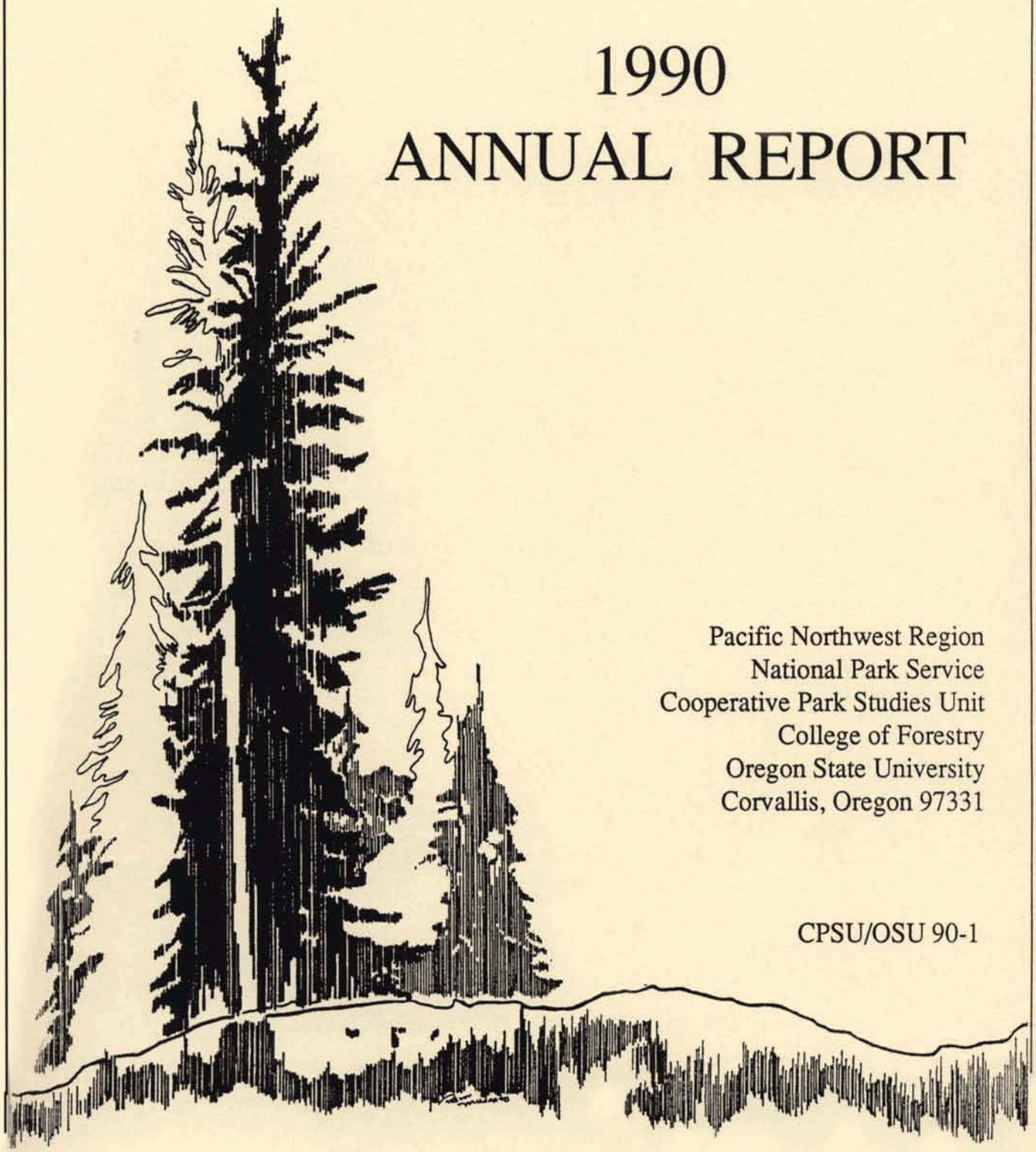
1990
ANNUAL REPORT



Pacific Northwest Region
National Park Service
Cooperative Park Studies Unit
College of Forestry
Oregon State University
Corvallis, Oregon 97331

CPSU/OSU 90-1

1990 Annual Report

National Park Service
Cooperative Park Studies Unit

Ed Starkey, Project Leader
Terrestrial Ecology

Perry J. Brown, Project Leader
Natural Resource Sociology

Gary Larson, Project Leader
Aquatic Biology

Cooperative Agreement CA-9000-8-0006

Subagreement 1
Subagreement 2
Subagreement 3

Pacific Northwest Region
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Corvallis, OR 97331

The Cooperative Park Studies Unit (CPSU) concept is a means by which the National Park Service and Oregon State University mutually strengthen their ability to conduct research, improve teaching, and provide training opportunities. The benefits of such cooperation are realized in the subsequent application of knowledge from the natural and social sciences to the improved management of natural, cultural, and human resources. We appreciate the continued partnership between both institutions in this continuing endeavor.

National Park Service

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Regional Director, Pacific Northwest Region

Oregon State University

George Brown
Dean, College of Forestry

Cooperators and Cooperative Park Studies Unit Staff

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Richard L. Winters, Associate Regional Director
James W. Larson, Regional Chief Scientist

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Bo Shelby, Associate Professor, Dept. of Forest Resources
George Stankey, Professor, Dept. of Forest Resources
Richard Tubb, Head, Dept. of Fisheries and Wildlife

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INTRODUCTION

The Pacific Northwest Region National Park Service Cooperative Park Studies Unit (CPSU) at Oregon State University was established in 1975. The purpose of the Unit remains the same since its inception: (1) to conduct original research on topics of importance to the management of natural and cultural resources; (2) to encourage and facilitate scientific research in national parks in the Pacific Northwest Region; and (3) to disseminate research results within the management system of the National Park Service. The NPS Cooperative Park Studies Unit is located in the College of Forestry.

The CPSU includes research programs in wildlife, aquatic biology, and natural resource sociology. The wildlife biology research program was initiated in 1975; in 1983 the natural resource sociology research program was established, and in 1984 an aquatic biology research program was initiated. These programs complement other such programs within the University and College of Forestry, as well as programs in operation within the Pacific Northwest Science Program, though each science project is unique and is not duplicated within the University or NPS research organization.

Terrestrial Ecology Program

During 1990, the CPSU terrestrial ecology staff consisted of Ed Starkey and two research associates.

A major study of ungulate ecology in national parks of the Pacific Northwest Region continued. A primary objective is the provision of improved baseline information on elk populations of parks with emphasis on census techniques, population dynamics, and movements and behavior. Potential influences of land management activities on adjacent nonpark lands are of special interest. A conceptual model of forest management impacts on national park elk was developed. Ongoing research on nutritional ecology of cervids inhabiting old-growth forests also continued. An assessment of the effects of elk grazing on plant communities of Mt. Rainier National Park was completed.

In 1990, a cooperative program continued with the Department of Rangeland Resources, Oregon State University, to provide technical assistance concerning vegetation management in arid parks. This included revegetation projects at Whitman Mission and fire ecology studies at John Day Fossil Beds National Monument, Oregon. Starkey served as coordinator for a major project at Great Basin National Park during 1990. The Department of Rangeland Resources is developing a grazing management plan for the Park and conducting needed rangeland research. The project will be completed in 1991.

A survey of animal disease issues in the National Park system was initiated in 1990. Special initiative funding was provided to distribute questionnaires to all parks in the system, as well as contact other federal and state agencies concerning diseases of

wildlife and domestic livestock within or near park boundaries. A cooperative relationship has been established with the College of Veterinary Medicine which should result in an improved ability to respond to animal disease concerns.

Starkey was a major contributor to the Global Change Research Capabilities and Interest statement prepared by Great Basin National Park (GRBA). GRBA was selected as a biogeographic core area, but was not awarded any research funding.

In spring 1990, Starkey taught an upper division course on "Ecological Aspects of Park Management." This course is taught each spring. He also served on the steering committee for a major fire ecology symposium to be held in January 1992 in Portland, and as a member of the Project Advisory Committee for the Rocky Mt. Elk Foundation.

Aquatic Biology Program

Gary Larson's main responsibilities, centered on the limnological studies of Crater Lake. The main emphasis of the project is on the inter-relationships among physical, chemical, and biological components of the lake system and their relationships to lake clarity. Samples were collected in January and June through September. Jack Dymond and Bob Collier completed their hydrothermal research report.

Larson also continued a survey of lakes and streams in Mt. Rainier National Park with Barbara Samora. He also continued a study of the effects of stocked fish on lake communities naturally barren of fish in North Cascades National Park Service Complex with William Liss and C. David McIntire. Peer reviews of the North Cascade project and backcountry human waste problems at Mt. Rainier National Park were convened.

Larson has courtesy appointments in the College of Forestry, Department of Fisheries and Wildlife, and the General Science Department at Oregon State University. He is a member of the National Park Service Global Change Committee.

Natural Resource Sociology Program

During 1990, the CPSU Natural Resources Sociology Program staff was led by Dr. Perry J. Brown, Professor in the College of Forestry, with Marty Lee and Denver Hospodarsky as Research Assistants.

Two research projects were continued during 1990: (1) the Great Basin National Park Visitor Study, and (2) the social science portion of the North Cascades High Lake Fisheries Study. Each is briefly reviewed below.

The Great Basin National Park Visitor Survey was begun in 1988 as part of a five-year research program studying the evolution of a new national park and its surrounding region. The purposes of the survey were to generate information about park visitors for use in management planning and to develop a baseline data set to be used to monitor

impacts of the Park's creation and subsequent visitation. Reports on the major visitor survey, a 1989 Easter weekend survey, and use trends were published previously. A report on the tourism infrastructure of White Pine and Millard counties was drafted in 1990 and will be published in 1991. During 1990, a survey of White Pine county residents was made. This survey looks at the use and perceptions of the park by county residents and is one of the baseline components of the study.

The social science work in North Cascades National Park has focused on use and impacts at high mountain lakes. A literature review and a user survey were published previously. In 1990, observations of use and impacts were made at selected lakes, and permanent impact study sites were established. The result of the observation study showed that fishermen are likely to cause a disproportionate impact to shoreline resources. The length and type of behavior of these recreationists appears to be much more impacting of shoreline resources than does the typical behavior of non-fishing recreationists. This is particularly evident in areas which previously have had little recreational use. A final report on this project will be forthcoming in 1991.

In late 1990, Marty Lee and Denver Hospodarsky left the CPSU for positions at Northern Arizona Uninversity but have remained active in completing current work of the CPSU.

PROJECT SUMMARIES:

RESEARCH

ANIMAL DISEASE ISSUES IN THE NATIONAL PARK SYSTEM

Principal Investigators: Donald Hansen
College of Veterinary Medicine
Oregon State University

Edward E. Starkey
Cooperative Park Studies Unit
Oregon State University

Research Associate: Alonso Aguirre
College of Veterinary Medicine
Oregon State University

Objectives: This project will provide a review and summary of existing knowledge of animal diseases which are of potential concern to park managers, as well as review the taxonomic status of disease-causing organisms with regard to classification as native or exotic.

Project: Questionnaires were mailed to most areas of the National Park System, as well as many federal and state agencies in an attempt to obtain information on significant wildlife and domestic livestock diseases. Responses will be tabulated and analysed, and an extensive literature review completed in early 1991.

The final report will be submitted in late summer 1991.

INFLUENCE OF ADJACENT LAND-USE PRACTICES ON ELK OF PACIFIC NORTHWEST NATIONAL PARKS

Principal Investigator: Edward E. Starkey
Cooperative Park Studies Unit
Oregon State University

Research Associates: Kurt J. Jenkins
Cooperative Park Studies Unit
Oregon State University

Objectives: The goal of this study is to determine the effects of forest management practices occurring outside national park boundaries on the long term carrying capacity of elk populations in national parks of the Pacific Northwest. Specific objectives are as follows:

1. To critically review carrying capacity models that are used to evaluate the environmental effects of forest management practices on elk populations,

2. To review existing information relating to elk ecology on lands adjoining northwestern national parks to derive data pertinent to the estimation of carrying capacities, and

3. To develop a conceptual model of forest management impacts on national park elk.

Progress: The project was completed in 1990. We have concluded that forest management practices have been largely responsible for the increases in Mt. Rainier elk which occurred during the 1960s and 1970s. Results were presented at the annual meeting of the Society for Range Management in February 1990.

INFLUENCES OF CERVID HERBIBORY ON UNDERSTORY FORAGE IN OLD-GROWTH SYSTEMS, OLYMPIC NATIONAL PARK

Principal Investigators: Edward E. Starkey
Cooperative Park Studies Unit
Oregon State University

Douglas B. Houston
E.S. Schreiner
Olympic National Park

William K. Kreuger
Dept. of Rangeland Resources
Oregon State University

Research Associate: Patricia J. Happe
Cooperative Park Studies Unit
Oregon State University

Objectives: To determine the effects of cervid herbivory on understory plants of an old-growth forest community.

Progress: The research was initiated in April 1987, and sampling was completed in March 1989. Specifically, we are investigating the amount of herbivory by cervids and the effects of herbivory on forage production, growth form, nutritional quality, and species composition in the south fork of the Hoh River, Olympic National Park. This research was conducted in cooperation and conjunction with a larger research effort aimed at assessing the role of cervid herbivory throughout the park.

The role of herbivory was assessed with cervid exclusion over several time frames. The effects of long term exclusion were examined using two 0.5 ha exclosures that were constructed in 1980. The effect of exclusion for a growing season was assessed using 20-25 square meter exclosures. The amount of herbivory was assessed with 100 portable 1 meter square cages. The influence of herbivory was examined on both herbaceous and shrub species and in grass and forb-dominated patches within old-growth stands. The 25 square meter exclosures and the 1 meter square cages were removed in June 1989.

Data analyses are underway. A final report will be prepared in 1991.

FORAGE QUALITY IN OLD-GROWTH FORESTS

Principal Investigators: Edward E. Starkey
Cooperative Park Studies Unit
Oregon State University

Steven Sharrow
Dept. of Rangeland Resources
Oregon State University

Research Associate: Patricia J. Happe
Cooperative Park Studies Unit
Oregon State University

Objectives:

1. Compare forage quality in old-growth forests and early seral clearcuts.

2. Compare quality of key browse species in and out of elk exclosures in old-growth forests.

Progress: Samples of current annual growth of four key browse species were collected in July 1985, October 1985, January 1986, and April 1986. Collection sites were four early seral clearcuts adjacent to Olympic National Park on the main stem of the Hoh River, four stands of old-growth along the Hoh within the Park, and within and adjacent to three ungulate exclosures within the Park.

Analyses conducted were: crude protein, in vitro digestibility, cell wall constituents, lignin, condensed tannins, hydrolyzable tannins, total phenolics, astringency, protein precipitating phenolics, leaf area, and leaf-stem ratio.

One manuscript from the clearcut-old-growth study was published in the Journal of Wildlife Management in 1990. Another has yet to be prepared for submission to the Journal of Chemical Ecology. One report, "Preliminary nutritional comparisons of browse in clearcuts and old-growth forests, Olympic Peninsula, WA" has been published. Results will be combined with ongoing studies on the effects of herbivory on forage production and community function and composition in old-growth systems.

THE ECOLOGICAL EFFECTS OF FIRE ON FUELS AND VEGETATION AT THE JOHN DAY FOSSIL BEDS NATIONAL MONUMENT

Principal Investigators: J. Boone Kauffman
William C. Krueger
David B. Sapsis
Ken Till
Dept. of Rangeland Resources
Oregon State University

Objectives: To improve our understanding of: (1) The presettlement vegetation composition of the John Day Fossil Beds National Monument, (2) the natural role of fire on vegetation dynamics and nutrient cycling, (3) the development of management recommendations concerning improving or maintaining native rangeland ecosystems.

Progress: Significant advances were made in 1990 with respect to our understanding of fire as a natural ecosystem process in semiarid-sagebrush (Artemisia tridentata subsp. tridentata) and western juniper (Juniperus occidentalis) dominated ecosystems. Much of the data of our initial experiments on vegetation response to fire are now yielding results, while additional studies concerning fire and nutrient cycling have been established and are now underway.

In order to ascertain the underlying ecological processes responsible for this vegetation response, a study was initiated in 1989 to quantify fire and nutrient cycling in this ecosystem. This study will yield critical information on: (1) fire as an ecosystem process in maintaining natural communities, (2) the effects of prescribed fire on nutrient loss and redistribution, (3) the postfire cycling of nitrogen, and (4) the relationships between fire, nutrients, and vegetation establishment. Currently, analysis of vegetation and soils is underway in the OSU Rangeland Resources Research Laboratory. A comprehensive study plan of this research phase was provided to the National Park Service in early 1990.

Detailed measurements of vegetation response and nutrient cycling continued through 1990. These measurements include both laboratory analyses, field work, and data synthesis and publication. Additional prescribed burns were conducted in the spring 1990.

MANAGEMENT OF VEGETATION AT WHITMAN MISSION NATIONAL HISTORIC SITE

Principal Investigators: Larry Larson
William Krueger
Dept. of Rangeland Resources
Oregon State University

Objectives: To return the vegetation in the park to a composition and appearance similar to the time period when the mission was active.

Progress: The project is designed to occur in two phases. The first phase requires the stabilization of abandoned cropland with species (native and non-native) that are ecologically similar to indigenous species. The second phase will emphasize the establishment of native species on each of the revegetated areas after they have been stabilized.

Phase one of the project is nearly complete. A variety of techniques including seeding, herbicide applications, plowing and irrigation have been used to stabilize most abandoned fields at the mission. Weeds have generally been controlled and stands of grasses established. The project will require several more years of significant effort to complete phase two.

LIVESTOCK GRAZING MANAGEMENT PLANNING AND RESEARCH AT GREAT BASIN NATIONAL PARK

Principal Investigator: Lee Eddleman
Dept. of Rangeland Resources
Oregon State University

Research Associate: Ray Jaindl
Dept. of Rangeland Resources
Oregon State University

Objectives:

1. Prepare a grazing management plan.
2. Develop a monitoring system to assess any short and long term changes in the ecosystem resulting from grazing or other factors.
3. Initiate selected high priority research projects.

Progress: The main thrust this year was field work on research projects to investigate concerns and problems relating to range management in GRBA.

Field work was completed in late 1990. The data includes species composition and cover, ground cover, age structure of the tree species, and a description of the environment. Sites from each of the following communities have been evaluated thus far: pinyon-juniper woodlands, mountain big sagebrush shrublands, aspen stands, conifer forests, and mountain mahogany stands.

A study evaluating pinyon pine and mountain mahoganies physiological response to seasonal change and location along an elevational gradient was completed. Data were collected monthly starting June and continued until the ground froze in late November. Results will be used to evaluate the direction of succession where the two species overlap.

Evaluation of the comparative nutrient status of sagebrush-grasslands, pinyon-juniper and mountain mahogany communities was completed also. Focus is on available nutrients for plant growth and nutrient dynamics on a seasonal basis. Results are to be used to assess successional effects on ecosystem processes.

The project will be completed in 1991.

THE EVOLUTION OF A PARK: A CASE STUDY OF GREAT BASIN NATIONAL PARK

Principal Investigator: Perry J. Brown
Dept. of Forest Resources
Oregon State University

Research Assistant: Marty Lee
Dept. of Forest Resources
Oregon State University

Objectives: The establishment of Great Basin National Park has offered the National Park Service and social science research community the unique opportunity to follow a park from establishment through development to maturity as a social/cultural institution within the state of Nevada. As an example of the park and region resource system, the research team will establish baseline data points and social science indicators which can be monitored over time.

Progress: An inventory of tourism facilities and services within the Great Basin National Park region has been completed and a summary of findings has been drafted into a report.

A survey of local residents has been dome to examine their relationship to the Park and their perception of the effects of the Park. Data are being analyzed for this survey.

Plans for next year are analysis of all surveys and preparation of reports. Major reports on the 1988 visitor survey and the 1990 residents survey will be prepared.

EFFECTS OF STOCKING FISH INTO HIGH-MOUNTAIN LAKES IN NORTH CASCADES NATIONAL PARK SERVICE COMPLEX: HUMAN USE ASSESSMENT

Principal Investigators: Perry J. Brown
College of Forestry
Oregon State University

Denver Hospodarsky
College of Forestry
Oregon State University

Objectives:

1. Identify lakes at which impacting behaviors were to be measured and impacts were to be monitored over time;

2. Identify and measure the impacting behaviors of anglers and non-anglers;

3. Develop an empirically based causal model relating impacts to the physical-biological, social, and managerial environment; and

4. Establish long-term impact monitoring sites and document monitoring methods.

Progress: The research objectives were addressed through four research methods generally classified as sample design, behavioral observation, inductive modeling, and physical-biological impact assessment monitoring. Sample design resulted in the selection of eight observation lakes, viz., Dagger, McAlester, Lower Thornton, Monogram, Rainbow, Copper, Egg, and Lake 6303 (a.k.a. Dee Dee). Two of these lakes, McAlester and Lake 6303, were also chosen as sites for long-term impacts monitoring.

Observations of angler and non-angler behavior were conducted at the eight lakes throughout the summer-use season. A total of 153 visitor observations were completed that described visitor movements or activities such as walking, standing, sitting, and swimming that were known to cause impacts to riparian soils and vegetation. Observations were compiled on 54 anglers and 99 non-anglers. Comparisons between the two user groups on the activities showed that anglers spent significantly more time engaged in impacting activities than did non-anglers.

A causal model was developed relating physical-biological impacts accruing to a site as a function of factors in the bio-physical, social, and managerial environments that circumscribe lake use. This management-oriented model was developed inductively from

the results of the observational study and the literature review completed in 1988. The model was intended to facilitate deductions about angling behaviors to lakes not included in the sample design.

Eight impact monitoring and control sites were established at McAlester and Lake 6303. These sites were mapped and permanent line transects were established to allow measurement of changes in impacts on the sites over time. The extent of overall site impacts could be determined through comparisons of impacted sites with unimpacted control sites located at the two lakes. A report on the results of the 1990 study is currently in preparation.

EFFECTS OF STOCKING FISH INTO HIGH-MOUNTAIN LAKES IN NORTH CASCADES NATIONAL PARK SERVICE COMPLEX

Principal Investigator: William J. Liss
Department of Fisheries and Wildlife
Oregon State University

Co-Investigators: Gary L. Larson
Cooperative Park Studies Unit
College of Forestry
Oregon State University

C. David McIntire
Department of Botany and Plant Pathology
Oregon State University

Collaborators: Greg Lomnicky, Beth Deimling, and Robert Hoffman
Department of Fisheries and Wildlife
Oregon State University

John Jarvis
Robert Wasem
North Cascades National Park Service Complex

Objectives:

1. Develop a literature review of the impact of stocked fish on biological communities in naturally fishless lakes.

2. Develop a system of classification of lakes in NOCA that could be used in designing field research intended to assess the effects of fish stocking.

3. Develop a research proposal and conduct the field research.

Progress: Very little is known of the effects of fish stocking on communities in naturally barren high lakes. This poverty of information necessitated use of literature from studies of other lake types. In general, the literature review indicates that stocking fish can alter the kinds and abundances of species composing communities and the complex interactions among species. Taxa affected by stocking include zooplankton, benthic macroinvertebrates, and phytoplankton. Elimination of prey species in high mountain and other lake types have been reported The kind and magnitude of impact of fish stocking is contingent on a number of factors. These include the vulnerability of prey species to predation, the species-specific characteristics and age/size structure of the stocked predator, habitat characteristics of the lake including presence of prey refuges,

and the structure of the community into which the fish are introduced.
A preliminary biogeoclimatic system of classification of lakes in NOCA was developed. The classification system is hierarchical, essentially subdividing the park into smaller and smaller geographic areas. The Park was initially classified into three major units based upon regional geologic and climatic features and major watershed boundaries. These units are the Nooksack-Fraser in the northwest part of the park, the Skagit located centrally, and the Stehekin in the southwest. These units differ in geology, climate as influenced by major air mass movements, extent of glaciation, and aspect.

Each major unit was divided into smaller subunits consisting of tributaries to the major watersheds. The subunits were identified and classified according to smaller scale geologic features, local climatic patterns including precipitation gradients, extent of glacial influence, and relative watershed size.

Lakes within each subunit were classified according to 1) total area of the watershed of each lake, 2) elevation of lake, 3) lake surface area and relative depth, 4) kinds of inlets to the lake, 5) vegetation, and 6) local geology. Using these variables, lakes were grouped into classes using cluster analysis.

Some of the lake survey data collected by park personnel over the past seventeen years was useful in developing the classification system. The Park's survey data meets the general objectives for which it was collected, but little of the information can be directly used to evaluate effects of stocked fish on lake communities in NOCA. A literature review of the effects of fish on lake communities was prepared.

A research proposal was prepared and peer reviewed. Based on the review, 21 lakes were sampled in 1990 with a focus on the subalpine. All forested lakes had some form of vertebrate predation. When fish were absent, salamanders were present. When fish were present, even at low densities, salamanders were rare or absent. In the subalpine, salamanders were rare or absent in lakes with fish. There were, however, several subalpine lakes without vertebrate predation.

In forested and subalpine lakes, trout fed on benthic, water column, and surface organisms. Benthic prey comprised the largest portion of the diets, especially in forested lakes. Fish appear capable of reducing densities of large calanoid copepods, perhaps eliminating them from lakes because catch per unit of effort (CPUE) for fish was inversely related to the density of large omnivorous adult copepods. Body size of the crustacean zooplankton varied with the CPUE. Salamanders also appear to alter crustacean zooplankton community structure, but not as much as populations of reproducing fish. Densities of large omnivorous adult calanoid copepods appeared to be inversely related to larval salamander densities.

Plans for next year include: (1) peer review of the 1990 field results of the 1991 revised research proposal, (2) analysis of data collected in 1989-90, and (3) initiation of the third field season.

HIGH MOUNTAIN LAKE SURVEY
OLYMPIC NATIONAL PARK

Principal Investigator: Gary Larson
Cooperative Park Studies Unit
College of Forestry
Oregon State University

Co-Investigators: Cat Hawkins-Hoffman
Olympic National Park

Elena Karnaugh-Thomas
Dept. of Fisheries and Wildlife
Oregon State University

Objectives:

1. Develop baseline data on the morphology and water quality of seven lakes.

2. Develop baseline data on the phytoplankton and zooplankton community structures in each lake.

3. Develop baseline data on benthic macroinvertebrates in the near shore (littoral) areas and in inlet and outlet streams of the lakes.

Progress: All of the physical, chemical, phytoplankton, and zooplankton samples have been processed and analyzed. A draft final report is being prepared.

Plans for next year include: (1) complete the final report, (2) present the findings to the park staff, and (3) prepare a manuscript for submission to a peer reviewed scientific journal.

WATER RESOURCES IN MOUNT RAINIER NATIONAL PARK

Principal Investigators: Gary Larson
Cooperative Park Studies Unit
Oregon State University

Co-Investigators: Mike Hurley and Andy Wones
Cooperative Park Studies Unit
Oregon State University

Barbara Samora
Mount Rainier National Park

Objectives:

1. Document the basic water quality of streams, springs, and lakes.
2. Conduct a limnological survey of Mowich Lake.
3. Evaluate the backcountry human waste issue.

Progress: The water quality survey of major streams initiated in 1986 continued in 1990. Twenty lakes were surveyed in 1988 for morphometry, water quality, phytoplankton, and zooplankton. More detailed studies were conducted at Mowich Lake in 1988, repeating a study conducted in 1967. A final report on stream water quality was submitted. A peer review discussion of the backcountry human waste issues was convened.

Plans for next year: 1) complete the analysis of the 1988 lake data, and 2) prepare a draft final report on the lake studies.

CRATER LAKE LIMNOLOGICAL STUDIES
CRATER LAKE NATIONAL PARK

Principal Investigator:

Gary Larson
Cooperative Park Studies Unit
Oregon State University

Collaborators:

Norm Anderson and Bob Wisseman
Dept. of Entomology
Oregon State University

Mark Buktenica
Crater Lake National Park

Jack Dymond and Bob Collier
Dept. of Oceanography
Oregon State University

Peter Fontana
Dept. of Physics
Oregon State University

Stan Gregory
Dept. of Fisheries and Wildlife
Oregon State University

Mike Hurley
College of Forestry
Oregon State University

C. David McIntire and Harry Phinney
Dept. of Botany
Oregon State University

Jim Milestone
Crater Lake National Park

Peter Nelson
Dept. of Civil Engineering
Oregon State University

Kelly Redmond
Desert Research Institute
Reno, Nevada

Objectives:

1. Develop a detailed baseline data set of the general limnological characteristics of the lake that will serve as a benchmark for future studies.
2. Develop an understanding of lake organization and structure.
3. Establish a long term limnological monitoring program.

Progress: The FY 1990 field season included sampling in January and June through September. Baseline data included general physical and chemical features, chlorophyll, phytoplankton, zooplankton, benthos, and fish. Primary production was estimated each trip.

Results to date have demonstrated that the lake is still unproductive (oligotrophic). Water clarity, as measured with a Secchi disk, is generally in the high 20 to mid 30-meter (m) range. Comparisons of Secchi disk readings suggest that the environmental-limnological conditions that produced 39-40 m Secchi disk readings in the month of August in 1937 and 1969 have not occurred during the period from 1978 to 1990. The limited number of August readings suggests that the maximum lake clarity readings appear to be about 18-25% lower in 1954 and 1978-1990 than in 1937 and 1969.

The apparent decline in Secchi disk readings can probably be explained by small increases in the densities of light scattering particles in the water column. The particle density can be affected by many factors, e.g., natural environmental changes, loading of anthropogenic material from atmospheric and on on-site sources, and perhaps internal lake processes such as hydrothermal and biological activity.

Studies are underway to examine the extent to which changing lake conditions can be explained by natural and human-caused reasons such as relationships between the climate and changing lake levels, interspecific relationships of fish, zooplankton and algae, and human-caused increases of nutrients from the atmosphere and on-site sources. The results from these studies will be used to evaluate whether the lake has undergone any extensive physical, chemical, and biological changes which might explain the apparent decline of the August Secchi disk readings.

The monitoring program is currently emphasizing the interrelationships among environmental, terrestrial, anthropogenic, and aquatic components of the lake system. Conceptual models have been developed which are being used to guide the studies.

Plans for next year include: 1) continuation of the monitoring program, 2) continuation of projects on water budget, nutrient budgets, particle flux, caldera spring chemistry, and phytoplankton community analysis, 3) extensive evaluation of lake temperature and turbidity, 4) processing of the 1988-1990 zooplankton samples and 1990 phytoplankton samples, and 5) preparation of a paper on the relationship between lake productivity and Secchi disk readings for publication in a peer reviewed scientific journal.

NUTRIENT CYCLING AND PARTICLE FLUXES IN CRATER LAKE CRATER LAKE NATIONAL PARK

Principal Investigators: Jack Dymond
Robert W. Collier
College of Oceanography
Oregon State University

Objectives: The objectives of this project are to quantify the carbon and nutrient cycles in the water column and sediments of Crater Lake, Oregon. This is accomplished through analysis of materials collected by particle collectors (sediment traps) which are moored in the lake. Comparison between the fluxes of carbon and nutrients with their burial rates in the sediment as determined from sediment core analyses constrains the total input of nutrients to the lake and the rates of recycling at the sediment-water surface.

Progress: This program is designed to determine the rain rate (flux) of particles which settles at various water depths in Crater Lake. A mooring was recovered and then redeployed in early July 1990. This mooring was then recovered and redeployed for a second time in early September. Each mooring contained particle collectors (sediment traps) at depths of 200, 390, and 585 m. During the 10-month sampling interval (September to July), the trap at 200 meters contained a sample changer which provided a two month temporal resolution in the particle flux. These experiments provide a seven year timeseries of particle flux measurements. The most recent mooring was our 15th recovered sample set.

Comparison of the composition of particles raining to the bottom with the composition of surface sediments in Crater Lake allows the determination of the fraction of the raining biogenic materials which is preserved by burial in the sediments. Less than 10% of the organic carbon and nitrogen which settles to the lake floor is preserved in the sediments. Approximately 20% of the opal, which originates from diatom tests, is preserved in the sediments. These data suggest that measurements of opal accumulation rates in the sediments is a better paleolimnological indicator than either carbon or nitrogen accumulation rates.

Future Plans: The mooring deployed in September 1990 will be recovered in July 1991. That mooring will be recovered and redeployed in September. Data from the seven-year timeseries will be analyzed and modelled.

STUDIES OF HYDROTHERMAL INPUTS TO CRATER LAKE CRATER LAKE NATIONAL PARK

Principal Investigator: Robert Collier
Jack Dymond
College of Oceanography
Oregon State University

Objectives: The third year of this four-year project was focused on evaluating the hydrothermal inputs to the deep basins of Crater Lake.

Progress: Submersible observations within the South Basin (1987-1989) have defined fine-scale variations in temperature and salt content of the near-bottom waters. Temperature variations of up to 0.5°C and conductivity variations of more than a factor of two occur over distances of a few meters. These thermal and salinity gradients can only be maintained by a continuing input of anomalous fluids.

Communities of bacteria, which produce impressive mat features on rock outcrops and sediment surfaces, mark sites of deep lake venting. The mats appear to be communities which use abundant reduced iron in the advecting fluids to fuel their metabolism. Although there were no visual indications of flow from the mats, advection is implied by the requirements of such prolific bacterial communities for continuous inputs of reduced chemical species. Furthermore, advection rates defined by temperature gradients within the mats are as high as 100 m/y. Consequently, the bacterial mats are visual markers of thermally and chemically enriched fluid venting.

Pools of saline water (brines) have been discovered in two widely separated areas of the lake. Although fluids from both areas have major element contents that are approximately a factor of 10 greater than background lake values, the two sites exhibit different elemental compositions which point to distinct sources.

Pore water measurements demonstrate non-linear gradients of enriched pore fluids that can be used to define vertical fluid advection rates of up to 2 m/y. The pore water compositions are similar to the pools found in the South Basin. These observations and similar ratios of certain major elements suggest the fluids which are advecting through the sediments, the brine pools, and the high temperature mat fluids have a common source. Chemical geothermometry suggest this source equilibrated with silicate rocks at temperatures up to 165°C. Subsequent mixing and conductive heat loss have resulted in a range of heat/salt ratios.

Sampling of mat fluids, pools, and pore waters has extended the range of anomalous water compositions which are found within Crater Lake. For example, the anomalies with respect to background lake levels for major elements are approximately a factor of

ten. Manganese is enriched in the end-member fluids by as much as a factor of 10^6 and ^{222}Rn is 10^5 times enriched over typical lake values. Helium-3, perhaps the most distinctive indicator of a magmatic source, is a factor of 500 enriched over values in equilibrium with atmospheric sources.

From the ionic relationships of the anomalous waters we are now able to account for the bulk lake compositions, which were hitherto unexplainable by known water sources (e.g., precipitation and caldera springs). From these data we have calculated geochemical mass balances for the lake which include realistic estimates of composition of a hydrothermal input. The mass balance models delimit the range of possible hydrothermal flows into the lake. Various independent steady state models indicate a net heat flow to the lake of 15 to 30 megawatts (MW). Similarly, calculated flow rates of a thermally and chemically enriched fluid are approximately 200-400 liters/sec.

As a result of the past three years of field studies and our interpretation of these and other data from the literature, we conclude that there <u>are</u> inputs of hydrothermal fluids into the bottom of Crater Lake. The dissolved materials associated with these thermally and chemically enriched fluids, coupled with the overall hydrologic balance, control the observed chemical composition of the lake. Because hydrothermal inputs dominate the material fluxes for most chemicals into Crater Lake, the hydrothermal process is highly significant. Furthermore, the geothermal inputs have a direct effect on the density structure of the deep lake, and consequently, the rates of heat, salt, and nutrient redistribution.

<u>Future Plans</u>: Submit the draft final report.

PHYTOPLANKTON TAXONOMY AND ECOLOGY OF CRATER LAKE CRATER LAKE NATIONAL PARK

Principal Investigator: C. David McIntire
Department of Botany and Plant Pathology
Oregon State University

Co-Investigators: Robert Truitt
Gary L. Larson
Cooperative Park Studies Unit
Oregon State University

Objectives: Describe the seasonal dynamics of phytoplankton assemblages at an intensive study site in Crater Lake and generate hypotheses that could account for the vertical and seasonal distribution and abundance of the constituent algal populations in the water column.

Progress: Data files were updated and integrated to include phytoplankton counts from samples through 1989. The integrated data file (1985-1989) was analyzed using the computer programs AID1, AIDN, CLUSB4, and the DISCRIMINANT subsystem of SPSS. The analysis included the estimation of community composition parameters, the calculation of similarity and niche breadth statistics, the generation of alternative cluster structures which summarized distributional patterns at the community level of organization, and the graphic display of the cluster structure in discriminant space. Computer programs were written which allow an investigator to extract information about the density and biovolume of individual species from the large data sets. This information was used to plot the distributions of individual dominant taxa.

The most recent statistical analyses support the hypothesis proposed earlier: that the phytoplankton of Crater Lake can be conceptualized as a sparse but diverse assemblage which is spatially and temporally modified periodically by local variations in the production dynamics of the more dominant species. Moreover, the analysis suggested that the flora is stratified in the summer, with a Nitzschia gracilis dominated assemblage in the surface waters and more diverse assemblages located below the metalimnion. This stratification is not present during the spring and winter months.

Future Plans: Next year the regular sampling program will continue. The 1990 samples will be processed according to our standard methods, and the statistical analysis of the data will be updated to include the new data sets. In addition, we will run some filtration experiments to determine the relative contribution of organisms smaller than 1 μm to the primary productivity of the lake.

WATER RESOURCES MANAGEMENT PLANNING AT GREAT BASIN NATIONAL PARK

Principal Investigators: Gary Larson
Cooperative Park Studies Unit
Oregon State University

William J. Liss
Department of Fisheries and Wildlife
Oregon State University

Ruth Jacobs
Cooperative Park Studies Unit
Oregon State University

Objectives:

1. Prepare a water resources management plan.

2. Develop an aquatic monitoring program.

Progress: A proposal was prepared and accepted by the park and the NPS Water Resources Division. One visit was made to the park by Ruth Jacobs to assess park needs and logistical requirements for the program.

Plans for next year include: 1) begin classifying park streams, 2) site visit by the principal investigators, and 3) site visits by selected aquatic experts.

LIMNOLOGICAL STUDIES OF SURPRISE LAKE ANIAKCHAK NATIONAL MONUMENT

Principal Investigators: Will Cameron and Gary Larson
Cooperative Park Studies Unit
College of Forestry
Oregon State University

Objectives:

1. Develop a limnological data base on Surprise Lake.
2. Examine whether the warm springs affect the ecology of the lake.
3. Describe the limnological characteristics of the inlet streams of Surprise Lake.
4. Develop a long-term limnological monitoring program.

Progress: Limnological studies of the lake were conducted in the summer of 1988 and in August 1989. Physical-chemical-biological samples were collected at several stations in the lake--at cold and warm springs and the inlet streams. Biological samples include phytoplankton, zooplankton, bottom fauna and fish. A draft final report entitled "Baseline Inventory of the Aquatic Resources of Aniakchak National Monument, Alaska," was submitted for informal review.

Plans for next year include: 1) completion of the final report and prepare a paper for submission to a peer reviewed scientific journal.

PROJECT SUMMARIES:

APPLICATION OF SCIENCE

FISHERIES AND AQUATIC SYSTEMS

Workshop Coordinators: Gary Larson and Ruth Jacobs
Cooperative Park Studies Unit
Oregon State University

Date: Offered as Requested

Objectives: Instruction includes extensive lectures and discussions combined with field trips to demonstrate field techniques and "on-site" issues and problems. The program is presented by scientists and resource managers from Oregon State University, U.S. Forest Service, Oregon State Department of Fish and Wildlife and the National Park Service. The course has one of two aspects depending on the background of the participants. One course emphasizes the basic elements of fisheries and aquatic sciences for those with limited experience in the fields. The other course is structured to meet the field and technical needs of professional fisheries and aquatic biologists. The former was offered in 1985, 1987, and 1989, the latter in 1987.

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G. Larson - Northwest Scientific Association. "Water quality of glacial and nonglacial streams in Mount Rainier National Park."

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