Proceedings of the
First Biennial Conference

of

RESEARCH IN CALIFORNIA'S NATIONAL PARKS

University of California
Davis, California
September 9-10, 1982

Sponsored by: National Parks Service, Cooperative Park Studies Unit,
University of California, Institute of Ecology
and the Public Service Research and Dissemination Program

AUTHOR: VAN RIPER, CHARLES, III
DATE: 1983

PROCEEDINGS

of the

FIRST BIENNIAL CONFERENCE

of

RESEARCH IN CALIFORNIA'S NATIONAL PARKS

Edited by

Charles van Riper III (CPSU and Department of Zoology, University of California, Davis)

Lynn D. Whittig (Department of Land, Air, and Water Resources, University of California, Davis)

Marsha L. Murphy (CPSU, University of California, Davis)

Sponsored by

Cooperative National Park Resources Studies Unit
Institute of Ecology
Public Service Research and Dissemination Program

Hosted by

University of California, Davis

Published—December 1983 at the University of California, Davis, CA 95616

FOREWARD

The papers published in this report were selected from the 75 papers and 14 posters presented at the First Biennial Conference of Research in California's National Parks. The Conference was held at the University of California, Davis, California, on 9-10 September 1982, and was sponsored by the Cooperative National Parks Resources Studies Unit, the Institute of Ecology, and the Public Service Research and Dissemination Program at the University of California, Davis.

The University of California and the National Park Service executed a Master Memorandum of Understanding in May 1979 that provided for the establishment and operation of the University of California Cooperative National Parks Resources Studies Unit (CPSU/UC) as an affiliate of the Institute of Ecology on the Davis Campus. The CPSU/UC at Davis serves as the focal point for coordination of research and studies conducted under the UC/NPS Cooperative Agreement, and acts as a liaison between UC scientists attempting to answer questions the NPS resource managers might have. In holding to the Cooperative Agreement charge, biennial conferences were initiated in 1982 in an effort to facilitate information exchange between scientists and NPS resource managers. The theme of the Conference was *The Integration of Research into NPS Resource Management Decisions,* and will continue to be the theme of future conferences, the next of which is to be held at UC Davis in the fall of 1984.

This first conference consisted of an opening keynote address by Dr. Roderick Nash, UC Santa Barbara, who talked on historical perspectives of the National Park Service. This was followed by a 4-person panel composed of a university professor (Dr. Phillip Rundel), an NPS research scientist (Gary Davis), an NPS superintendent (Boyd Evison), and an NPS regional Chief Scientist (Dr. Donald Field). Each panel member presented their insights into the problems associated with the integration of research results into NPS resource management decision making. This was followed by a discussion and question session moderated by the panel chairman, Dr. Geoffrey Wandesforde-Smith from UC Davis. The contributed papers and posters were divided into four broad sections: 1) studies dealing with the physical sciences; 2) those dealing with floristic studies; 3) those concerning faunistic studies; and 4) studies dealing with the social sciences. The final session of the conference was devoted to synthesizing the topics covered under the various sessions. This panel was chaired by Dr. David Parsons, and consisted of NPS (Dr. Dennis Fenn, Dr. Jan van Wagtendonk, James Mills, William Ehorn), USGS (Dr. Michael Shulters), and UC (Dr. Daniel Anderson) personnel.

The conference and this proceedings are a direct result of the efforts provided by numerous institutions, agencies, and individuals. In the planning of the conference, Zackary O'Donnell assisted in the much needed work with meeting arrangements, and Sharon Lynch provided help in putting the Conference packets together. Christine Robinson, Sandra van Riper, and Betty Whittig all contributed many hours at the registration desk. During the conference Christopher Asay, William Davis, and Anthony Robinson coordinated the poster and film sessions and maintained continuity of slide projections during the paper sessions. We thank Kelly Carner and Paula Sullivan for their scrutiny of details in typing the manuscript and Theresa Carson for editing the literature cited section of this Proceedings. Dr. Dennis Fenn and Howard Chapman of the National Park Service, and Noreen Dowling of the Public Service Research and Dissemination Program provided impetus and support at every stage.

Financial support for publication of the Proceedings was provided by the National Park Service, and through grants from the Institute of Ecology and the Public Service Research and Dissemination Program at the University of California, Davis. We are deeply indebted to all the talented individuals who gave their valuable time to seeing this conference through to the publication stage.

Charles van Riper III

Lynn D. Whittig

Marsha L. Murphy

LIST OF CONTRIBUTORS

Abbas, B. School of Veterinary Medicine, Univ. of California, Davis, CA 95616

Anderson, D. G. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

Asay, C. E. Graduate Group in Ecology, 2146 Wickson Hall, Univ. of California, Davis, CA 95616

Babcock, E. M. Redwood National Park, P.O. Box 36, Orick, CA 95555

Baltz, D. M. Department of Wildlife and Fisheries Biology, Univ. of California, Davis, CA 95616

Behymer, D. Wildlife Investigations Laboratory, Calif. Department of Fish and Game, 1701 Nimbus Rd., Suite D, Rancho Cordova, CA 95670

Blair, N. T. Redwood National Park, 1111 Second Street, Crescent City, CA 95531

Brown, R. A. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

Considine, K. A. 7431 River Rd., Oakdale, CA 95361

Cooke, W. B. 1135 Wilshire Court, Cincinnati, OH 45230

Davenport, D. R. California Department of Fish and Game, P.O. Box 47, Yountville, CA 94559

Davis, W. E. Graduate Group in Ecology, 2146 Wickson Hall, Univ. of California, Davis, CA 95616

Dawson, K. J. Department of Environmental Design, Univ. of California, Davis, CA 95616

Delgado, J. P. Golden Gate NRA, Building 201, Fort Mason, San Francisco, CA 94123

Duriscoe, D. M. Sequoia and Kings Canyon National Parks, Three Rivers, CA 93271

Field, D. R. Pacific Northwest Region, National Park Service and College of Forest Resources, Univ. of Washington, Seattle, WA 98195

Giles, K. D. 6509 Seville, Goleta, CA 93117

Gogan, P. Univ. of California, Berkeley, CA 94720

Grubbs, D. E. Department of Biology, Calif. State Univ., Fresno, CA 93740

Hagans, D. K. Redwood National Park, P.O. Box 36, Orick, CA 95555

Harrington, J. M. Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

Hatzopoulos, J. N. School of Engineering, Calif. State Univ., Fresno, CA 93740

Hektner, M. M. Redwood National Park, P.O. Box SS, Arcata, CA 95521

Hofstra, T. D. Redwood National Park, P.O. Box SS, Arcata, CA 95521

Howell, J. A. Golden Gate NRA, Building 201, Fort Mason, San Francisco, CA 94123

Jessup, D. A. Wildlife Investigations Laboratory, Calif. Department of Fish and Game, 1701 Nimbus Rd., Suite D, Rancho Cordova, CA 95670

Keller, E. A. Dept. of Environmental Studies and Geological Sciences, Univ. of California, Santa Barbara, CA 93106

Klein, R. D. Redwood National Park, P.O. Box 36, Orick, CA 95555

Kveton, K. J. Redwood National Park, P.O. Box 36, Orick, CA 95555

LaHusen, R. G. Redwood National Park, P.O. Box 36, Orick, CA 95555

Larson, J. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

Lenihan, J. M. Redwood National Park, P.O. Box SS, Arcata, CA 95521

Lennox, W. S. Redwood National Park, P.O. Box SS, Arcata, CA 95521

McKeon, J. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

McLeod, D. Calif. Department of Fish and Game, Eureka, CA 95501

Martin, R. W. Redwood National Park, P.O. Box 36, Orick, CA 95555

Mastrogiuseppe, R. J. Redwood National Park, P.O. Box 36, Orick, CA 95555

Milestone, J. F. Golden Gate NRA, Ocean District, Building 201, Fort Mason, San Francisco, CA 94118

Moyle, P. B. Department of Wildlife and Fisheries Biology, Univ. of California, Davis, CA 95616

Popenoe, J. H. Redwood National Park, P.O. Box 7, Orick, CA 95555

Reed, L. J. Redwood National Park, P.O. Box 36, Orick, CA 95555

Ricks, C. L. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Geology, Oregon State Univ., Corvallis, OR 97331

Robertson, D. A. Department of English, Univ. of California, Davis, CA 95616

Salamunovich, T. Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Fisheries, Humboldt State Univ., Arcata, CA 95521

Schroeder, M. T. Redwood National Park, P.O. Box SS, Arcata, CA 95521

Seltenrich, M. S. Calif. Tahoe Regional Planning Agency, P.O. Box 11467, South Lake Tahoe, CA 95702

Sproul, F. T. Land Restoration Associates, Box 3120 Hillcrest Station, San Diego, CA 92103

Sugihara, N. G. Redwood National Park, P.O. Box SS, Arcata, CA 95221

van Wagtendonk, J. W. Yosemite National Park, El Portal, CA 95318

Vezie, D. J. Redwood National Park, P.O. Box 36, Orick, CA 95555

Vogler, D. R. Forest Pest Management, USDA Forest Service, San Francisco, CA 94111

Wallner, D. W. Resources Management, Sequoia-Kings Canyon National Parks, Three Rivers, CA 93271

Warner, T. E. Resources Management, Sequoia-Kings Canyon National Parks, Three Rivers, CA 93271

Weaver, W. E. Redwood National Park, P.O. Box 36, Orick, CA 95555

Wilson, D. S. Department of American Studies, Univ. of California, Davis, CA 95616

Wood, R. Calif. Department of Fish and Game, Eureka, CA 95501

TABLE OF CONTENTS

PHYSICAL SCIENCES

OZONE INJURY TO PONDEROSA AND JEFFREY PINES IN SEQUOIA-KINGS CANYON NATIONAL PARKS

T.E. Warner, D.W. Wallner, D.R. Vogler[1]

ABSTRACT

A survey of ponderosa and Jeffrey pines between 4,000 and 8,000 ft elevation in Sequoia-Kings Canyon National Parks has confirmed the presence of foliar ozone injury symptoms on approximately 37% of the trees sampled. Installation and initial evaluation of permanent 10-tree plots began in 1980 and will be completed in 1982. Sample design and methodology are patterned after similar surveys being conducted by the US Forest Service in California. Approximately 55 plots will be established. Objectives are to identify the current distribution and intensity of injury to two indicator species and to provide baseline data for future reference. Results to date indicate individual tree scores ranging from no to very severe (on current year needles) symptoms. Plot ratings range from no symptoms to severe (on second year needles). Current overall mean injury level rating is slight (fourth year needles).

INTRODUCTION

Ozone injury to pines in the southern Sierra Nevada was first identified at McKenzie Ridge just west of Grant Grove, Kings Canyon National Park, in 1970 (Miller and Millecan 1971). This was 8 yrs after similar symptoms on pines in Southern California were identified as being caused by ozone damage (Miller et al. 1963). Since then, several authors (Williams et al. 1977, Vogler 1979) have described symptoms on pines in Sequoia-Kings Canyon National Parks. Prior to this project however, no permanent sample plots had been established in the parks, although several had been established on adjacent Forest Service lands.

Ozone injury to ponderosa and Jeffrey pines, the two most sensitive conifer species in the parks, is characterized by a diffuse chlorotic mottle affecting progressively younger needles and is distinguished from that caused by other biotic/abiotic sources of injury, the most noticeable being weather fleck caused by freezing water or ice crystals. Other symptoms include tip necrosis, reduced needle length, reduced needle retention, excessive branch mortality, reduced height and diameter growth, and eventually death of the tree.

This paper summarizes work to date on a project initiated in 1980 to establish permanent trend plots to determine the severity and distribution of ozone injury to ponderosa and Jeffrey pines in Sequoia-Kings Canyon National Parks. Besides current injury status, data from these plots are intended to be used as a baseline for future comparison.

METHODS

Sample design was the same as that utilized by the U.S. Forest Service in an earlier survey (Pronos et al. 1978). Potential plot sites were originally identified on a 1:125,000 scale map of the Parks wherever roads or trails intersected 4000, 5000, 6000, 7000 and 8000 ft contour lines. These intersections were then transferred to 15 ft USGS topographic maps. A total of 267 potential sites were thus identified. These were then initially screened by comparison with maps of the same scale showing the five major vegetation zones of the Parks: chaparral/oak woodland; mixed-conifer; sequoia mixed-conifer; white/red fir; and subalpine/ alpine. Those sites located in the chaparral/oak woodland and

Forestry Technicians, Resources Management, Sequoia-Kings Canyon National Parks, Three Rivers, CA 93271

[1]Forest Pathologist, Forest Pest Management, USDA Forest Service, San Francisco, CA 94111

subalpine/alpine were immediately eliminated. Those in the mixed-conifer, sequoia mixed-conifer, and white/red fir were further screened by comparison with 4 in = 1 mi vegetation type maps from typed 1:15,840 black and white aerial photographs.

Plot sites were visited on the ground and considered valid if 10 ponderosa and/or Jeffrey pines were found within an area one chain (66 ft) by six chains (396 ft) on each side of and parallel to the road or trail (Fig. 1). The near edge of the plot in most cases was separated from the edge of the road or trail by 1/2 chain (33 ft). Minimum size of the trees was 4 in dbh; the maximum size restriction was that the tree must have a prunable live crown within 32 ft (length of pruning pole) of the ground. Within each plot, various site and tree characteristics were observed or measured. These data included besides ozone injury level, needle retention and length, dbh (to nearest 0.1 in), crown position, crown ratio, associated pests, plot elevation, aspect, slope percent, and stand composition, density and age.

Pest data were collected to avoid confusing possible synergistic effects or similar symptoms associated with biotic agents. Trees with a dwarf mistletoe rating of 4-6, or an Elytroderma needle cast rating of 7-10, for instance, were not sampled.

Sampling entailed pruning several needle bundles from various locations in the lower crown of each tree and examining the individual needles to determine the extent of injury. Ozone symptoms were evaluated and rated using the scoring system developed by the U.S. Forest Service (Pronos et al. 1978) based on the severity of chlorotic mottle present on the foliage. Trees were given a score between zero and four, the number indicating how many years of retained needles were healthy or free of mottle. Trees with no symptoms and trees with symptoms on fifth or older needles received scores of four. The 10 individual tree scores were averaged to arrive at a plot score.

Since these are permanent plots which need to be relocated on a regular basis, plots and sample trees were identified by small (2-3 in diameter) paint dots, 1 ½ in aluminum tags, and plastic flagging.

RESULTS

Frequencies of mean plot scores and individual tree scores appear in Figures 2 and 3 respectively. The majority (67%) of plot scores fell in the slight (3.0-3.9) and moderate (2.0-2.9) range. While roughly 81% (42) of the plots exhibited symptoms, only 37% of the trees did.

Plots were about equally distributed at the 6,000 to 8,000 ft elevations (Table 1). The greatest number (29) of plots are located in the Kaweah River drainage followed in descending order by the Kings (18) and Kern (5) (Table 2). Final data summarization and analysis is pending completion of this season's fieldwork. To date, 52 out of the 55 plots established since 1980 have been evaluated. Seventeen plots were established in 1980, 20 in 1981, and 18 in 1982. Fourteen of those plots established in 1980 were evaluated that year; 18 plots were evaluated in 1981 and 20 plots have been evaluated so far in 1982. Besides the three established plots left to be evaluated, there are six potentially valid in-type plot locations to be field-checked and possibly established/evaluated. By the culmination of 1982, all of the plots will have been established and initially evaluated.

DISCUSSION

Preliminary analysis of data so far collected indicates a similar level of injury to that reported elsewhere in the Sierra Nevada Mountains (Pronos et al. 1978, Pronos and Vogler 1981, Allison 1982), namely, 60-83% of the plots but only 19-30% of the trees exhibited symptoms. Also, severity of injury is similar with 59-83% of the plots with slight or moderate symptoms.

It is unlikely at current levels of injury that growth reduction, direct mortality, or community structure changes are taking place; however, these questions require further research.

Problems encountered during the course of the project included the question of whether or not to consider plots on unmaintained trails, lack of a suitable pruning pole for backpacking and the visual impact of marking plots along some high-use trails. It was decided to establish plots on unmaintained as well as on maintained trails if the trails were locatable in the field (sometimes a problem in itself). Plots in recently burned areas were omitted, however. Criticism of marking techniques along some wilderness trails led to modification of the previously described methods in some cases. An eight-piece pole which collapses into two 4 ft sections was constructed for backcountry plots.

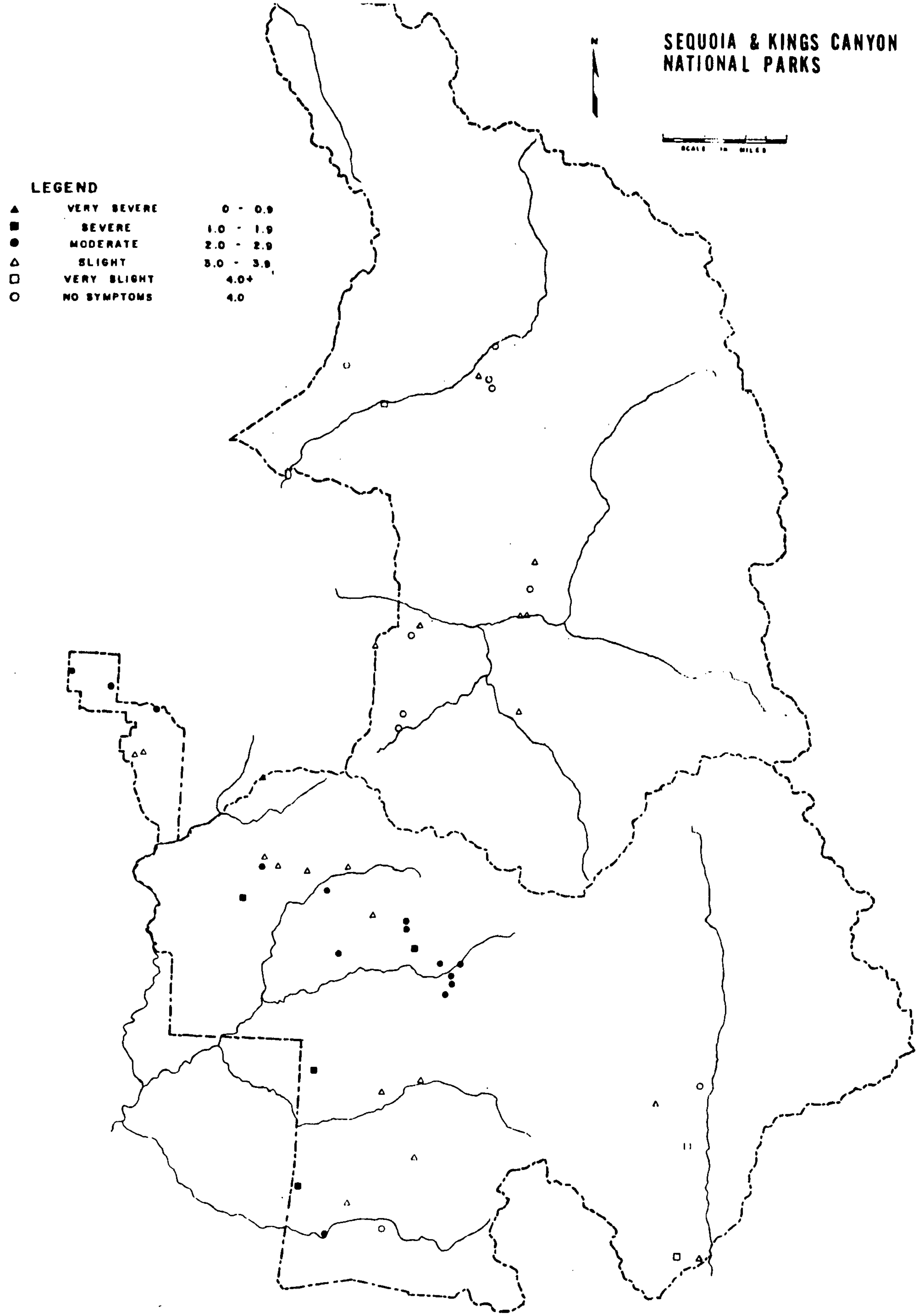


Figure 1

Map Showing Location and Rating of 52 Plots Evaluated as of September 9, 1982

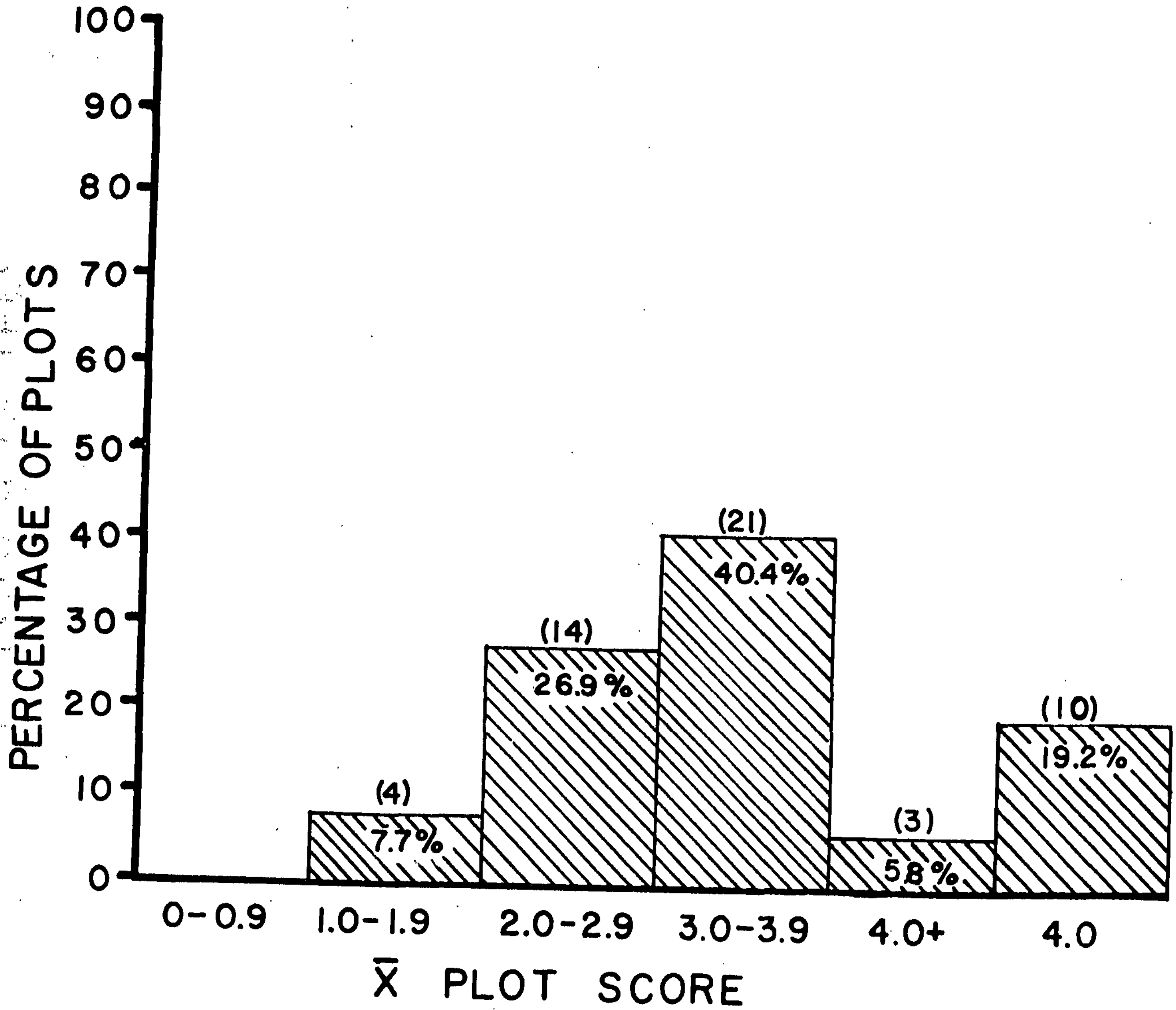


Figure 2

Histogram showing frequency of mean plot scores. Rating system: 0-0.9—very severe; 1.0-1.9—severe; 2.0-2.9—moderate; 3.0-3.9—slight; 4.0+—very slight; 4.0—no symptoms.

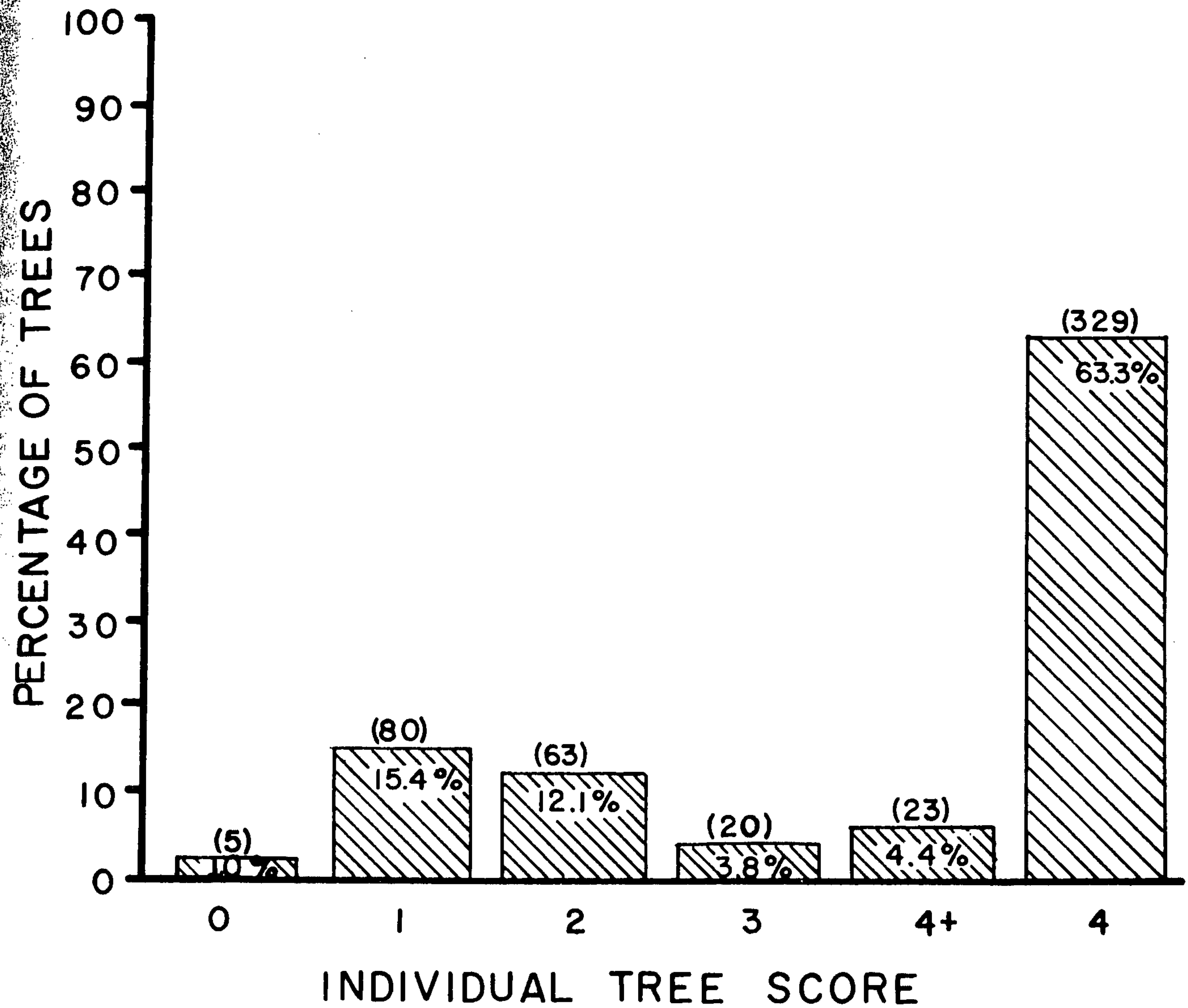


Figure 3

Bar graphs showing frequency of individual tree scores. Rating system: 0—current year; 1—second year; 2—third year; 3—fourth year; 4+—fifth and older; 4—none.

Table 1

Plot Ratings by Elevation

Elevation	V. Severe	Severe	Plot Rating Moderate	Slight	V. Slight	No Symptoms	Total
4000 ft	0	0	0	0	0	0	0
5000 ft	0	2	1	3	1	0	7
6000 ft	0	2	7	4	0	2	15
7000 ft	0	0	5	7	0	2	14
8000 ft	0	0	1	7	2	6	16
Totals	0	4	14	21	3	10	52

Table 2

Plot Ratings by Drainage

Drainage	V. Severe	Severe	Moderate	Plot Rating Slight	V. Slight	No Symptoms	Total
Kaweah	0	4	12	12	0	1	29
No. Fork	0	1	1	4	0	0	6
Marble Fork	0	0	1	3	0	0	4
Middle Fork	0	1	8	1	0	0	10
East Fork	0	1	1	3	0	0	5
South Fork	0	1	1	1	0	1	4
Kern	0	0	0	2	2	1	5
Kings	0	0	2	7	1	8	18
Middle Fork	0	0	0	1	1	4	6
South Fork	0	0	2	6	0	4	12
San Joaquin	0	0	0	0	0	0	0
Totals	0	4	14	21	3	10	52

CONCLUSIONS

The extent and distribution of ozone injury to pines in the National Parks not only provides an indication of the current status of the problem, but also furnishes a baseline against which to measure future change. Since the source of the problem, photochemical smog, is located outside National Park boundaries, this information has few direct implications in terms of National Park management. It does, however, provide a basis for gauging the effect of any future modifications of air quality standards, or increased urbanization or industrialization of the California Central Valley.

MANAGEMENT RECOMMENDATIONS

Following are suggestions for future work to be conducted by the National Park Service: 1) Re-evaluate plots already established on a 3-yr interval, preferably all on the same year, if logistically possible. 2) Obtain similar information from Yosemite National Park to complement that being collected on National Forest lands. 3) Establish large, permanent trend plots in selected locations in each of the major airsheds in the Parks. 4) Attempt to correlate damage (growth reduction) with injury level on the most severely affected plots.

ACKNOWLEDGEMENTS

Dan Duriscoe's contribution of time and creative genius resulted in the design and construction of a backpack pruning pole, while Jack Fiscus assisted with its construction. Many people assisted with the fieldwork, including: Dan Duriscoe, Mitch Fong, Tim McLaughlin, Mona Selph, Betty Rubin, Diane Ewell, Bill Reisland, Amy Eisenberg, Bill Buchholz and Calvin Hom. Nate Stephenson assisted with preliminary project preparation. Finally, John Pronos, Dick Smith and other members of the Forest Pest Management staff in San Francisco, provided assistance in the form of training and other support.

AN AIR QUALITY MONITORING PLAN FOR SEQUOIA AND KINGS CANYON NATIONAL PARKS

D.M. Duriscoe

ABSTRACT

Sequoia and Kings Canyon National Parks are subjected to significant quantities of atmospheric pollution owing to their geographic and topographic position in the south-central Sierra Nevada of California. Pollutants originating in the urban, industrial, and agricultural areas of the San Joaquin Valley are swept up the west slope of the Sierra by both general and localized circulation patterns. The extent to which these Parks are affected by these pollutants is either partially or totally unknown. A program of air quality monitoring for these Parks is needed to identify possible threats to park resources and to determine relationships which might exist between ambient pollutant concentrations and observed changes in ecosystem parameters. Monitoring is needed in five areas: 1) acid deposition, 2) sulfur dioxide, 3) visibility, 4) ozone, and 5) particulates. Cooperation with other agencies in this monitoring effort by the National Park Service has provided a means of acquiring the necessary equipment and technical support to accomplish the task. The data obtained should prove valuable to researchers and park managers.

INTRODUCTION

The need for a comprehensive air quality monitoring program as part of resources management at Sequoia and Kings Canyon National Parks has become increasingly apparent in recent years. A growing interest in acid deposition in California is evident in the literature (Bradford et al. 1981, McColl 1981, Melack et al. 1983, Williams 1978). The adverse effects of ozone on yellow pines in the Sierra Nevada has been well documented (Pronos and Vogler 1981, Williams 1980, Miller et al. 1972). Scenic vistas within the parks have been identified and the quality of the air within these viewsheds is a prime resource. Our National Parks, particularly those like Sequoia and Kings Canyon, that have been given the status of biosphere reserves should serve as a natural baseline for the rest of the world. If the pristine nature of these parks is compromised by pollution, they are no longer valuable in this regard. The monitoring of ambient atmospheric conditions is therefore fundamental to the management of these areas. Any man-induced change may then be identified and quantified, and any deviations which might be observed in physical, chemical, or organic systems may be correlated with these changes.

Under the Clean Air Act and its amendments, Sequoia and Kings Canyon are designated Class I areas—areas of pristine or unspoiled air quality. They are thus subject to the strictest standards; there should be no increases in ambient levels of pollutants. Monitoring of air quality is necessary to verify compliance with these standards. Should any violations be observed within these national parks, their identification would be cause for immediate concern by the California Air Resources Board and all Californians. Only by the systematic collection of factual data can such an identification be made.

The major objectives of an air quality monitoring plan for these parks are: 1) to detect any significant deterioration in the parks' air quality through long-term monitoring of background concentrations of pollutants; 2) to relate levels of air pollution observed to existing or potential levels of resource damage; and 3) to make the data available to regulatory agencies, the scientific community and the public. To achieve these objectives an air monitoring survey design must be devised.

Sequoia and Kings Canyon National Parks, Three Rivers, CA 93271

METHODS

The first step in developing an air quality monitoring plan to define monitoring needs is to identify the pollutants which pose a threat to park resources. One of the most obvious effects of pollution is the deterioration of visibility. John Muir (1894) described the view of the Sierra from Pacheco Pass in 1868 as follows: "At your feet lies the great Central Valley . . . extending north and south as far as the eye can see. Along its eastern margin rises the mighty Sierra miles in height . . . rising like a smooth cumulus cloud in the sunny sky." Today, one is lucky to see the peaks of the Great Western Divide protruding from a layer of smog and dust. The enabling legislation that created the parks stated ". . . to protect the grandest scenery of America and the world" (Senate Report No. [illegible] 65th Congress, 3rd Session). Yet, all too often this grand scenery is barely visible because of the obscuring clouds of polluted air. Vistas which are integral to the visitor's experience within Class I areas are protected from future degradation even if they overlook areas outside the parks, such as the Owens Valley or the San Joaquin Valley. It is the parks' responsibility to monitor the transparency of the air at and near these viewpoints so that any deterioration in the quality of the view may be documented.

Ozone is one of the major pollutants that has received attention in these parks prior to the initiation of the resources management air quality program. Transport of ozone up the mountains from valley sources has been well documented (Miller et al. 1972, Unger 1978, Williams et al. 1977, Williams 1980). Data indicates that the highest ozone concentrations may be expected at altitudes of from 1,500 to 6,000 ft in the valleys during the summer. The U.S. Forest Service has been monitoring ozone at selected sites in Sequoia and Sierra National Forests and Sequoia National Park since 1976. Values in excess of the state primary standard of 10 parts per hundred million (pphm) were consistently recorded at these sites (Pronos and Vogler 1981). The documented ozone-induced damage to yellow pines in these National Parks and forests demonstrates the significance of this pollutant and the need for its monitoring (Pronos and Vogler 1981, Wallner 1981, Warner et al. 1982).

In July 1980, Sequoia National Park became part of the National Atmospheric Deposition Program's (NADP) monitoring network with the installation of a station at Giant Forest. A rain gauge and a special sampler which collects incident precipitation have been operating since that time. A more complete array of instruments and a greater number of sample sites are planned. This will lead to a better understanding of dry deposition, both gaseous and particulate, acidity in snowfall, and the distribution of acid deposition over a large altitudinal gradient. This monitoring effort is a vital part of a 10-year study (Parsons and Graber 1981) on the effects of acid rain on Sequoia National Park ecosystems.

Particulate matter in the air is another important area of concern. The monitoring program now includes two high-volume air samplers and a third is planned. The samplers draw air through glass filters upon which atmospheric dust is collected for analysis. Also, samplers designed to collect fine particulates would be useful in assessing sulfur and nitrogen oxide concentrations in the parks.

With the important pollutants identified, suitable sample sites must be selected. Meteorology and topography have direct influences on the surface circulation patterns which affect atmospheric pollution concentrations. Sequoia and Kings Canyon National Parks are located in the San Joaquin Valley Air Basin, an area which experiences temperature inversions most of the year with corresponding stagnant air. The height of the inversion layer often dictates the point at which trapped pollutants will impinge upon the mountain slope. However, upvalley winds, common in the afternoon during the summer, draw polluted air upstream far above the top of the inversion, resulting in fumigation of the headwaters of east-west trending canyon systems, particularly the Kaweah River Gorge (Fig. 1).

Sequoia and Kings Canyon contain parts of four drainage basins: the Kaweah, Kern, Kings, and San Joaquin (Fig. 2). The Kaweah is the most exposed to valley pollutants, owing to its relatively straight east-west canyon system and proximity to valley sources. Site locations should be spaced over the altitudinal gradient within the canyon, from the park boundary to the timberline; in the Kaweah this encompasses altitudes of between 1,400 and 10,000 ft. The Kings River basin is somewhat more isolated from valley sources, but Cedar Grove is a sensitive area, with topography somewhat

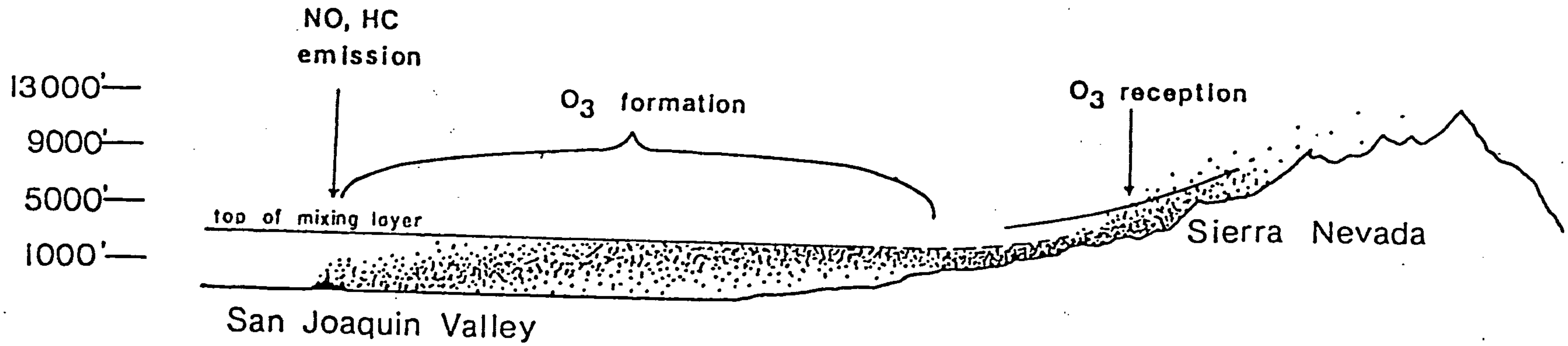


Figure 1

Pollutant Transport to the Sierra Nevada

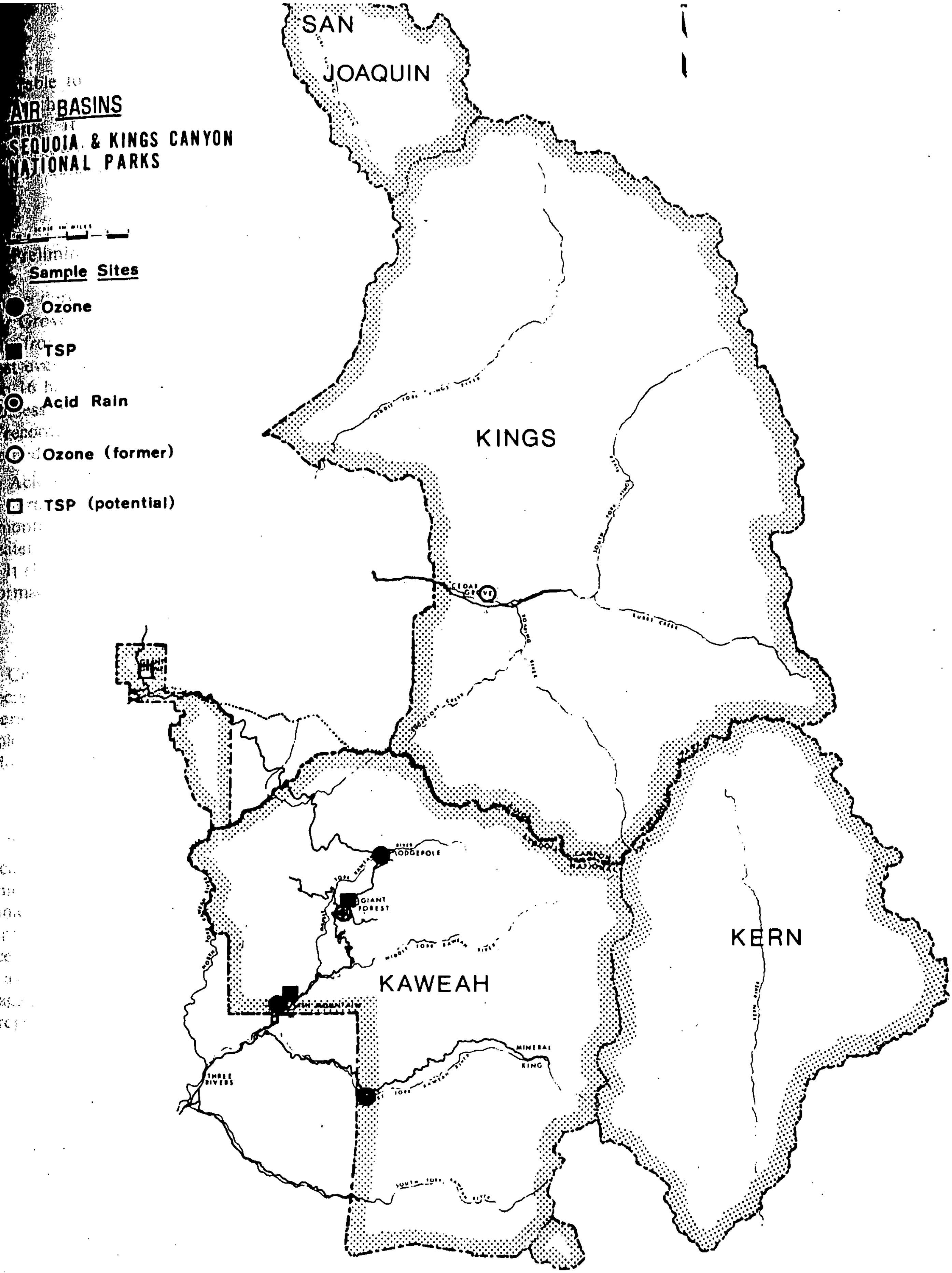


Figure 2

Air Monitoring Sample Sites as of September 1982

comparable to Yosemite Valley. The San Joaquin and Kern basins include only isolated backcountry areas in these Parks. These areas would not be expected to receive high concentrations of gaseous pollutants. It should be noted, however, that acid deposition has been shown to have the potential to be transported over long distances, and monitoring of this phenomenon throughout the entire park should be considered of importance.

RESULTS AND DISCUSSION

Preliminary results from the past two season's monitoring efforts reveal some interesting facts. Ozone levels in the Kaweah drainage attained concentrations twice that experienced in the Kings drainage during the summer of 1981. Maximum hourly averages of from 5-7 pphm were recorded at Cedar Grove while values in the range 10-14 pphm were recorded at Lodgepole. Fig. 3 summarizes the results from the Lodgepole and Ash Mountain sites. Ozone levels exceed the state standard of 10 pphm almost every day at Ash Mountain; maximum hourly averages in the 12-15 pphm range are common. Up to 16 hrs of the 24-hr day experience violations of this standard at this location. Lodgepole appears to possess slightly cleaner air; the incidence of hourly concentrations exceeding 10 pphm is about half that recorded at Ash Mountain and the number of hours per day to which these high numbers are attributed is far less.

Acid precipitation has been recorded at the Sequoia NADP station. Fig. 4 compares observed pH with nitrate and sulfate concentrations directly. Ion concentrations are highest in the late summer and fall months, possibly as a result of drier surface conditions in the valley during these times, resulting in a greater amount of airborne dust. Values of precipitation pH are variable, but seem to average about 5.0. It should be noted that this is not a weighted average and winter snows, which appear to be closer to normal in acidity, constitute the vast majority of the precipitation falling at this site.

CONCLUSIONS

Continued and expanded monitoring of air quality is essential if the parks' resources are to be protected. The parks can no longer be viewed as an island, and management must be conducted in cooperation with agencies outside the National Park Service. Only by providing an accurate and complete picture of the air quality in Sequoia and Kings Canyon National Parks can intelligent conclusions and decisions be made.

ACKNOWLEDGMENTS

This monitoring effort cannot be conducted without cooperation from several individuals and agencies. The California Air Resources Board has been of great assistance in providing equipment and technical support for the program. Dave Ross, D.L. Montgomery, and George Shahinian of the Technical Services Division have been especially helpful; Doug Lawson of the Research Division has also provided support. Paul Miller and Det Vogler of the U.S. Forest Service have provided valuable advice in the design of this plan. Gary Criscione of the Tulare County Air Pollution Control District has assisted in obtaining monitoring equipment. Finally, several persons on the Resources Management staff at Sequoia and Kings Canyon have provided valuable assistance in the preparation of this report; thanks to Diane Ewell, Tom Nichols, Tom Warner, and Larry Bancroft.

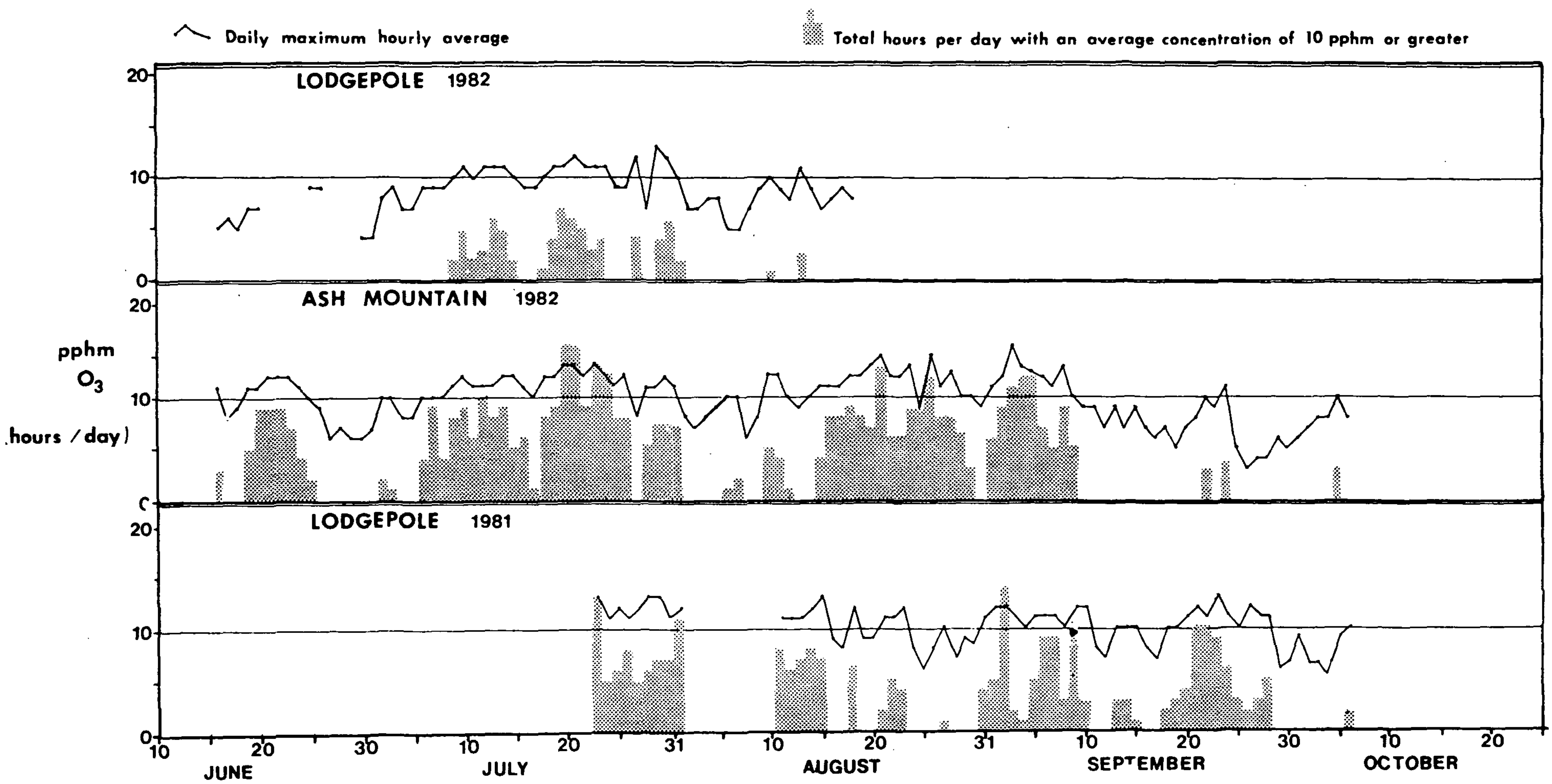


Figure 3

Ambient Atmospheric Ozone Concentration at Sequoia

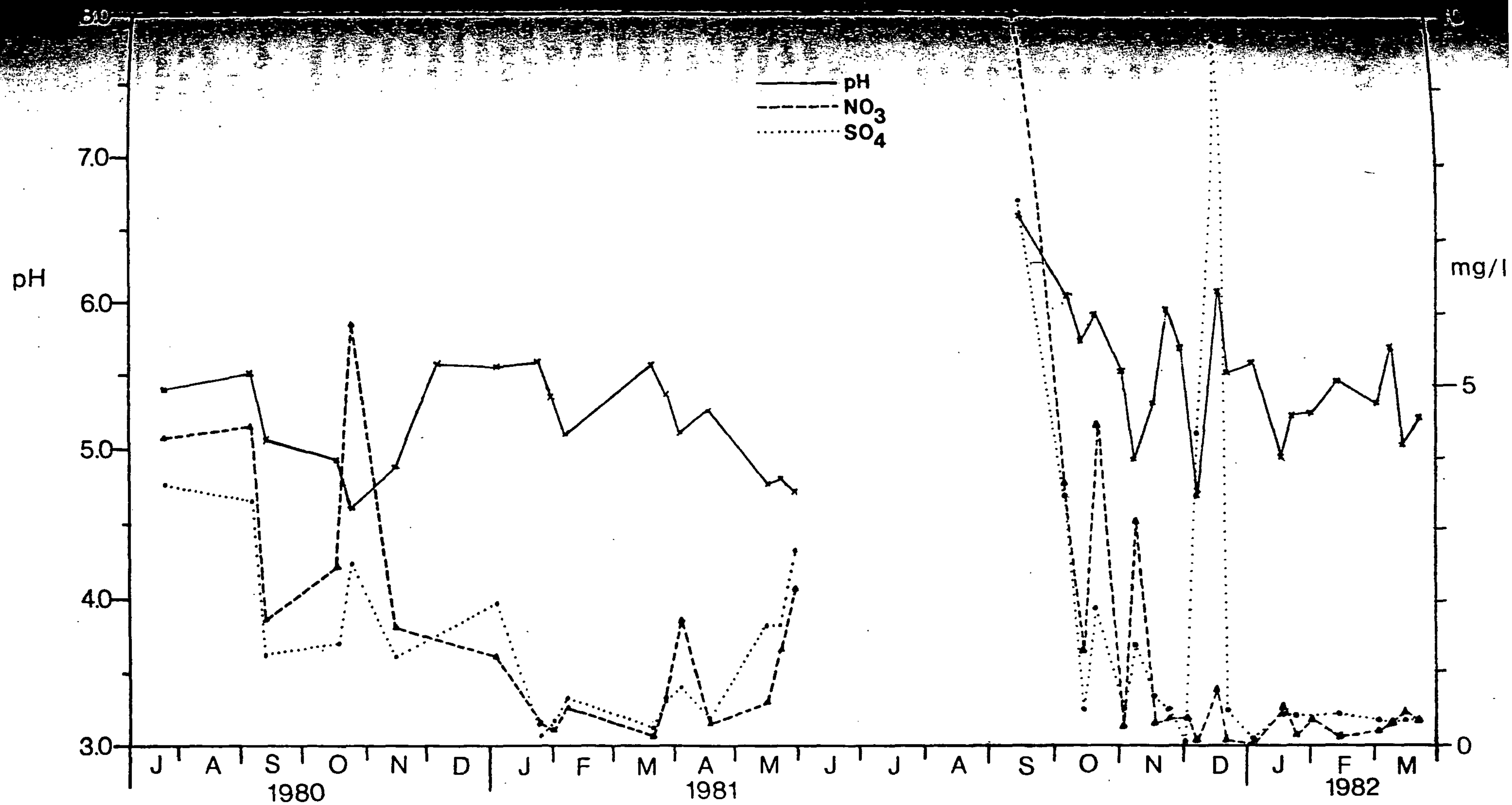


Figure 4

Precipitation Chemistry at Sequoia

TUNNEL-GULLY EROSION ON SANTA BARBARA ISLAND, CHANNEL ISLANDS NATIONAL PARK

K.D. Giles

ABSTRACT

Santa Barbara is a one square-mile volcanic island located 24 mi west of Santa Catalina. It is covered by thick Pleistocene soils that are being eroded to bedrock. A badlands has formed on the large marine terrace of the east side. One of two island peaks is deeply gullied. Previous literature has linked this erosion to normal sheetwash and surface processes. However, the morphology of these gullies is indicative of subsurface piping processes and ground water through-flow with subsequent collapse of tunnel roofs to form the present channels. The island was infested with rabbits after WW II. During drought years the introduced rabbits devastated the island vegetation. In 1959 the island was accidently burned in entirety. Similar tunnel-gully erosion in New Zealand has been attributed to large-scale burrowing by rabbits and burning of the vegetation by farmers.

INTRODUCTION

Santa Barbara Island rises abruptly from the ocean 38 mi southwest of Los Angeles and 24 mi west of its nearest neighbor Santa Catalina. It comprises an area of only one square mile (2.6 sq km) and is the smallest of the California Channel Islands (Fig. 1).

The island represents all that remains of an extinct Miocene volcano (Howell 1976, Kemnitzer 1933). Most of the basalt apparently was erupted under water. Subsequent lowering of sea level and wave action cut submarine terraces. It is on these terraces that most of the thick island soils were formed in submarine deposits. The shoreline is precipitous and beaches are rocky. Cliffs on the east side of the triangular island rise 200 ft to a broad terrace that rises gently to a north-south trending ridge connecting the high points, North Peak (573 ft) and Signal Peak (634 ft). To the west of the ridge lies Webster Point consisting of a series of progressively lower wave-cut terraces that form a peninsula (Fig. 2).

Although the island emerged millions of years ago, the entire area was again under water during the Pleistocene. It re-emerged as little as 100,000 yrs ago (the end of an ice age) and the entire island ecology has developed in that relatively short time span.

The Channel Islands ecology is unique in that it has acted as a refuge for numerous representatives of Pleistocene flora and fauna no longer found on the mainland. Despite 180 yrs of documented abuse by man, including overgrazing of sheep, dryland farming, introduction of exotic vegetation, burning, and devastation by the European wild rabbit *Oryctolagus cuniculus* this relict biota survives on Santa Barbara Island (Philbrick 1972). Resource management is aimed at reestablishment of native species.

Santa Barbara Island has suffered extensive soil erosion. Despite attempts at control, the large eastern terrace is rapidly becoming a badlands. The southeast slope of Signal Peak is deeply dissected by gullies, and erosion is evident everywhere on the island. Previous erosion control efforts have been based on the assumption that overland flow or sheetwash, rilling, and gullying have been the operant erosional processes. However, other processes may be active, specifically on the southeast slope of Signal Peak.

509 Seville, Goleta, CA 93117

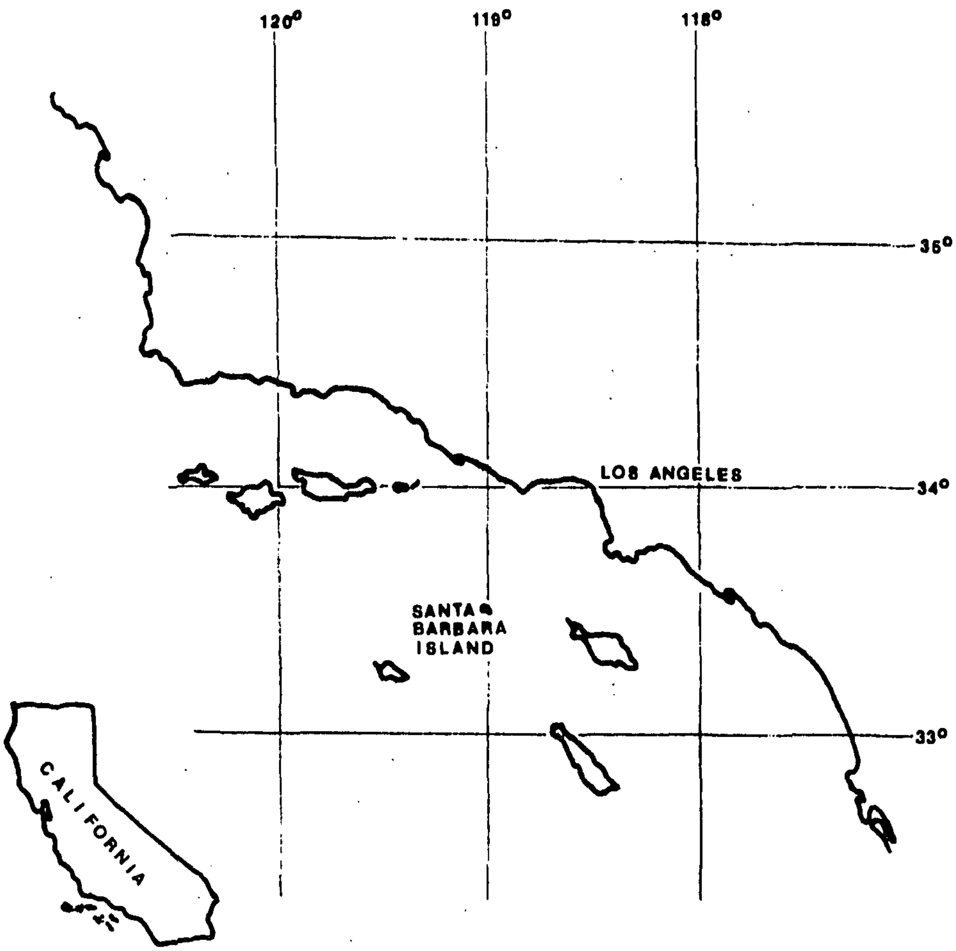


Figure 1

Location of the California Channel Islands

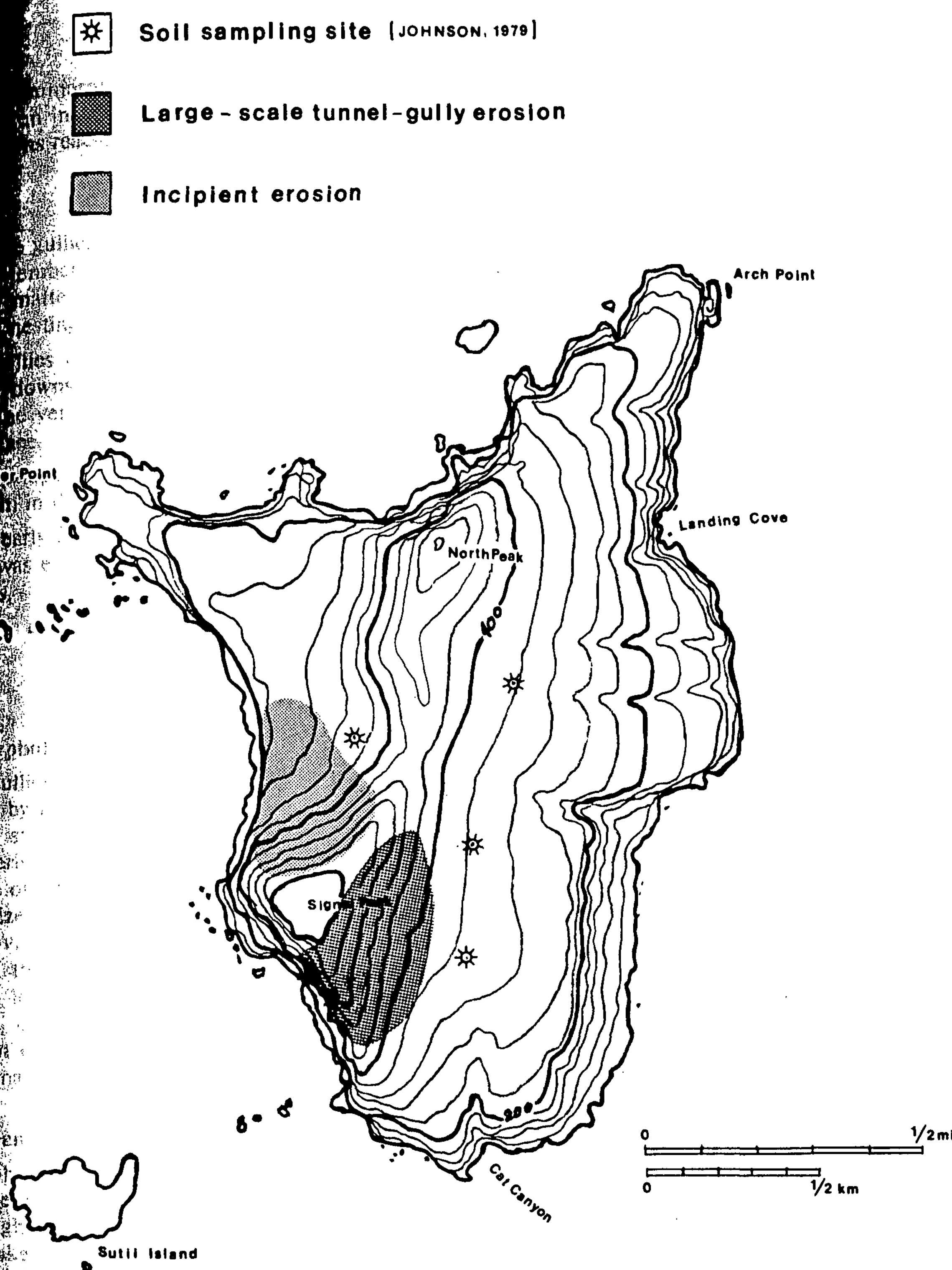


Figure 2

Santa Barbara Island, California Study Areas

METHODS

A geomorphological analysis of the erosional landforms and processes operant on Signal Peak was undertaken in the field. Geological, chemical, and historical data were correlated and used to confirm conclusions reached by geomorphological analysis.

RESULTS

The gullies on southeast Signal Peak were studied over a period of three months in July, August, and September of 1981. Slopes in this area are approximately 30° . Vegetation ranges from absent to densely matted crystalline iceplant *Mesembryanthemum* spp. to individual sueda bushes. Bare areas are used as nesting areas by gulls.

Gullies are narrow and deep, typically 1/2 - 1 m wide by 3 m deep at midslope. They trend linearly downslope. One wall is usually nearly vertical. The deepest part of the gully is flat and lies below the vertical wall. The opposite wall slopes upward at 30°-60° angles and then rises vertically to the surface.

Upslope near the slopebreak, sections of the gully are roofed and connected by tunnels as much as one m in diameter. No dendritic drainage was observed.

Nearly 25 m of recent gully-head migration was noted in two of the gullies. That the collapse was recent was evidenced by whole sections of surface soil still covered by iceplant mat lying intact in gully bottoms.

The described landforms are diagnostic of advanced tunnel-gully erosion.

DISCUSSION

Geomorphology

Gullies on slopes can develop by two different processes. Cuts and depressions in the slope can enlarge by rill flow and coalesce into channels that erode by downcutting. Gullies formed in this way may be steep-sided but have a characteristic V-shape. The drainage pattern feeding these channels is characteristically dendritic at some point upslope. Gullies may also form by subsurface erosion and the collapse of pipes and tunnels in the subsoil. Piping is the development of subsurface channels about 10 cm in size. Enlarged pipes are termed tunnels and may be fed by a system of pipes. As tunnels enlarge and move to the surface, support for the overlying soil horizons weakens, collapse occurs and gullies form at the base of the slope. The gully-head advances rapidly upslope (Morgan 1979, Gibbs 1945) because less energy is needed for water to erode the same amount of material in a pipe than on the surface. On the surface, turbulent flow occurs at Reynolds' numbers above 2,000. In a pipe, turbulent flow can occur at Reynolds' numbers of only 300-400. Eventually no direct evidence of the tunnels may remain, only the characteristic shape (Parker 1963) (Fig. 3).

Soil Chemistry

Johnson (1979) analyzed soils at four sites on Santa Barbara Island (Fig. 2). Three soil types were identified: Typic Chromoxererts, Vertic Argixerolls, and Lithic Xerorthents. All of these soils show high exchangeable sodium ion percentages (ESP). ESP ranged from 4.3 to 12.0%. High ESP has been linked to piping in clay soils with 30% or more clay (Fletcher and Carroll 1948, Thornes 1980). Heede (1971) found that piping soils in Alkali Creek, Colorado had an ESP greater than 1.0 and averaged 12.0. Non-piping soils had an ESP of less than 1.0. The high dispersability of subsoils was correlated with their high ESP and low organic carbon content in New Zealand by Laffan and Cutler (1977).

At the four soil sampling sites on Santa Barbara Island, the percentage of clay ranged from 29.0 to 60.3% at all sites, and from 49.0 to 60.3% in the SE Signal Peak area (Johnson 1979). From cation exchange capacities (Grim 1942) the clay fraction appears to be primarily illite (Davidson and Sheeler 1953). The presence in the SE Signal Peak soil of a layer at 10-40 cm depth where pH drops

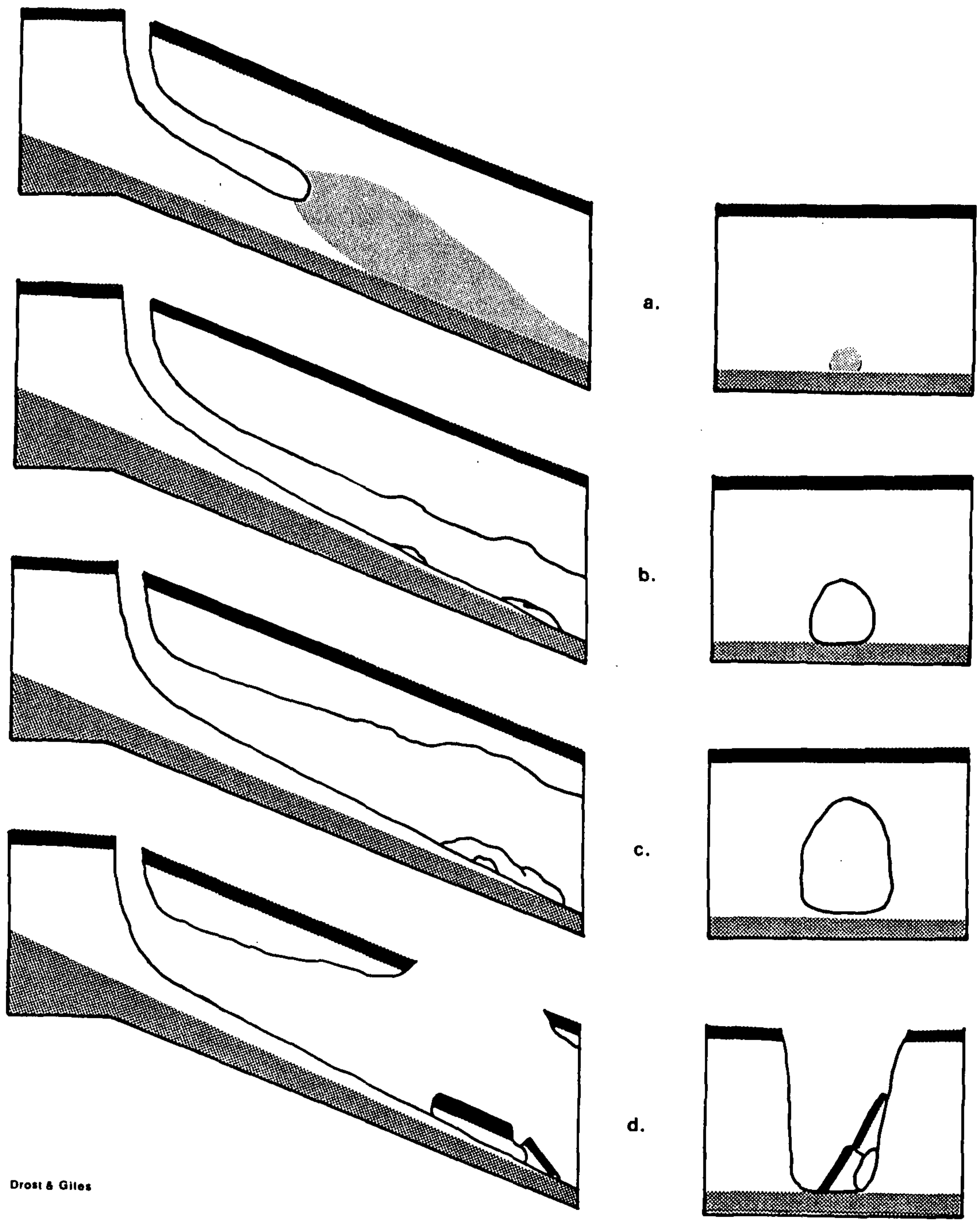


Figure 3

Tunnel-Gully Erosion Sequence

(a) Surface vegetation stripped. Soil cracks let runoff penetrate hardpan and fill burrow system. Saturated zone develops in wet season trending downslope above duripan; (b) percoline (saturated zone) emerged from soil crack or burrow exit downslope. Tunnel created as dispersed clay washes out; (c) tunnel enlarges rapidly as walls and ceiling collapse. Floor is flat above duripan; and (d) roof collapses. Eventually no direct evidence of tunnelling will remain.

significantly and saturation of hydrogen ion rises from zero to 19.0 - 30.9% may indicate the presence of a percoline or incipient pipe. At other sites the presence of hydrogen ion at depth correlates directly with a significant clay horizon (50-55%) and may represent subsurface drainage above a clay pan.

History

Denudation of soil and burrowing of hillslopes by the European Rabbit *Oryctolagus cuniculus* has been linked to tunnel-gully erosion in New Zealand (Gibbs 1945) and Australia (Downes 1946, Higginson and Emery 1972) where climate and vegetation are similar to Santa Barbara Island. The island was infested with introduced European wild rabbits from the mid-1940s until 1981. In 1953 population estimates ranged from 2000-6000 rabbits living on 1 sq mi. Much of the island vegetation was destroyed by rabbits between 1950 and 1954 (Sumner 1959).

Maps compiled from National Park Service records show that areas of rabbit warrens coincide with gully erosion (Figs. 2, 4). Furthermore, the areas of highest rabbit use are also the most deeply gullied.

Tunnel-gully erosion at an early stage was observed at the base of the north slope of Signal Peak in 1981. Comparison of maps showing the distribution of rabbits from 1952-1974 and from 1978-1979 showed that rabbits colonized the north slope after 1975 due to hunting pressure (Fig. 4). Thus, incipient tunnel-gully erosion is positively correlated with the appearance of *Oryctolagus cuniculus*.

CONCLUSIONS

□ The soils, climate and history of land use of Santa Barbara Island are all conducive to piping and tunnel gully erosion.

□ The eroded soils are relict and the same kinds of soil will not be regenerated if lost. Most of the soil material was deposited underwater on marine terraces. There may also be a loessial component deposited subaerially during glacial retreat at the end of the Pleistocene. Neither of these conditions is operant today.

□ The deep gullies of Signal Peak were formed by tunnel-gully erosion, a sub-surface process. These gullies indicate a severe disequilibrium that threatens to entirely strip the soil from affected areas.

□ Relatively recent tunnel-gully formation on the north slope of Signal Peak may be related to the activity of rabbits between 1974 and 1981.

MANAGEMENT RECOMMENDATIONS

Control of gully erosion is expensive and difficult. It is extremely important to recognize the cause of the erosion. Steps taken to treat surface erosion may actually exacerbate subsurface erosion because surface erosion control is often achieved by increasing infiltration through the use of diversions and dams. But ponding of water provides an hydraulic head for pipes and may open up a tunnel system.

The best and most cost-effective way to treat soil with susceptibility to subsurface erosion is through revegetation (Thornes 1980, Gibbs 1945). Where tunnels have reached an advanced stage, they must be broken by ripping prior to revegetation (Morgan 1979). Slopes should then be graded to a stable, concave, low-erosion shape (Meyer and Kramer 1969). Dryland sodding of graded areas with native grasses has proven effective in preventing erosion and will provide immediate results. The transplanting of deep rooted native plants such as *Coreopsis gigantea* will eventually hold the slope, and may restore original conditions.

Because tunnel-gully erosion has now been identified on both Anacapa (Bond 1941) and Santa Barbara Island, erosion mapping should be done on all islands within the park. Three maps should be made: 1) erosion extent; 2) erosion process; and 3) susceptibility to piping. Mapping of erosion extent should be done at regular intervals.

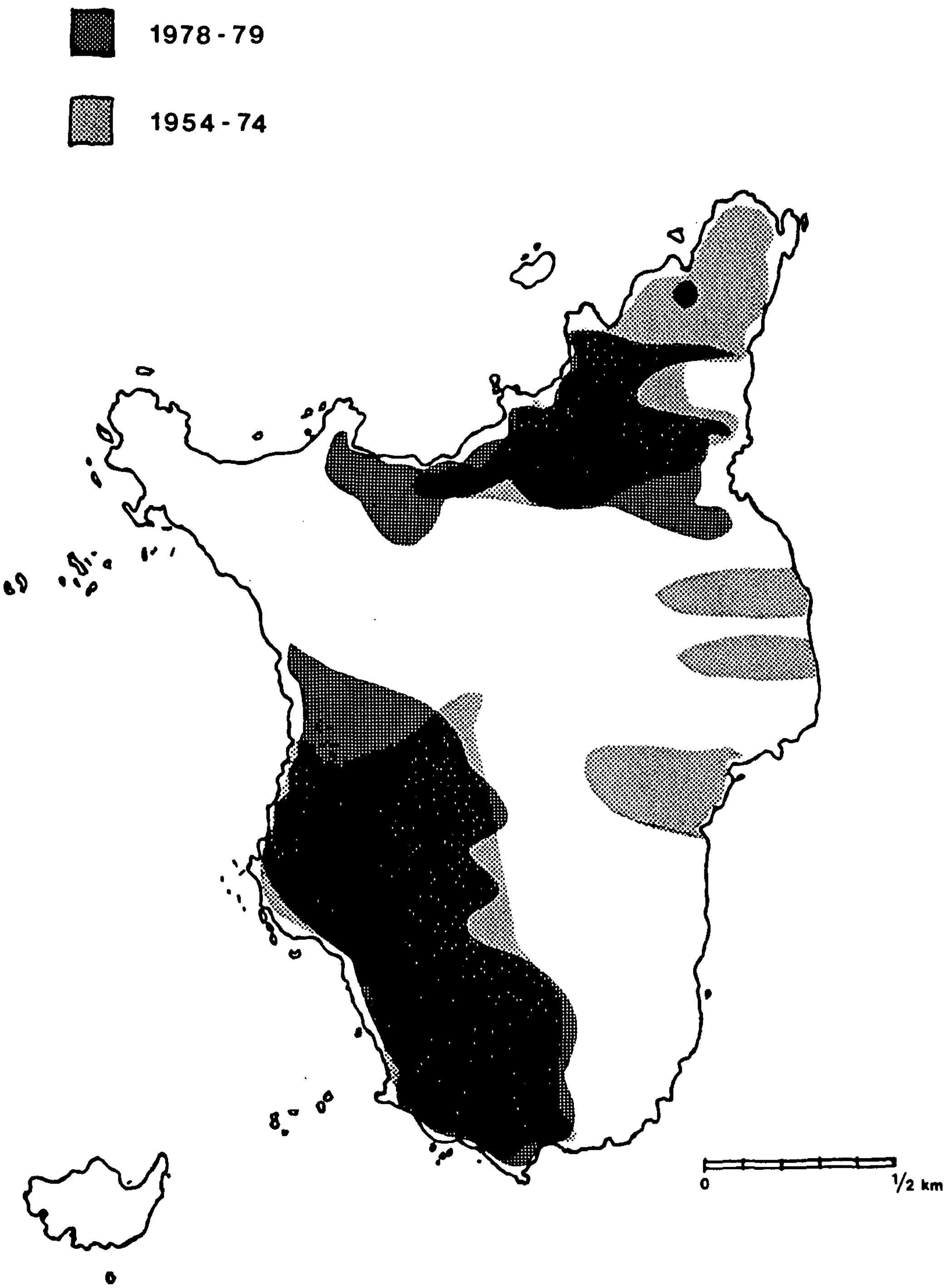


Figure 4

Past Distribution on Santa Barbara Island of *Oryctolagus cuniculus* (European Rabbit)

SECTION II:

BIOLOGICAL SCIENCES - Floristic Studies

FUNGI OF LASSEN VOLCANIC NATIONAL PARK

W.B. Cooke

ABSTRACT

On the basis of collections made during 23 visits to Lassen Volcanic National Park between 1942 and 1981, more than 500 species of fungi have been listed. The annotated list, subject to expansion by more intensive collection efforts in search of special groups of fungi, and to include additions from as yet unidentified specimens, forms the basis for deriving information about soil fungi, mycorrhizal fungi, wood decay species, and the occurrence of fleshy-fruited fungi in the Park. An inventory of a portion of this important segment of the biota of the Park is thus available.

INTRODUCTION

Decomposers, which through exoenzymes, absorption, and endoenzymes, convert organic matter into compounds, ions, and elements which can be reutilized by plants, animals, and other organisms. The fungi are the most important decomposers in this system. Very little consideration has been given to this member of the ecosystem. One reason may be that speciation of fungi in any given region is not well known. This summary of my census of the fungus populations of Lassen Volcanic National Park is an attempt to close the gap on one unit of resource information in the National Park System.

METHODS

Specimens of fungi of all observed types were collected. Each sample was placed in a wax paper bag in the field and carried to an area where the dryer was set up. Here the specimens were placed on a drying rack over an electric hot plate, and when dry were placed in wax paper bags and packed for transport to an area where more critical studies could be undertaken.

Some of the species were identified in the field, others at home, and others were sent to specialists on various groups of fungi. Following identification, specimens were packeted, labeled, and sent to herbaria. Primary points of deposit have been the Herbariums of the University of California, Berkeley, and the Botany Department, Miami University, Oxford, Ohio. In certain cases, reports by specialists have not yet been made. In some cases no specialists have been found for some of the groups with which I am not familiar.

Three samples of soil were taken for processing. Samples were scooped into plastic vials and plastic caps were applied without touching the soil. In the first set, samples were taken from the shores of Lake Helen and Emerald Lake as well as from relatively undisturbed water. The second set of samples was taken from materials in the floor of a fumarole in the summit crater. The fumarole had been used for incineration of luncheon garbage. The third set of samples was taken from soil near a stove, a table, and a tent area in the campground at Manzanita Lake. Samples were also taken in plastic vials from the top layer of soil. This was done after the first year of operation of the campground in a site under a Jeffrey pine tree and a site under chaparral. A sample of soil was also taken from under a pine in an undisturbed but adjacent area. Further sampling was done near the Visitor Center at the base of a litter can, near a bench and in a lawn. These samples were returned to Cincinnati where, after refrigeration, they were plated for soil fungi using Cooke's rose bengal-Aureomycin-neopeptone-dextrose agar. Colonies were counted and identified.

Lichens were collected from rock surfaces, and from twigs and branches of trees. These were submitted to the late Dr. A.W. Herre for identification.

1135 Wilshire Ct., Cincinnati, OH 45230

RESULTS

To date, 567 species of fungi have been listed systematically for Lassen Volcanic National Park (Cooke, in press). The list includes all reports found in the literature, and in the Herbarium of the University of California, Berkeley. Also included is the list of Myxomycetes (slime molds) submitted to the Park Naturalist by D.T. Kowalski of California State University at Chico. Included in the list are [illegible] species of Myxomycetes, or slime molds; six species of Zygomycetes isolated from soils or parasitizing mushrooms; 104 species of Ascomycetes including powdery mildews, several soil fungi, flask fungi including a fungus growing on overwintered perianth segments of *Juncus parryi,* the newly described *Bricookea sepalorum,* cup fungi, and three true truffles; 91 species of Fungi Imperfecti, mostly as soil molds, leaf disease fungi, and a few molds such as *Bahusakala cookei* forming a black mold on alder branches; 288 species of Basidiomycetes including a number of smuts and rusts causing diseases of flowering plants, wood decay fungi including species of conk- or bracket-producing fungi, a large number of gill fungi—mushrooms and toadstools, puffballs and their relatives, and several species of false truffles; and 25 species of lichens.

Throughout the Park many species of naturally occurring wild plants are attacked by a variety of leaf, stem, and root parasitic fungi. Most plants so attacked survive without a significant loss of vitality, although in several cases sterility of the host plant may occur. As leaves and other plant parts become senescent, they are increasingly subject to fungal attack but this appears not to harm the plant.

Many of the common heart, butt, and root rots of conifers and hardwood shrubs occur in the Park. This is true of any stand of timber but becomes more apparent in the Park forests where older timber is permitted to stand without the culling of infected stems. Thus, the Park forms a source of infection for trees in forests on adjoining lands. Many of these heart rot fungi continue their activities in fallen trees fruiting on supporting logs. Some of the fruit bodies are perennial and continue shedding spores in season as long as nutrients are available in the log. In addition to heart rot fungi, there are sapwood rot fungi and numerous slash rot and secondary rot fungi which fruit on dead and fallen wood and branches. An excellent example of substrates made available to such fungi was presented by the 1962 blowdown which left many logs above the peak highway southwest of Summit Lake.

Dead stems of annual and perennial flowering plants are quickly rotted away by a variety of flask fungi and imperfect fungi, some species being associated with only one kind of plant, others with a wide range of host species.

A very important group of fungi includes those which form mycorrhizae with forest trees as well as with other types of forest plants. A mycorrhiza, of fungus root, is a combination of root hair around which are developed the hyphae of a fungus which in the ectotrophic mycorrhiza do not penetrate the cells but grow between them, while in the endotrophic mycorrhiza the hyphae do penetrate the cells. In both cases the mycelium of the fungus produces fruit bodies, those of the ectotrophic mycorrhizae being more obvious since a number of mushroom-producing fungi are involved. Without these fungi the forest would be less luxurient since the mycorrhizal fungus aids the tree, providing it with nutrients not readily available otherwise, and the tree providing the fungus with carbon compounds not readily available to it. Probably endotrophic mycorrhizae are also present in the Park since incense cedar, members of the Orchidaceae and Ericaceae, and other plants form only this type. An interesting variation on this theme is the so-called saprophytic plant which has been found to be parasitic on fungi which are mycorrhizal with other plants.

A small group of fungi includes those found on dung, mostly on that of herbivorous animals, and many of these are restricted only to this habitat. Spores are discharged in such a way that they may come to rest on leaves which may be eaten by an herbivorous animal. In many cases spores germinate only after being acted upon by gastric juices in the animal's digestive tract.

A group of mycorrhizal fungi includes those which fruit underground, the hypogaeous fungi or true and false truffles. Several species of these fungi are found in the Park and its vicinity.

A wide spectrum of fungi whose fruit bodies are commonly called mushrooms or toadstools occurs in the Park and its environs. Many of these fruit bodies are highly photogenic, and most appear to be tempting as a source of food. However, a few are poisonous and others may be toxic to some degree. The edible or poisonous nature, so far as is known, of species reported in the Park list is noted in Cooke (in press).

Fungi require moisture for successful fruit body production, not only in the soil where the mycelium is growing, but also in the air as high relative humidity is required where the fruit body is discharging spores. Most species can be drowned by excess water. In Lassen Volcanic National Park the required moisture comes in two seasons of the year. In each season it may trigger fruit body production by different species. In the spring, as the snow melts, members of a group of snow bank fungi appear at the edges of the melting snow banks. As the moisture produced by the melting snow percolates or evaporates, the habitat dries out, not to be significantly moistened again until late summer or early autumn when fall rains start. This warmer moisture triggers the development of a wide variety of fruit body development, much of which is not seen since the mushroom produced pushes up layers of litter and duff without surfacing. In nearby forest lawns regular irrigation triggers the development of many kinds of fleshy fungi, suggesting that in less well irrigated areas many fungi are merely waiting for moisture to complete development of their fruit bodies.

DISCUSSION

A number of the fungi identified in Cooke (in press) have a greater significance in the economy of the forests of the Park than merely the removal of dead organic matter. While one set of unreplicated samples yielded insufficient data, there was an indication that as greater human use of a wild soil occurs, more fungi become available to attack the increasing amounts or organic matter left by visitors.

CONCLUSIONS

For every bit of organic matter present in any environment there is at least one fungus available to reduce it to elemental components, thus recycling it and making the components available for other organisms. Microfungi in the soil, or macrofungi in wood, litter, mycorrhizae, or the soil, continue the process of decomposition of organic matter only to the extent of the capabilities of their enzyme systems. Parasitic fungi initiate the process of decomposition, but in living tissues. However, in many cases host and parasite have come to a relatively secure balance since the relationship rarely leads to the elimination of the host. With the addition of organic matter to soil, fungal populations increase not only in numbers but also in speciation.

MANAGEMENT CONSIDERATIONS

In general, the fungi are a normal part of the ecosystem of any area. In the wilderness there is no problem. In areas where man can influence the environment, sometimes in adverse ways, the keeping of such adversities to a minimum is suggested. The damaging of trees by off-road vehicles or by heavy equipment could lead to infection and resulting death of the tree. If this occurs near population centers, damage to individuals, their living accommodations, and their vehicles could result. Keeping an unclean campsite could lead to increased populations of soil fungi including some species which could be clinically damaging to man. In these days of increased interest in edible fungi, knowledge of what species are present and their potential effects on those who would eat them would be useful to management in cases of suspected mushroom poisoning.

ACKNOWLEDGEMENTS

Thanks are due to all Park Naturalists who have given permission to collect fungi in the Park and who have arranged for working space; to Lester D. Bodine who has arranged collecting trips and aided in many ways, to the late Dr. Lee Bonar, Botany Dept., University of California, Berkeley, for inspiration and help in identification of some materials, to all those who have given of their time and expertise in identification of submitted materials, and not least to my wife, Vivian, who has driven me to the Park many times and who has accompanied me in the field, found many of the specimens, put up with the drying procedure, the packeting, identification, and storage of collections in our home.

A SURVEY OF *ELYMUS* SPP. (WILDRYE) AND POSSIBLE HYBRIDS AT MALIBU CREEK STATE PARK, SANTA MONICA MOUNTAIN NATIONAL RECREATION AREA, CALIFORNIA

F.T. Sproul

ABSTRACT

Large rhizomatous and spikeless clones of *Elymus* sp. are among the most successful plants of Malibu Creek State Park. Preliminary identification of its associates indicate the presence of *E. triticoides, E. glaucus,* and in mesic sites *E. condensatus.* Despite these known taxa the presence of spikes, awns, and rhizomes varies considerably. Morphological comparisons are made herein of these collections with the hybrids studied by G.L. Stebbins in which he found intermediate clones which varied widely between *E. triticoides* and *E. condensatus.* Further analyses are made with the work of F.W. Gould to determine the possible presence of *E. triticoides* ssp. *multiflorus.* This initial work was conducted to establish a basis for further cytological work, revegetation, or plant breeding within this genus.

INTRODUCTION

Reapplication of some methods and findings of former research with several species of the genus *Elymus* (Wildrye) has been of practical use in recognizing the hybrid origin, increased vigor, and fertility of grass collections at Malibu Creek State Park.

A highly variable assemblage of three Wildrye taxa occur throughout the Valley Oak Grassland at Malibu Creek State Park in the Santa Monica Mountain National Recreation Area. Their identity could only be vaguely established by the most commonly available floras and grass keys. Only 6 of 11 *Elymus* spp. collected in this study could be identified with such sources; they are: *Elymus triticoides* (Creeping Wildrye), *Elymus glaucus* (Blue Wildrye), and *Elymus condensatus* (Giant Wildrye). Several large clones, one which singly covered nearly an acre, lacked any flower spikes and 6 collections shared characteristics of two of these three species.

Comparisons of plants collected here with those studied by Stebbins and Walters (1949), suggests that some of the most prominent, weed-like, usually sterile wildryes are hybrids that persist in large clones, reproducing only by rhizome. This seemed to describe some of the material we have found at Malibu. Two specimens have features that suggest hybridization between *E. triticoides* and *E. glaucus,* though such combinations are rare or unknown in the wild.

METHODS AND MATERIALS

Measurements of the morphological characteristics of 11 collections were made from selected wild stands at Malibu Creek, many of which were intermingled or within several yards of each other. Of major value in comparing these specimens were some of the vegetative observations used by earlier workers, especially Stebbins (1956, 1959), Snyder (1950), and Gould (1945). Seven characteristics are recorded for each collection (Table 1). The use of just three characters is sufficient to establish the probable parentage of most specimens; those are: 1) the presence of long rhizomes, 2) the number of spikelets per node of the rachis, and the width of leaf (subapical culm leaf).

Certain characteristics, if most similar to one or the other of the feasible parents, constitute strong evidence to indicate the origin of hybrids. Four statements in Stebbins and Walters (1949) are crucial to keying out *Elymus* hybrids: 1) "Taxonomic" *Elymus triticoides,* which has "three or more spikelets at the nodes of the rachis, are probably derivatives of hybridization between *E.*

Exploration Associates, Box 3120 Hillcrest Station, San Diego, CA 92103

Table 1

Measurements of *Elymus* Specimen

	Rhizomes (+/0)	Leaf Width (subapical culm leaf)	Color	Maximum Spikelets Per Node of Rachis	Abundance of Spikelets	Stand Density (0) tufted (1) 25% cover (2) 50% (3) 75% (4) 100%	Seed Set (+/0)
[illegible]*aucus* ([illegible]2)	0	3.5 mm	glaucous	2	many	0	+
[illegible]*aucus* (EM-9)	0	6.7	glaucous	2	many	0	+
[illegible]*aucus* (EM-5B)	0	2.5	yel-green	2	many	0	+
[illegible] *(X E.g. ?)* (EM-7)	+	2.8	glaucous	0	0	4	0
[illegible] *(X E.g. ?)* (EM-1)	+	3.0	glaucous	0	0	4	0
[illegible]*iticoides* (EM-3)	+	4.0	glaucous	2	few	2	+
[illegible]*iticoides* (EM-6A)	+	1.5	glaucous	2	few	3	0
[illegible] *X E.c.* (EM-10)	+	8.5	yel-green	5	3	4	0
[illegible] *(X E.g. ?)* (EM-11)	+	4.5	glaucous/ yel-green	0	0	4	0
[illegible] *(X E.c. ?)* (EM-4)	+	6.0	yel-green	0	0	4	0
[illegible]*ondensatus* (EM-14)	+	13.0	yel-green	7-8	few	2	0

[illegible]*densatus* and *E. triticoides.*" 2) "(Typical) *E. condensatus* does not produce rhizomes. Plants [illegible]ich produce rhizomes probably contain in every case genes derived by hybridization from *E.* [illegible]*iticoides* Buckl." 3a) "Hybridization between two different strains of *E. triticoides* and *E. glaucus* [illegible] been attempted," (unsuccessfully). 3b) Sterile clones that failed to produce flowers could well be [illegible] hybrids of *E. triticoides* X *E. glaucus* (G.L. Stebbins, pers. comm.)

Other characteristics that were important in the tenuous identification of large clones were: 1) *Stand density*— increases in sterile hybrid clones reputedly apparently due to hybrid vigor. 2) *Color of leaves and stems*— tend to have varying degrees of chlorosis in the cases of artificial hybrids produced by Stebbins. 3) *Abundance of spikelets*— is decreased or eliminated altogether due to the usual sterility of hybrids. 4) *Seed set*— is rare in hybrids even if a few flower spikes do occur. Seed set is naturally scant in *E. triticoides* according to Crampton (1974). It has, however, been used as a wild grain by Indians according to accounts given in the Range Plant Handbook (USDA 1937). These differences, though conflicting, give further clues about the identity of these grasses.

RESULTS

Six of the 11 collections made during this study are reported here as hybrids, but their identity can only be inferred at present by morphological evidence (Table 1). Four collections, EM 4, 11, 1, and 7, are assumed to be hybrids first by their sterility (none had flower spikes). Next, their relationship to *E. triticoides* is fairly certain because they all are extensively rhizomatous. Finally, these four collections were further identified by comparisons of leaf widths of unknown hybrids with pure forms of the three *Elymus* spp.

The failure of artificial hybridization between *E. glaucus* and *E. triticoides* should not preclude the possibility of this cross occurring in the wild. Even though *E. glaucus* is supposedly more closely affiliated with some grasses of other genera (i.e. *Sitanion, Agropyron* and *Hordeum),* it has been successfully crossed with *E. condensatus* which is known to hybridize with *E. triticoides.* The perfect example of an *E. triticoides* X *E. condensatus* is given by collection EM-10. It had only three spikes, all of which were sterile with the highly diagnostic five spikelets per node. This specimen conforms very closely with Gould's (1945) description of *E. triticoides* ssp. *multiflorus.*

Collection EM-14 is short rhizomatous only, the stand was not very dense and highly clumped. Except that it set no seed and could be a hybrid it is assumed here to be purely *E. condensatus.*

Both specimens of *E. triticoides,* EM-6A and EM-3, failed to set seed. Despite the fact that these specimens fit the description of *E. triticoides,* sterility does raise doubt about its origin. Substantial fertility is characteristic of Creeping Wildrye (USDA 1937). It may be that little is sacred in *Elymus* and 8 of these 11 collections are in fact hybrids between these three species.

In Gould (1945), a new subspecies of Wildrye was described as being intermediate between Giant Wildrye and Creeping Wildrye; he named this new taxon *Elymus triticoides* ssp. *multiflorus.* It seems that this new subspecies was in fact a long-lived hybrid of the cross between these two and the same as collection EM-10 (see Table 1). The wide variability of characteristics filling the entire range of intermediates between these two parent species and the highly sterile character, seems to indicate that this subspecies is from multiple, single origins by hybridization.

CONCLUSIONS

Elymus spp. are widespread in the western United States and were recognized as late as the 1880s as a valuable hay crop and forage. Formerly *E. condensatus* was important as a winter forage plant in parts of Nevada (USDA 1937). Referring to the genus *Elymus* the same source reported: "Old time freighters report that they never carried hay for their oxen but turned them loose at evening in patches of this grass which were so extensive, tall, and dense that the beasts were often lost for several days. Today the grass cover is so scanty on some of these same areas which have been seriously overgrazed that cattle are easily visible across the entire area."

The practical importance of some of these hybrid *Elymus* clones is in their weedy quality and long-lived persistence as sod formers and soil builders. Such successful plant species are recognizably valuable to National Parks, National Forests, and many public lands and range lands, where stable ecosystems, soil conservation and range improvement are important.

Preservation of native flora necessitates a rather strict interpretation of the identity of these many forms of *Elymus*. Any short-sighted revegetation schemes that use only the seed bearing forms *(E. glaucus)* would be simplifying and thus ignoring the full diversity and more vigorous forms of this grass. Singular use of superior clones may be appropriate in farming or certain range improvement, but such uniformly ideal conditions are rarely available or desirable in range or park lands.

MANAGEMENT RECOMMENDATIONS

At Malibu Creek the preservation of these clones for revegetation offers some useful advantages. It is most useful as a soil binder, but is also desirable as a perennial soil cover which remains green throughout most of the summer. Apparently the hybrids of *E. triticoides* X *E. condensatus* are sometimes fertile because some specimens are reported of backcrosses with either parent. Such rare individuals could be very useful in tracing parentage and in further breeding. Failure to recognize the value of these clones, especially if rare undiscovered fertile hybrids were somewhere extant, could be a serious oversight if such clones were unintentionally destroyed.

It is important that land managers realize the value of such 'mongrel' strains of grasses that may be more successful than their more easily distinguished parent species, even though such strains may be less easily obtained or propagated. Such clones may retain intermediate characteristics such as tolerance of saline or disturbed soils, drought adaptations, or desirable horticultural qualities.

In the hills at Malibu Creek are the survivors of the experiments of millenia of natural hybridizations among *Elymus*. Such combinations of two and possibly three diverse species are of significant interest. It is suggested here that the natural breeding systems in ***Elymus*** constitute a uniquely valuable resource, which, with its exchange of genes between these species provides a matrix from which new and useful strains are constantly being recreated.

MANAGEMENT ALTERNATIVES FOR THE PROTECTION AND ENHANCEMENT OF REMNANT NATIVE VEGETATION OF THE NORTHERN SAN FRANCISCO PENINSULA

J.F. Milestone

ABSTRACT

Starting in the 1880s dramatic changes occurred to the indigenous vegetation of the San Francisco headlands from urbanization and introduction of exotic vegetation. The installation of a railroad grade in 1887 further accelerated the mass wasting along the coastal headlands. Landslides resulting from improper drainage and unengineered fill material is still causing large areas to erode at an accelerated rate. Park visitor trampling has taken its toll on the low lying chaparral. The National Park Service established GGNRA in 1972 and sought means to restore and enhance the remnant native coastal vegetation. Three programs are underway to accomplish this goal: 1) designation of specific trails and elimination of the myriad social paths; 2) reestablishment of native plants through the park's Native Plant Nursery; and 3) removal of exotic species.

INTRODUCTION

Howell et al. (1958) described the vegetation of the San Francisco area as: "one of the outstanding local floras of California . . . that displays in a limited insular like way an assemblage of plants marked by a distinctive floristic facius and having significant photogeographic features. Not only do we find here a mingling of north coastal and south interior elements with a number of species reaching a northern and southern distributional limit, but we also find a small impressive group of plants that are found nowhere else." Following World War II, vast industrial development and extensive housing projects on bulldozed hillsides and graded sand dunes made it apparent by 1949 that the flora of San Francisco was disappearing rapidly. Howell et al. in their closing discussion pleaded "the fringe of natural wilderness in San Francisco has been trimmed very close but there are still some precious tattered remnants. Before this wonderful flora is finally and completely extinguished, one wishes that an adequate conservation barrier against population pressures might be set up . . . in San Francisco we hope that man's destruction of nature will not completely prevail." Urban sprawl continued to extend across the expansive sand dunes of northwestern San Francisco, to the extent that development crept to the unstable cliff edges of the San Francisco Headlands. The conservation barrier that Howell et al. had hoped for to protect the "fringe of wilderness" was never created. Instead, the preservation of San Francisco's flora was precariously clinging to the eroding cliffs and bluffs of the City's coastline. Since stretches of the coast were military reservations set aside for coastal defense emplacements, never developed beyond the construction of a string of small batteries, the remaining sections of the city's coast were municipal dumping grounds scarred with massive landslides that guaranteed the area from further urbanization.

In October 1972, Golden Gate National Recreation Area was created. Stretching from the Golden Gate Bridge, southwest to Ft. Funston, the thin strip of coastal headlands was placed under the protection of the National Park Service. Although the area is managed by the National Park Service, deterioration of the vegetation continues due to a combination of factors, namely, park visitor trampling, introduction of exotic species, poorly designed and constructed roads and placement of unengineered fill material, and natural coastal erosion processes.

Management objectives focused on the protection and enhancement of the native plants are dependent on reducing the threat of the man-caused factors contributing to adverse impacts while at the same time implementing cost-effective methods of accelerating the spread of native plants throughout

Golden Gate National Recreation Area, Ocean District, Building 201, Fort Mason, San Francisco, CA 94118

park lands. Management practices designed to achieve management objectives are described and analyzed.

STUDY AREA

The study area can be divided into three sections: the Ft. Funston area located on the southern boundary of GGNRA and the City of San Francisco; the Lands End area in the northwest corner of San Francisco Peninsula; and the Ft. Scott area to the east of Lands End and immediately west of the Golden Gate Bridge. These areas represent the largest concentration of coastal native plants (Fig. 1). Ocean Beach connects Ft. Funston with Lands End, and China and Baker Beaches connect Lands End with Ft. Scott. Together the three areas and connecting beaches comprise 9 mi of coastline.

The Ft. Funston area, once a military reservation, rises about 170 ft above the Pacific Ocean and extends 1.5 mi in length. Geologically the Ft. Funston cliffs are part of the Merced and Colma formation, composed of sandstone, mudstone and conglomerate (Wahrhaftig 1974). The topography prior to 1938 was a product of a dune environment. In 1938, and again in 1954, extensive landscaping leveled the area to make way for coastal defense batteries. Exotic plants from Africa and Australia were planted over 95% of the area for defense and erosion control purposes (Table 1). Currently, native plants are reestablishing themselves throughout the area.

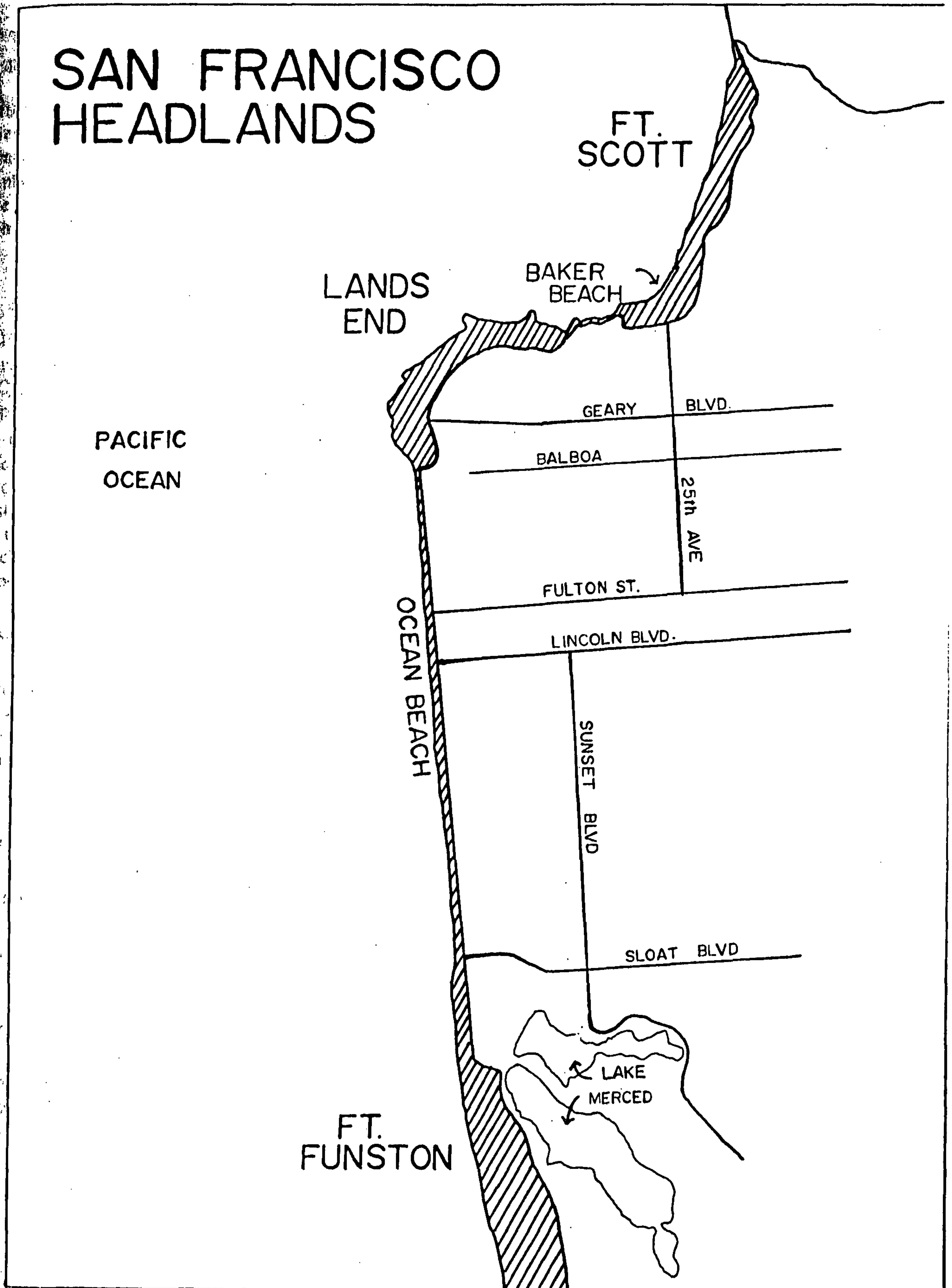
Table 1

Introduction of Exotic Species

Area	Year of Exotic Revegetation	Dominant Exotic
Ft. Funston	1938-1954	*Mesembryanthemum e.*
Lands End	1886-1926	*Cupressus m. & Pinus r.*
Ft. Scott	1904	*Cupressus m.*

The Lands End area, approximately 2 mi long, extends from the Cliff House to the Sea Cliff neighborhood. The area was originally owned by the U.S. Army and private citizens. In the early century, the City acquired the privately owned lands and incorporated them in the Recreation and Parks Department. Geologically the area is part of the Franciscan formation with graywacke, radiolarian chert, basalt and serpentine rock as the foundation material. The Colma formation with its sandy soils can be found blanketing the Franciscan formation in several locations. Large active landslides and slumps scar the 300 ft high cliffs throughout the entire area. The 1887 ferries and the Cliff House railroad grade constructed in 1886 are causing accelerated erosion throughout the area to this day. Eleven of the 30 landslides found in Ocean District were related to the railroad grade, known today as the Lands End Trail. The city used the landslides of the area as dumping grounds for concrete and granite rubble from the 1906 earthquake and earlier urban development projects. Adolf Sutro, designer of the railroad grade, mayor, and land holder of the area, started Arbor Day in California in 1886 and planted tens of thousands of Monterey Cypress *Cypressus macrocarpa* and Monterey Pine *Pinus radiata* throughout the area. Again in 1926, the city Parks Department planted thousands of more trees in the area. As a result, the dominant foliage today has changed from coastal prairie to forest. The importation of rubble and dirt as fill material introduced many exotic species, mostly garden escapes to the area.

Figure 1


SAN FRANCISCO
HEADLANDS
FT.
SCOTT
BAKER
BEACH
LANDS
END
GEARY BLVD.
BALBOA
PACIFIC
OCEAN
25th AVE
FULTON ST.
LINCOLN BLVD.
OCEAN BEACH
SUNSET BLVD
SLOAT BLVD
LAKE
MERCED
FT.
FUNSTON

The Ft. Scott area, also a military installation like Ft. Funston, is a steep slope rising over 400 ft. Also part of the Franciscan formation, in the area is mostly serpentine with large coastal slides. The Ft. Scott area extending down to Marshalls and Baker Beach has extensive acreage of native plants. Construction of military gun emplacements on the bluffs above the area was camouflaged with exotic species. The non-native species have expanded down slope beyond the original fence line on the emplacements. The Ft. Scott area is particularly sensitive to exotics for two reasons: four of the five rare plants known to occur in San Francisco on GGNRA lands are situated at Ft. Scott; and, because of active coastal erosion large shallow seated slides occur annually, opening up large areas of vegetation which become invaded by exotic species.

METHODS

Throughout the 9 mi coastline of the Ocean District, which includes the Ft. Funston, Lands End and Ft. Scott areas, native vegetation is found in tattered remnants. Over 95% of Ft. Funston area is covered with exotic vegetation, mostly Hottentot Fig *Mesembryanthemum edule.* The Lands End area has *Cypressus macrocarpa* as the dominant foliage. The Ft. Scott area coastal scrub is being invaded by Pampas Grass *Cortederia jubata* creeping down the slope.

Coastal erosion activating slope failures is probably the most dynamic force removing large portions of vegetation and topsoil. This process by itself plays a minor role in the natural landscape. However, with cliff faces cut and tons of rubble perched upon the slopes, the process is accelerated. Coastal erosion becomes a more important factor in influencing native plants when only a thin strip of land remains. Until the rubble fill and road grades slide into the ocean in the structurally weak areas of the cliffs, little can be done to save the slopes. Dumping of rubble debris has been permanently stopped since GGNRA was created.

Constructing Designated Trails

In 1981, over 6.4 million people visited the Ocean District. The primary impact from such large crowds of visitors is trampling of vegetation at vista points and development of social trails. Eventually this will lead to accelerated erosion and permanent damage. The challenge to park managers is to reduce the development and use of social trails by concentrating the foot traffic to designated trails. Such trails must be designed to meet three goals:

1) To complement traditional routes that visitors have used historically to reach specific locations.

2) To accommodate functions appropriate to the users it serves, i.e. dog walkers, joggers, horses and bicycles.

3) To serve as a structure to halt existing erosion problems and does not contribute or create additional erosion.

In constructing designated trails the main routes are formalized, eliminating the need for a maze of trails throughout the landscape. Reducing the social trails will provide more ground for vegetation, thereby reducing the erosion potential.

Stair-trail

In the Ocean District, three trail structures have been used extensively. They include railroad ties assembled into a structural staircase, fixed in place using 5/8 reinforcement rod driven by hand-held sledge hammer (Fig. 2). The railroad tie "stair-trail" is used on steep slopes to achieve a rapid rise within a short distance. The stair-trail provides two additional features:

1) When placed within a gully, created by visitors trampling down slopes of erodable soils, the individual risers act as checkdams to retain soil.

2) The stair trail serves as a base-level of erosion to prevent further degradation of the gully.

Figure 2

Stair-trail

Stair-trail at Eagles Point constructed in a gully created by park visitors trampling a hillslope. Steps are built using recycled railroad ties and anchored in place with three foot lengths of reinforcement rod. The stair-trail stabilizes the base-level of erosion and retains soil as each step serves as small checkdam.

Gabion

The second trail structure is known as a gabion. It incorporates railroad ties, reinforcement rod, and rock. The structure provides a wider trail tread by raising the height of the downhill slope which the trails runs across (Fig. 3). The structure is secured with deadmen to hold the wall in place and is built with space to provide drainage. Rock fill placed behind the railroad tie prevents loose fill and trail surface material from washing out, yet still allows drainage of water through the spaces provided.

Dutch Sand Ladder

Within the Ocean District the most difficult trail surfaces to walk up are the sand dunes. Furthermore, trails over dune environments are especially susceptible to erosion. An innovative structure used to provide sure footing, minimize erosion and still make a route through sand appear as a formalized trail is the Dutch Sand Ladder (Fig. 4). The sand ladder is similar to a rope ladder which lays on the sand dunes surface. The ladder has wooden rungs with flexible galvanized cable. The ladder is built in 25 ft sections with the up hill end anchored to 4x4 posts buried in the ground. If drifting sand buries the ladder, the bottom rung is pulled, re-exposing the entire ladder, and simply laid again on the surface. Two sand ladders exist in the Ocean District, one at Sutro Baths nearly 200 ft long, and another at Ft. Funston 491 ft long. The Ft. Funston sand ladder was designed specifically to assist hang-glider pilots in hauling their kites up the steep cliffs.

Revegetation

Many vista points and hillslopes which attract people for the views and are used as access to beaches have been trampled severely. Trampling low lying chaparral and grass lands eventually led to exposing fragile soils and subsequent removal through surface erosion. This type of degradation developed several large gully fields on the coastal cliffs.

Restoration and rehabilitation of the sites included construction of designated trails, waterbars, check dams, and barrier fencing. Revegetation of the sites occurred very slowly if at all, because certain sites had lost all soil cover, nutrients were lacking, and visitors who ignored the closure signs and barrier fencing did sufficient damage to prevent revegetation. Furthermore, exotic species often invaded the disturbed areas, crowding out native plants. After completing trail projects in Marin and San Francisco headlands to reduce the erosion, it became apparent that more than just grass cover was needed to guarantee long-time protection against accelerated erosion. Additional benefits to establishing brush cover, is that brush would serve as a low-cost natural barrier to discourage foot traffic through sensitive areas and enhance wildlife habitat. To accelerate the natural revegetation, coastal plants would need to be planted. Two problems arose: first, a source for purchasing native species that are indigenous to the San Francisco Peninsula, did not exist, especially since thousands would be required to do an effective job. Second, the parks budget did not have adequate funds to purchase the necessary amounts of plants.

An alternative to this problem was to create a low-cost native plant nursery. Created in 1980, the Ocean District built a small greenhouse and additional cold frames, installed an automatic mist propagation system and then began a two prong collection of plants: by collecting stem cuttings; and by collecting seeds of native plants. After developing a sizable stock of 3,000 plants, the shrubs were transplanted following the first winter rains to sites in the field. This nursery saved the park $7,000 by not having to commercially purchase the plants. The native plant revegetation program provided the following benefits:

1) Accelerates revegetation of specific sites with native plants.

2) Maintains the indigenous genetic strains of the plants in a specific area.

3) Provides a high number of plants that were selected from specimens with favorable characteristics at a low cost.

Figure 3

Gabion

The gabion elevates and widens the trail tread on steep slopes where the trail traverses the hillside. Using railroad ties and reinforcement rod, with rock backfill the structure is anchored into the hillside with four foot timbers which are buried beneath the tread.

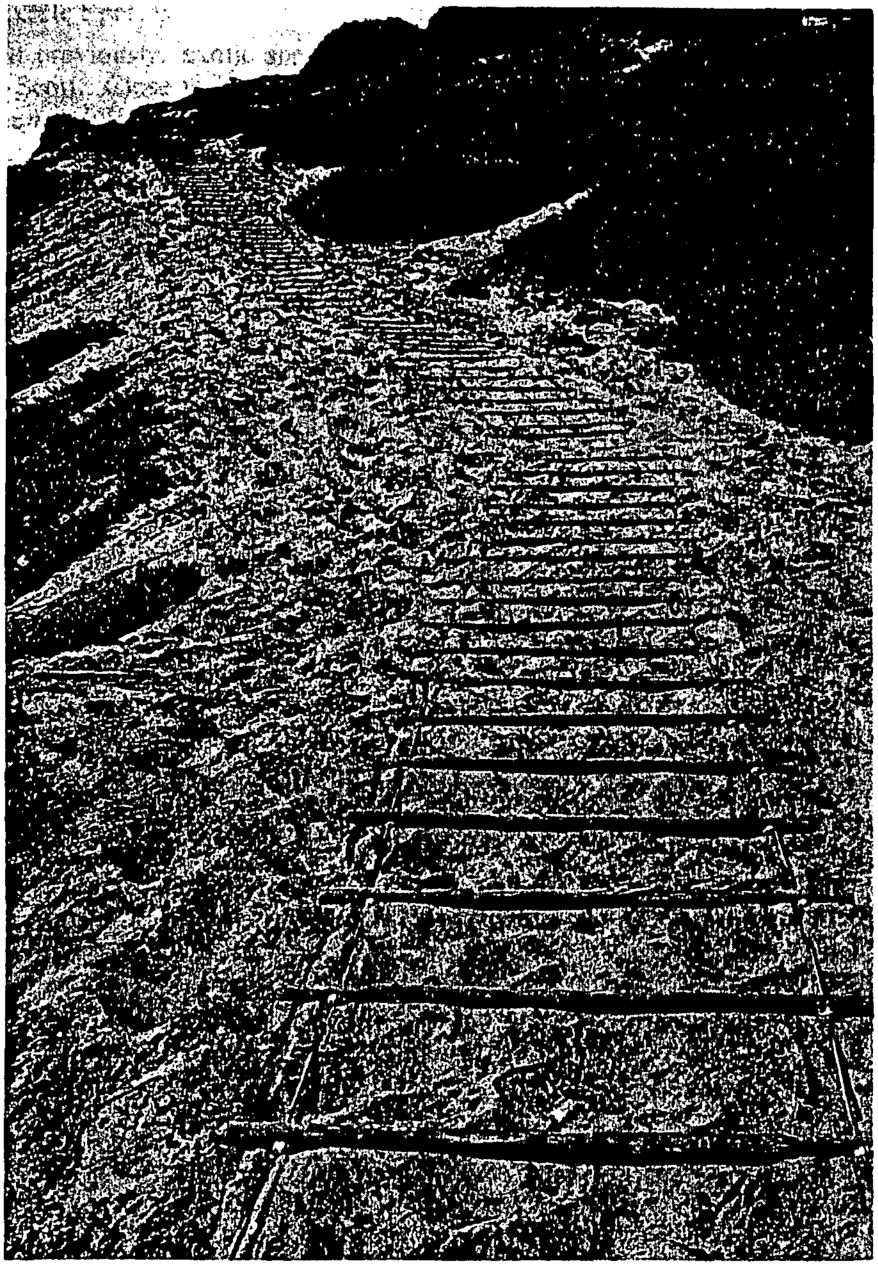


Figure 4

Dutch Sand-Ladder

Used in the dunes of northwestern Holland, the sand-ladder provides a sure-footing while ascending soft-erodible soils. The sand-ladder is dynamic with the flexible wire-rope and so adjusts to the topography without disturbing the surface material. When drifting sand buries the ladder, one simply pulls the bottom rung up, lifting the 25 foot sections out of the sand and then relays the structure on the surface.

Introduction of Exotic Species

As explained previously, exotic species were widely distributed in Ft. Funston, Lands End, and high bluffs of Ft. Scott. Close to 90% of the Ft. Funston vegetated area is covered with Hottentot Fig *Mesembryanthemum edule*, an exotic species from South Africa. The dominant foliage in Lands End area is from Monterey, California: Monterey Cypress *Cupressus macrocarpa* on the headlands; and a high percentage of Monterey Pine *Pinus radiata* placed on interior slopes. Only the Ft. Scott area has indigenous flora that dominates the landscape (Table 2).

Table 2

Predominant Exotic and Noxious Plants in the Ocean District*

Ft. Funston Area	
Mesembryanthemum e.	- Hottentot Fig
Albizzia m.	- Stink Bean
Leptospermum l.	- Australian Tea
Eucalyptus g.	- Blue Gum Eucalyptus

Lands End Area		Ft. Scott Area	
Cupressus m.	- Monterey Cypress	*Cortederia j.*	- Pampas Grass
Pinus r.	- Monterey Pine	*Cupressus m.*	- Monterey Cypress
Leptospermum l.	- Australian Tea	*Pinus r.*	- Monterey Pine
Eucalyptus g.	- Blue Gum Eucalyptus	*Albizzia l.*	- Stink Bean
Raphanus s.	- Wild Radish	*Cytisus m.*	- French Broom
Albizzia l.	- Stink Bean	*Cytisus s.*	- Scotch Broom
Cytisus m.	- French Broom	*Tropaeolum m.*	- Garden Nasturtium
Cytisus s.	- Scotch Broom	*Leptospermum l.*	- Australian Tea
Sidalcea m.	- Wild Hollyhock	*Conium m.*	- Poison Hemlock
Conium m.	- Poison Hemlock	*Senecio m.*	- German Ivy
Tropaedum m.	- Garden Nasturtium		

*Information taken from Howell 1981.

Since the initial revegetation programs were implemented, no cyclical maintenance program was incorporated. Fortunately, the exotic species at Ft. Funston and Lands End are not regenerating in pace with the reestablishment of native species. The large forest of *Cupressus macrocarpa* are overmature and large stands are deteriorating. As the canopy opens, native and exotic species of brush are invading the forest floor.

RESULTS

To make a formal trail system work, park managers need to make it attractive and functional. When possible the trail should be constructed in such a manner to correct or prevent further aggravation of an erosion problem.

Seven trails were developed in the Ocean District since 1979 to minimize erosion and discourage the use of social trails. Below is a brief description of four of the problem sites, the corrective design and the results of the project.

Ft. Funston Area

Ft. Funston Beach access trail— The cliffs of Ft. Funston provide some of the best hang-glide soaring in the United States. Hang-gliders landing at the base of the cliffs on Ft. Funston beach have hauled their kites straight up the sandstone cliffs. Severe erosion, gully development, and trampling of vegetation activated shallow seated slides. The sport of hang-gliding has also attracted masses of spectators. Park visitors also used the direct routes to the beach below, accelerating the erosion. Barrier fencing cannot be installed since it is a hazard to the pilots who occasionally lose control. Access to the beach by descending through the soft sand has always been enjoyable. Ascending the sand cliff was trudgery.

The Ft. Funston access trail built in the summer of 1982 by the Youth Conservation Corps incorporated both the sand-ladder and stair-trail. The railroad tie steps were built in two incised gullies along the chosen route. The upper flight had 37 steps and the lower stair-trail used 14 steps. Connecting the two stair-trails is a 246 ft long sand ladder constructed in 25 ft lengths. A 128 ft sand ladder (built in sections) extends from the base of the stair-trail down to the dynamic surface of the beach. The entire trail was built so pilots carrying their assembled kites can easily ascend the hill and have clearance through the gullies.

Lands End Area

Sutro Baths access trail— Prior to corrective measures, social trails descended from Merrie Way parking lot through a steep gully onto a dune slope to the service road below. The trail brought tourists and fishermen to the ruins of Sutro Baths and coastal fishing sites. The trail branched out in two directions which fed four additional social trails. Eight feet of soil was washed downslope by trampling. Two gully fields were formed at the base of the trails. Major concern developed over this particular trail because it crossed through prime habitat of the rare plant Dune Tansy *Tanacetum camphoratum.*

The situation was corrected by the Young Adult Conservation Corps with construction of two massive railroad tie stair trails in the main gullies, one at the base of the hill, the other at the top of the slope. On the sand slope between the stair trails, a 200 ft sand ladder was installed. Finger trails were blocked by a 4 ft barrier fence and railings. Although the main branch trail was blocked, vandals destroy the fence repeatedly.

The trail is used by hundreds of people on the weekend and concentrates approximately 75% of the foot traffic. The rare plant *Tanacetum camphoratum* has sprouted alongside the railroad tie steps behind the handrails. The gully is stabilized. Sand drift still occurs, but erosion on the sand slope where the sand ladder lays is minimal. This project is a good example illustrating the benefits of structural trail designs providing designated routes and erosion control to improve native plant habitat.

Dead Man Point Slide— The Lands End Trail east of Dead Mans Point crossed an ancient landslide which the city had used as an extensive dumping area for urban rubble. Over 4 ac of rubble nearly 25 ft deep was laid on the slide area. The heavy winter rains from January through March 1982 served as a catalyst to activate the slide area. Soil creep, followed by large tension cracks, evolved into a 400 ft long, five block rotational slump. The trail was destroyed. Social paths quickly developed across the serpentine flow creating mucky conditions. In June, 1982, the Youth Conservation Corps dug a trench 2 ft deep down the middle of the slide with branch ditches draining water from the slide's edges to the center of the slump. The purpose was to divert surface drainage away from the slip-surface of the slide and dry the surface material. The ditches were filled with rock rubble. A 36 ft boardwalk was built in four sections and simply rests on posts elevated 1 ft above the ground. The boardwalk sections can be easily lifted and carried in sections up slope as the slide is reactivated in the following winters (Fig. 5).

Eagles Point— An approximately 2 ac vista point overlooking the Golden Gate Channel with panoramic view extending from the Golden Gate Bridge to Point Reyes attracted thousands. Ground vegetation representing coastal prairie was originally disturbed by the planting of 30 *Pinus r.* and *Cupressus m.* in 1926. Trampling became heavy in the late 1960s when local surfers challenged the rocky shoreline below and tourists photographed the seascape. After the ground cover was destroyed, accelerated erosion removed 3-5 ft of topsoil. Eventually tree roots were exposed, killing 28 conifers.

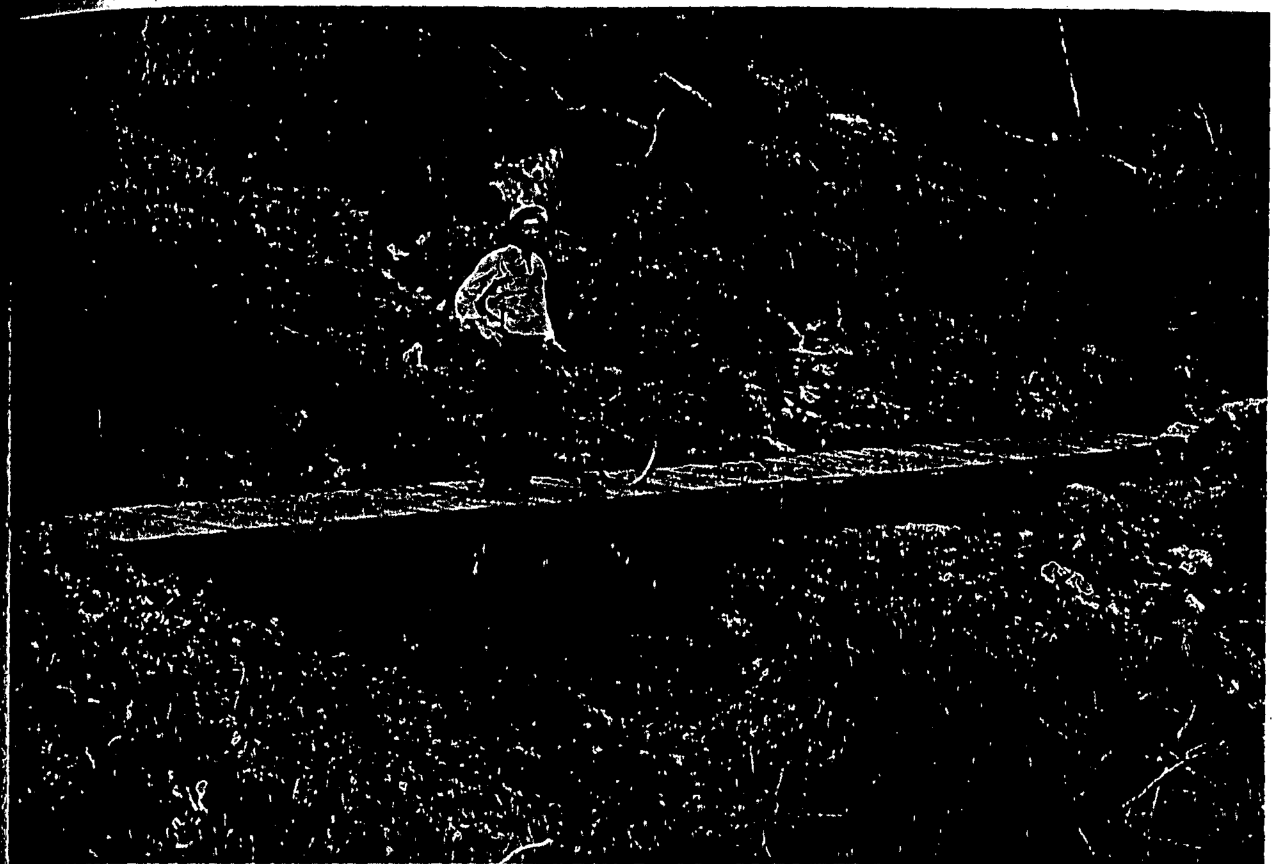


Figure 5

Four-Section Boardwalk

Resting on 4x4 posts this 36 foot boardwalk is constructed in four 9 foot sections that can be easily removed. Since this structure rests on an active five-block rotational slump slope failure, a dynamic structure was needed. The boardwalk allows joggers, dog-walkers, and horses to cross over the slide area without going through the mud. Drainage ditches filled with rock rubble collect spring seepage and direct it away from the edges of the slump where water adds lubrication and acceleration of movement.

...land erosion set in and two gully fields were established. The site became denuded of plant life (Milestone 1981).

In 1980, the Young Adult Conservation Corps followed by the Youth Conservation Corps installed an extensive stair trail, terraces, vista platforms, gabions, checkdams, and barrier fence at Eagles Point. Approximately 70% of the area was closed to the public with the remaining area carefully designed to provide scenic access and not contribute to the erosion. The entire vista was revegetated with native plant species from the Ocean District's nursery. The site has a solid cover of coastal prairie vegetation with Coyote Brush *Baccharis p.* and California Lilac *Ceanothus t.* planted strategically to serve as a protective barrier against foot traffic attempting to cross down the slope (Table 3).

Table 3

Evaluation of the Native Plant Revegetation Program
Eagles Point

Species	No. Transplanted (November 1981)	Field Count (July 1982)	Percent Survived
Yellow Bush Lupine *Lupinus arboreus*	385	346	90
Coyote Bush *Baccharis pilularis* var. *consanguinea*	357	181	51
Beach Sagewort *Artemisia pycnocephala*	91	52	57
Coastal Strawberry *Fragaria chiloensis*	75	75	100
Wild Buckwheat *Eriognum latifolium*	11	11	100
California Lilac *Ceanothus thyrsiflorus*	85	16	18
Seaside Daisy *Erigeron glaucus*	38	25	66

Evaluation of the Native Plant Revegetation Program

During the fall of 1981, 1042 native plants from the district's nursery were transplanted at Eagles Point (Milestone 1982). A vista point had over 3 ft of topsoil removed by park visitor trampling. Blowing sand, gale force winds and poor soils make conditions harsh. Today, visitor trampling is restricted to 30% of the area, with the remaining 70% contained behind a barrier fence. The excluded zones prove to have the highest success rate of survivability among the transplants. All plants came from the district's nursery in 1 gal containers (Table 3).

A 67.5% survival rate of native plants occurred. This included vegetation transplanted on both the protected and unprotected side of the barrier fence. For example, 65 *Ceanothus thyrsiflorus* planted around the vista and trail shoulders were trampled. Fourteen plants of 16 survived behind the barrier fence. *Lupinus arboreus* had a 10% mortality. However, hundreds of small seedlings that were broadcast from seed both from the park and natural disbursal from local shrubs exist across the site.

The Battery Davis Barrow Pit at Ft. Funston was totally barren of vegetation in 1980. The U.S. Army had used it as a sand quarry during their administration of the military reservation. Since GGNRA was established the area had a major horse trail through it. In the fall of 1981, the horse trail was realigned to run adjacent to the site and 298 plants were transplanted in the barrow pit. All stock came from the district's nursery in 1 gal containers (Table 4).

Table 4

Evaluation of the Native Plant Revegetation Program
Battery Davis Barrow Pit

Species	No. Transplanted (December 1981)	Field Count (July 1982)	Percent
Yellow Bush Lupine *Lupinus arboreus*	212	84	39
Beach Sagewort *Artemisia pycnocephala*	84	59	70
Coyote Bush *Baccharis p.* var. *consanguinea*	2	1	50

Low success rate for *Lupinus arboreus* can probably be attributed to wind burn, since most of the plants were over 24 in high. *Lupinus arboreus* does considerably better from broadcast seed then container stock specimens. *Artemisia p.* had a high success rate since the specimens were shorter in height and adapt better in transplants. *Baccharis p.* in this test is too small a sample to make quantitative recommendations.

DISCUSSION

The park's attempt to preserve the remnant fragments of coastal flora and reestablish native vegetation on erosional landforms is the first step in restoring the "fringe of wilderness". The increasing rise in park use increases the threat of trampling the vegetation. Also, the spread of exotic species such as Pampas Grass *Cortederia jubata,* Scotch Broom *Cytisus scoparius,* Wild Hollyhock *Sidalcea malvaeflora,* Hottentot Fig *Mesembryanthemum edule* and German Ivy *Senecio mikanioides* are major threats to the remnant fragments of native flora. In addition to the above, natural coastal erosion is constantly altering the topography of the coastal cliffs. Wave action is not succeeding in reducing the landmass of the San Francisco Peninsula at a dramatic rate. However, it is activating numerous shallow seated slides. In the winter of 1982, 30 slides were activated along the coast. Many little gardens of coastal strand vegetation slipped into the Pacific Ocean leaving behind exposures of graywacke, sandstone, and serpentine rock.

While exotic species are spreading, visitors are trampling coastal prairie habitat and coastal erosion is swallowing up the few remaining slopes of native flora, there are also natural processes improving the habitat. Evidence of this can be seen at Ft. Funston. Since the military's plantings of *Mesembryanthemum e.* throughout the entire Ft. Funston area in the 1950s, there has not been a continued upkeep. As a result, ***Lupinus arboreus*** is reestablishing itself throughout the entire area. Also, Mock Heather ***Haplopappus ericoides*** and ***Baccharis pilularis*** has sprouted in the protective ravines and interior hillocks. *Mesembryanthemum e.* is dying off in many areas, while thriving in other areas. ***Lupinus arboreus*** is filling in the voids. When the military leveled the upper bluffs of Ft. Funston in 1954, the dunes were bulldozed over the 170 ft cliffs and vegetated. After 30 yrs, coastal erosion has exposed nearly the entire cliff face that was buried by the sand fill.

Another example of habitat restoration can be seen in the Lands End area. The dominant foliage of *Cupressus macrocarpa* is not regenerating. Old age and harsh environmental conditions are deteriorating the large groves. The canopy is opening and a variety of species, both indigenous and exotic, are invading the forest floor. It is therefore important to introduce native species of plants to prevent the noxious species from dominating the area.

Another slow process occurring is nature's removal of the imported fill and concrete rubble dump sites in Lands End. Fifteen slope failures occurred in Lands End area during the winter of 1982. Eleven of these erosional landslides moved fill and rubble downslope into the waters of the Golden Gate Channel. In time, the slopes will be nearly clear of the rubble and fill material that was haphazardly dumped on the historical landslide scars. The combination of structurally weak geologic formations, blocked drainages and excessive weight make the dump sites escalators into the Pacific Ocean. Both time and natural processes are working in favor of restoration of the landscape.

CONCLUSIONS

In less than 30 yrs, dramatic changes in land use have brought about significant losses in the native flora of Golden Gate NRA. Since the 1950s, when urbanization of San Francisco was completed, the only land areas where coastal vegetation existed was confined to remnant fragments on unstable slopes of the San Francisco Headlands.

An appreciation of native flora has developed since Golden Gate NRA was established. Progressive steps are being taken to halt man-caused erosion. Extensive trail projects utilizing new designs to minimize the impacts of increasing visitation and concentrate foot traffic are being implemented. Hillslopes which were barren and heavily eroded are being restored with native plant communities propagated in the district's Native Plant Nursery.

Continued enhancement of the park's native flora is dependent on controlling the spread of exotic species, reducing accelerated erosion, eliminating social trails by designating main traffic routes and continuing the revegetation of native plants. It is important that the park staff and citizen volunteer groups are not misguided in attempts to maintain the forest of *Cupressus macrocarpa* in the Ocean District. The mind-set that parks must have trees can be changed by pointing out the unique beauty of the coastal flora and the importance of preserving the habitat of San Francisco's five known rare and endangered plants. The existing stands of Monterey Cypress and Monterey Pine provided little if any protection against strong winds to the Richmond and Sea Cliff Districts as claimed, except for those homes directly behind the trees.

Wayne Savage, of San Jose State University's Botany and Plant Ecology Department, who composed the initial plant list of GGNRA in 1974, warned in his report ". . . the status quo should not be considered as an acceptable alternative since a continuation of negative impact at current rates will lead to the ultimate extinction of these rare plants . . . A loss of scientific, educational and aesthetic value that is irreplaceable" (Savage 1974).

It is the responsibility of the National Park Service, as the land managers of the San Francisco Headlands, to sew together the precious tattered remnants of native flora into a permanent "fringe of natural wilderness."

MANAGEMENT RECOMMENDATIONS

1) Protection and enhancement of the habitat where the rare and endangered plant species naturally occur in Golden Gate.

2) Continue the reintroduction of native plants in areas which have become denuded and trampled of vegetation, utilizing the resources of the district Native Plant Nursery.

3) Accelerate the eradication of exotic and noxious plants in the Ocean District. Incorporate the labor of volunteer groups in this campaign.

4) Prohibit the planting of any exotic species of plants or trees within the District boundary with exception of Sutro Heights Park.

5) Continue the formalization of designated trails and the elimination of social paths.

6) Educate the public to the significance and botanical importance of preserving San Francisco native flora.

ACKNOWLEDGEMENTS

Thanks are extended to Frank Dean and Mark Kelly for their work, support and encouragement in our common goal to protect and enhance the native flora of the San Francisco Peninsula.

WHIPPLEA MODESTA TORR: PROMISING NATIVE FOR EROSION CONTROL IN THE REDWOOD REGION

J.H. Popenoe, L.J. Reed, and R.W. Martin

ABSTRACT

Whipplea modesta is a ground-hugging, slightly woody perennial common in cutover redwood forests. Its low growth and spreading habit provide effective erosion control. *Whipplea* is very sparse in uncut forest, apparently populating cutovers from buried seed. Culture from seed has not proven practical as few seeds are viable. Germination is slow and sporadic and new seedlings are too small for outplanting. *Whipplea* roots freely and is easily propagated from cuttings. Growth has been suboptimal in the nutrient-poor subsoil typical of rehabilitation sites. A greenhouse bioassay has established that fertilizer or compost greatly accelerate growth in subsoil, and future field use of compost is intended.

INTRODUCTION

In 1978, Congress expanded Redwood National Park to increase protection for irreplaceable resources within the Redwood Creek watershed. The majority of new park land was cutover redwood with miles of temporary logging roads on steep mountain slopes. De-stabilized slopes threatened to release voluminous sediment into tributary basins of Redwood Creek during major winter storms. Congress authorized the park to rehabilitate its portion of the watershed in an effort to minimize these induced threats and, at the same time, to encourage return of natural patterns of vegetation.

Whipplea modesta is a conspicuous pioneer on cutover lands in the redwood region. The species is present on most, if not all, logged units in the park. *Whipplea* is a creeping subshrub that roots as it spreads. Under favorable growing conditions it forms a continuous groundcover, ideal for control of surface erosion. Although common on logged lands, *Whipplea* rarely occurs in the dense shade under redwood forests. Before logging, it is most abundant on relatively dry, rocky sites with an open or light overstory (Becking 1982) in light intensities ranging from 4% to 39% of full sunlight (Waring and Major 1964). *Whipplea* was studied to determine propagation and growth requirements and to evaluate its usefulness in the watershed rehabilitation program. Further documentation on the role of *Whipplea* in watershed rehabilitation has been reported by Hektner et al. (1982), Madej et al. (1980) and Reed and Hektner (1981, 1983).

Several ways of propagating *Whipplea* were investigated: 1) dispersing seed in the field; 2) transplanting plants from one site to another; and 3) growing plants from seed or cuttings in a greenhouse for outplanting. The challenge in terms of growth requirements is dealing with deficient rooting media. Sites needing intensive revegetation are most often recontoured roads in subsoil or into subsoil. The upland subsoils in Redwood National Park are very low in organic matter and available nutrients. *Whipplea* would be of little use in erosion control or revegetation if it could not be made to sustain adequate growth on such sites. The growth under these deficiencies and response to fertilizer or compost were of primary importance in this study of *Whipplea*.

METHODS

Germination Trials

Seed was hand collected from plants in August 1980. Treatment trials were initiated in September and October 1980 by selecting filled, hard seed, sowing the seed in standard nursery flats of potting mix and covering the seed to about 1 mm depth. Flats were watered regularly and kept in a greenhouse

National Park, Operations Center, P.O. Box 7, Orick, CA 95555

where the monthly average temperature ranged from about 10° to 13° C. Flats were checked for seedlings about twice a week and each new seedling was identified with a colored pin. The experiment was terminated in August 1981.

Buried Viable Seed

Ten locations were selected in old-growth redwood forest and 10 in adjacent 8-yr-old clearcut near the trailhead to the Tall Trees Grove in Redwood National Park. Four samples were collected from each site in November 1981:

1) 0 horizon: forest litter, decomposing litter and duff

2) mineral soil: 0 cm - 5 cm depth

3) mineral soil: 5 cm - 15 cm depth

4) subsoil control

Sample areas were a 20 cm by 50 cm rectangle. The subsoil controls were collected from a roadcut at approximately 1.5 m depth. Samples were placed in standard (40 cm x 40 cm) greenhouse flats on a covered table and watered regularly. The flats were inventoried for seedlings in July 1982.

Vegetation on the old-growth sites was redwood forest. Canopy trees included *Sequoia sempervirens, Pseudotsuga menziesii, Lithocarpus densiflora, Tsuga heterophylla* and *Arbutus menziesii.* There was a dense shrub layer including *L. densiflora, Vaccinium ovatum, Rhododendron macrophyllum* and *Mahonia nervosa,* and a very sparse herb layer which included *Polystichum munitum, Trientalis latifolia, Smilacina racemosa, Viola sempervirens* and *Trillium ovatum.* No *Whipplea modesta* was observed in the old-growth sites.

Vegetation on the cutover sites was dominated by the pioneer shrub, *Baccharis pilularis* ssp. *consanguinea,* and subshrub, *Whipplea modesta.* Also present were seedlings of *P. menziesii, T. heterophylla, Lathyrus Torreyi, L. pauciflorus, T. latifolia* and *Iris Douglasii,* and remnant individual shrubs and resprouting trees. The vegetation would be classified in the *Baccharis/Whipplea* Type according to Muldavin et al. (1981), bordering most closely on their *Rhododendron/Vaccinium* Type.

Rooting of Cuttings

Contracts were let for rooting of *Whipplea* cutting in 1979, 1980 and 1981. Contractors for the 3 years were; NOR CAL Nursery of Eureka, California; Simpson Timber Company Nursery, Korbel, California; and FLAPCO Nursery, Phillipsville, California. Techniques, to the extent they are known, are described in the RESULTS section.

Outplanting Trials

Several kinds of planting material have been tested in Redwood National Park since the expansion of 1978. For *Whipplea,* these include unrooted cuttings, field transplants and outplantings of containerized nursery stock. Cuttings consisted of healthy shoot tips 10 cm to 20 cm long from the current year's growth. These were inserted deeply enough to bury several nodes and watered in. Cutting and planting were done during the winter. Field transplants consisted of clipped plants with a soil ball about 30 cm in diameter. Transplanting was done during the winter. Two kinds of containerized *Whipplea* have been used. The first was rooted cuttings in 5 cm (2 in) nursery pots. These were planted with garden tools and, in rocky cutbanks, with the aid of geology hammers and pulaskis. The 15 cm (6 in) standard conifer planting tube was also used for rooted cuttings. The procedure for this type of container was to punch a hole with a dibble, slip the rooted cutting into the hole and firm the soil around it by foot. Containerized stock has been planted from January to May.

Soil Bioassay Using *Whipplea*

Subsoil (B horizon) samples were collected at two locations on C-Line Road, Redwood National Park. The two selected sites were judged most representative and closest to median values in color, texture, percentage, coarse fragment percentage and pH of 37 described sites. The soil on the first site was a brown Inceptisol derived from graywacke sandstone and shale. This soil appears on the 1961 Soil-Vegetation map as "Hugo" (Alexander et al. 1961). The soil on the second site was a red Ultisol derived from schist. This soil would have been called "Sites" on the 1961 Soil-Vegetation map.

Analytical subsamples were sent to the Oregon State University Soil Testing Laboratory for analysis of total N, OM, pH (H_2O suspension), P (dilute acid fluoride), exchangeable cations and CEC. The analysis methods are described by Berg and Gardner (1978). Mineralizable N was determined at North Coast Laboratory, Arcata, California, according to Powers (1980), except that ammonium was determined by ion-specific electrode (Bigg and Alexander 1980) rather than by distillation.

The bioassay subsamples were sieved of rock fragments coarser than 6 mm (¼ in). Vegetatively propagated *Whipplea* were planted bare-root (and still nearly dormant) in 10 cm (4 in) pots in April 1980. Tops were harvested in June 1980, 82 days after planting. Separate samples were taken of the current year's growth and of remaining older shoot down to soil level once the current year's growth had been clipped away. The clipped material was dried for 24 hrs at 80° C, then weighed.

Experimental design was a randomized complete block design as follows:

2 SOIL SOURCES x 2 FERTILIZER LEVELS x 2 COMPOST LEVELS x 3 BLOCKS x 4 REPLICATES PER BLOCK

Fertilizer levels were 0 and 1.78 g/pot of Osmocote (14-14-14) slow-release fertilizer. The rate was 3/4 that recommended by the manufacturer for ornamentals in well drained, porous soil. Compost levels were none and one-third by volume (30 g/pot, dry) University Formula redwood compost. A sample of the compost was sent for analysis along with the soils. The dry 2 mm soil fractions averaged approximately 600 g/pot without compost and 400 g/pot with compost.

RESULTS

Seed Germination Trials

Primary observations are from the control treatment which consisted of 200 seeds sown in a standard nursery flat.

Whipplea seeds are in globose, four- to five-celled capsules about 2 mm in diameter. There is one seed per carpel. Sound seeds are hard. At least half of the seeds collected were unfilled, soft, undersized or otherwise physically defective. Given hard, selected seed, there was 8% germination (16 out of 200) 10 months after sowing in a flat with no other treatment. The first seedling emerged in November after 69 days. The sixteenth seedling emerged in late June. Most seedlings appeared in three to four months. The hypocotyl emerged first. It was common for the seedcoat to be pushed up, cotyledons within, above the planting medium.

Whipplea's true leaves are strigose but those of the cotyledons are glabrous. Newly emerged cotyledons are 1 mm long, 0.5 mm wide, linear and truncate at the base. The shape changes as they grow. After about 1 wk they are 2 mm long, 1 mm wide, linear to lanceolate, and truncate. After 2 or 3 wks they are 4 mm long, 2.5 mm wide, ovate to oval, and rounded at the base; the first true leaves are just emerging. At 4 to 6 wks, the cotyledons reach their maximum size: 6 mm long, 3.5 mm wide, oval, and rounded to cuneate at the base; there is one pair of true leaves. If transplanted to 10 cm pots at this time, given regular watering and fertilization, tops grow to about 15 cm across in six months.

Additional trials were run to determine environmental conditions which might promote germination. Each of these tests used 50 seeds in pots. Conditions and results were as follows:

1) greenhouse (10° C to 13° C) - two seedlings/50 seeds

2) excelsior burned over seeds on a dry surface, then treated as (1) - no germination

3) boiling water poured over seeds, then treated as (1) - no germination

4) stored moist in pot refrigerated at 4° C for 30 dys, then treated as (1) - no germination

5) moistened 24 hrs in planting medium, frozen 24 hrs, then treated as (1) - two seedlings/50 seeds

6) indoors (16° C to 18° C) - no germination. The surface of the planting medium was covered with fungal mycelia. Of 21 seeds or carcasses found, nine were still hard and intact.

There is no evidence, based on these trials, that any treatment stimulates germination. On the other hand, there is no evidence on what might happen if a fungicide were used, and since there were no replicate pots, it is possible that an outbreak of disease may have obscured a potential positive response.

Buried Viable Seed

The densities of *Whipplea* seedlings which germinated in the flats in samples from old-growth forest, cutover forest and subsoil controls were as follows:

	seedlings/m^2
old-growth 0 horizon	8
soil, 0 cm - 5 cm depth	12
soil, 5 cm - 15 cm depth	15
	25
cutover 0 horizon	13
soil, 0 cm - 5 cm depth	4
soil, 5 cm - 15 cm depth	0
	17
subsoil controls	0

The hypothesis that the vertical distribution of seeds was the same for old-growth and cutover forest was evaluated by Chi square test. The Chi square statistic was 8.99 (d.f. = 2), which is significant at $p = 0.012$.

Rootings of Cuttings

Cuttings were collected by NOR CAL Nursery in August 1979 under the supervision of Mr. Jim Simmons. According to Mr. Simmons, the cuttings were all dipped in the rooting hormone, Rootone 10. He first tried rooting the cuttings under mist in flats of vermiculite. He said that he had his best results rooting the cuttings directly in 5 cm (2 in) pots on benches with less moisture. Some of the cuttings rooted more quickly than others and some cuttings never rooted at all. Mr. Simmons estimated 80% rooting success overall. There were 9,130 rooted *Whipplea* delivered to Redwood National Park in February 1980.

In August 1980, park personnel provided Simpson Nursery with approximately 30,000 *Whipplea* cuttings and Rootone 10. Cuttings were rooted directly in 15 cm (6 in) planting tubes commonly used for conifer outplanting. Just as during the previous year, rooting was somewhat uneven. There were 13,800 rooted *Whipplea* ready for outplanting during winter and spring 1981. Estimated rooting success was 46%.

In September 1981, park personnel provided FLAPCO Nursery with approximately 42,000 *Whipplea* cuttings and Rootone 10. FLAPCO delivered 1,713 rooted *Whipplea* in 15 cm tubes in April 1982. Estimated rooting success was 4%.

Outplanting Trials

Survival of different kinds of *Whipplea* outplantings are shown in Table 1. Not all planted material was found. It was difficult to find *Whipplea* carcasses under field conditions because stem remains are very small and decompose rapidly. Growth of staked plants is documented in Table 2. The diameters were estimated by using the mean of the plants' widest and narrowest girths.

Table 1

Summary of First-Year Outplanting Survival

Outplanting Method	Number Planted and Monitored	Number Found Alive	Estimated Survival
Unrooted cuttings	500	52	10%
Field transplants	124	60	48%
Rooted cuttings (5 cm pots)	4,009	1,849	46%
Rooted cuttings (15 cm tubes)	41	22	54%

Table 2

Summary of Diameter Measurements on Outplanted *Whipplea*

		First Year (cm)		Second Year (cm)	
Planting Method	Number	$\bar{x}$	s	$\bar{x}$	s
Field transplants	8	13.3	4.1	15.6	4.1
15 cm tubes	20	6.1	2.2	11.6	5.1

Bioassay

Results of the soil analyses are presented in Table 4.

Data from the bioassay consisted of an initial shoot weight and additional (current year's) shoot weight for each of the 96 plants in the experiment. The raw data had an upward-skewed, rather than a bell-shaped, distribution and variances differed among treatments. Once data were transformed by the algorithm, $\log_{10}(4X + 1)$, tails of distributions evened out and, when variances among treatments were compared, the variances were not significantly different using Bartlett's test of homogeneity $p = 0.05$). Transformed data are plotted in Figs. 1 and 2.

Treatment effects were evaluated using packaged analysis of variance (Nie et al. 1975) and analysis of covariance (Hull and Nie 1981) programs. The first analysis of variance on transformed initial shoot weight established that there were no statistically significant differences ($\alpha = 0.05$) among treatments at the onset of the experiment. The second analysis of variance on transformed data (Table 5) revealed significant differences in current year's growth due to fertilizer level and due to fertilizer-compost interaction. The analysis of covariance (Table 5) used initial shoot growth as covariate and current year's growth as the principle, dependent variable. There were large, highly significant differences due to fertilizer and fertilizer-compost interaction. There were also small but significant soil-compost interaction and fertilizer-compost-block interaction effects. A second covariance analysis evaluated parallelism among regression coefficients. There was no significant difference $p = 0.05$) in regression coefficients among treatments.

Means of transformed current year's growth were converted back to their real values for comparison of growth rates. These values are given in Table 3, along with leaf colors observed.

Table 3

Mean Shoot Weights (g) and Foliage Colors Under Different Fertilizer and Compost Treatments

	No Compost	With Compost
No fertilizer	.212 light yellowish green (5GY 6/8-7/8)	.409 medium to dark green (7.5GY 4/4-4/6, 5GY 4/6-5/6)
With fertilizer	.736 dark green (7.5GY 4/4-4/6)	.512 medium to dark green (7.5GY 4/4-4/6, 5GY 4/6-5/6)

Since LSD 0.05 = 0.036, treatments are all different from one another.

Table 4

Properties of Soils and Compost used in *Whipplea* Bioassay

Sample Description	Color (moist)	Texture	pH	OM (%)	Total N (%)	Mineralizable N (ppm)	P (ppm)	Exchangeable cations (me/100g) Ca	Mg	K	Na	C (me/
Bt horizon of Ultisol derived from schist	2.5YR 4/6	Clay	5.2	.79	.07	12	4	1.0	.52	.31	.03	10
Bw horizon of Inceptisol derived from graywacke sandstone	10YR 5/4	Clay loam	5.7	.85	.06	29	12	2.0	1.2	.56	.06	11
University Formula redwood compost				98.00	.58							

Table 5

Analysis of Variance and Analysis of Covariance on *Whipplea* Shoot Growth

Source of Variation	SS	df	MS	F	SS′	df	MS′	F′
Soil	.057	1	.057	3.783	.074	1	.057	10.231**
Fertilizer	.919	1	.919	60.807**	.740	1	.740	101.650**
Compost	.011	1	.011	.697	.005	1	.005	.674
Blocks	.074	2	.037	2.449	.050	2	.025	3.425
Soil x Fertilizer	.015	1	.015	.996	.026	1	.026	3.622
Soil x Compost	.006	1	.006	.389	.038	1	.038	5.278*
Soil x Block	.005	1	.005	.165	.011	1	.011	.741
Fertilizer x Compost	.426	1	.426	28.188**	.344	1	.344	47.246**
Fertilizer x Block	.000	2	.000	.015	.002	2	.001	.162
Compost x Block	.043	2	.022	1.425	.024	2	.012	1.648
Soil x Fertilizer x Compost	.002	1	.002	.136	.029	1	.029	3.937
Soil x Fertilizer x Block	.003	2	.001	.092	.012	2	.006	.803
Soil x Compost x Block	.007	2	.003	.229	.001	2	.000	.007
Fertilizer x Compost x Block	.066	2	.033	2.178	.088	2	.044	6.050**
Soil x Fertilizer x Block	.065	2	.033	2.165	.040	2	.020	2.739
Regression					.571	1	.571	78.544**
Residual	1.088	72	.015		.517	71	.007	
Total	2.787	95						

* = Significant at .05 level ** = Significant at .01 level

SS = Sum of squares SS′ = Sum of squares, adjusted for covariate

MS = SS/df MS′ = SS′/df

F = ANOVA F Statistic F′ = ANCOVA F Statistic

Data were transformed by the algorithm, $\log_{10}(4x + 1)$, prior to analysis.

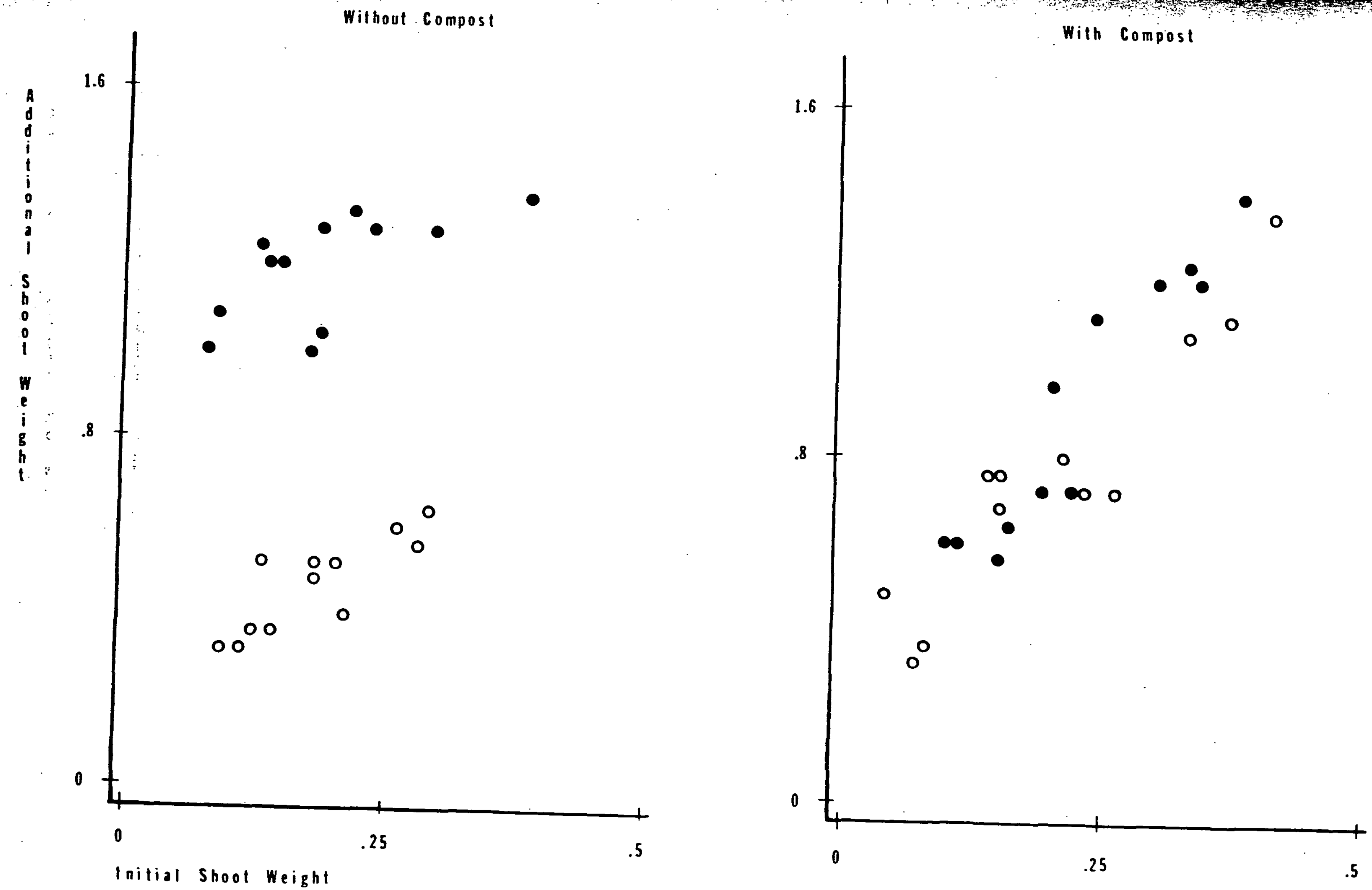


Figure 1

O Unfertilized

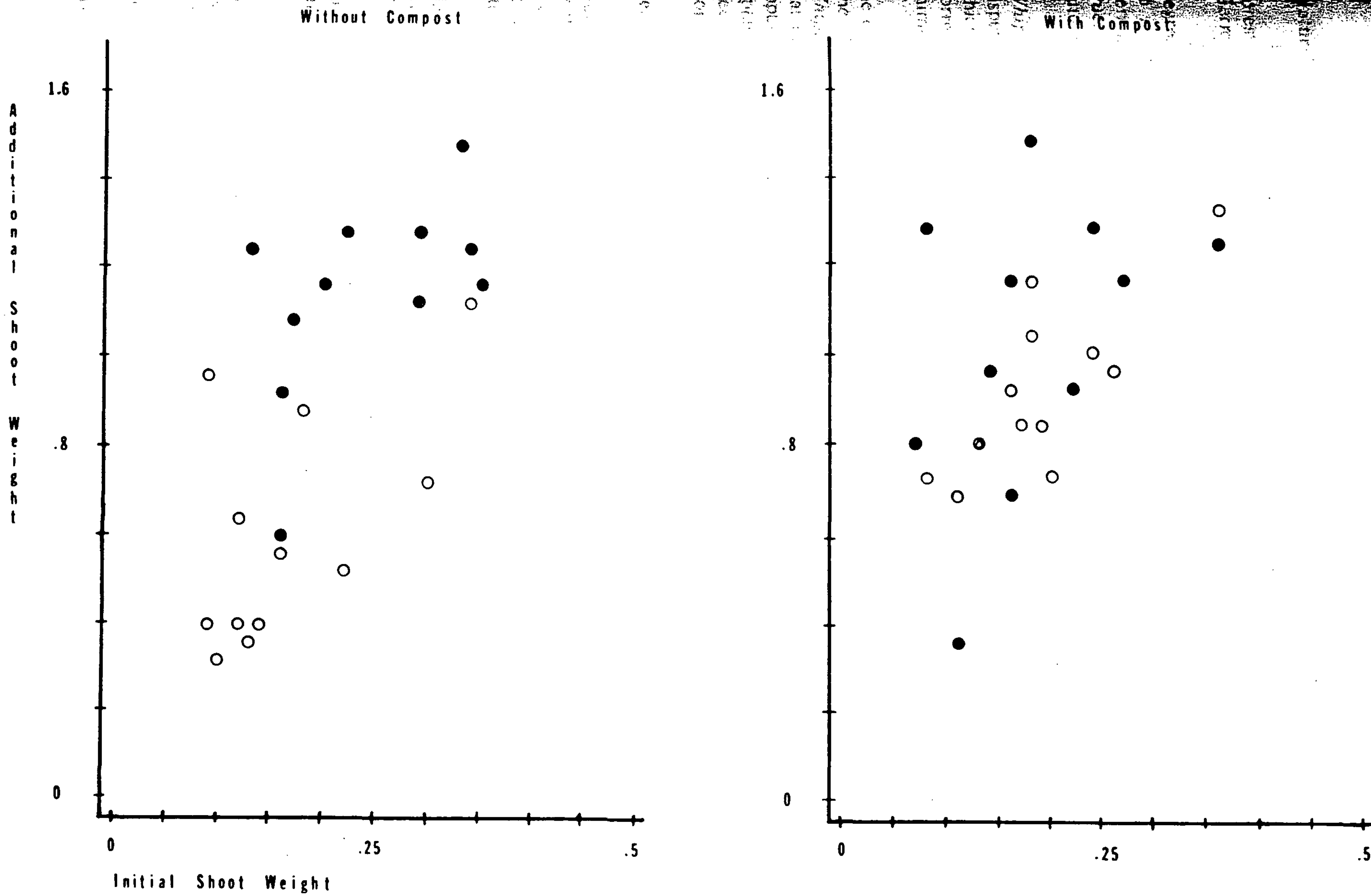


Figure 2

Whipplea bioassay results for plants grown in

DISCUSSION AND CONCLUSIONS

Natural Population Dynamics

Whipplea modesta is abundant on cutovers in the redwood region, although sparse in old-growth forest. Popenoe (1981) hypothesized that *Whipplea* pioneers in cutovers mostly from buried seed. Germination of *Whipplea* in soil from old-growth forest confirms the presence of viable buried seed.

The vertical distribution of viable seeds in different layers of the forest floor reflects, to a large degree, how buried seeds were deposited over time, the extent to which forest floor layers are subject to mixing, and the length of time that seeds remain viable. In old-growth forest there was more germination from mineral soil samples than from overlying organic layers. In cutovers, the reverse was true. Furthermore, the density of seedlings was greater in mineral soil from old-growth than from cutover areas, even though no *Whipplea* was observed in the old-growth forest.

The buried seed in old-growth areas could have been deposited in place or transported. Since *Whipplea* is very low growing and its seeds lack structures for wind dispersal, the only likely means of dispersal from the location of parent plants is by animals. There are at least two possible mechanisms which could account for the *Whipplea* seeds buried in old-growth redwood forests: seeds could lie dormant between disturbances which open the forest canopy; seeds are dispersed from open areas by animals and the animals maintain and can restore *Whipplea* seed populations in the forest floor.

Seed germination in the 8-yr old cutover was confined mostly to the organic layer. Compared to the old-growth forest, there were more viable seeds in the organic layer but fewer in the mineral soil. The abundance of seed in the organic layer is probably a reflection of the recent seed crops from *Whipplea* covering the sites. Since there were fewer viable seeds in the mineral soil samples, it may be that more than a decade is required for the seed to work down and to restore that portion of the seed population. From the meager data we have, we suspect that in mineral soil the rate of seed replenishment, period of seed viability and resulting rate of population turnover of buried *Whipplea* seed is more than a decade. The rates of seed replenishment and dispersal are too slow for rapid, spontaneous re-population to occur in areas where surface soil has been removed.

Methods of Population Restoration

Propagation methods were compared and outplanting was monitored to develop techniques for re-establishing *Whipplea* effectively and at minimum cost. Buried seed offers a reasonable explanation for the lush (50%) *Whipplea* cover on logged forest lands where A horizons are present. The density of seedlings in greenhouse flats would be enough to produce a continuous cover in just a few years. On the other hand, there was not such an excess of *Whipplea* seedlings that the floor of virgin forests or cutovers could be tapped efficiently for seed to restore areas of exposed subsoil.

Collection of seed directly from the plants was also tried. Although there were many seeds and collection was feasible, actual culture from seed was difficult because: 1) few seed were viable; 2) germination was slow and sporadic; and 3) seedlings remained too small for outplanting until their second year.

Whipplea roots freely and is easily propagated from cuttings. Among the vegetative methods, results show that rooted cuttings and transplants have four to five times higher rates of survival than unrooted cuttings. Rooted cuttings may require twice the labor, but the added investment more than pays off in performance. Increased survival also results in better control of plant spacing. Although field transplant survival compares favorably with survival of rooted cuttings, the larger transplants are much more costly to perform. There are often shortages of healthy, on-site plants to move, and field transplanting requires soil and site disruption disproportionate to other methods and may be somewhat wasteful of material.

Rooted cuttings have been the most effective and cost-effective way of establishing *Whipplea* on bare soil sites to date. Planting was much faster with standard (15 cm) planting tubes than with 5 cm nursery pots. Container selections should be application-specific, since plants grown from the two types of container did not differ significantly in rate of survival. In general, the nursery pots are well suited for horticultural projects. Silvicultural equipment, including planting tubes, are better for large-scale wildland revegetation, including that undertaken in Redwood National Park.

Technique may be very important to the success of vegetative propagation. In observations to date, the failure rate increased when temperatures were greater than 15° C (59° F) when there was excessive moisture and when cuttings were taken later in the year. The highest success achieved so far has been 80%. Even greater success may be possible with technique refinement.

Soil Requirements

In their classification of vegetation types following logging of redwood forest, Muldavin et al. (1981) distinguished a *Baccharis/Whipplea* Type from a *Hypochoeris/Aira* Type. This floristic distinction is a consequence of two different kinds of disturbance and soil conditions. The *Hypochoeris/Aira* Type is best represented on skid trails and abandoned roads where the A horizon has been removed. It is dominated by ruderal, primarily wind-dispersed species. The *Baccharis/Whipplea* Type occupies tractor islands where the A horizon has been disrupted but not removed. The vegetation includes seedlings arising both from buried seed from the forest (such as *Whipplea)* and wind-dispersed seed (such as *Baccharis).*

In logged redwood forests, *Whipplea modesta* is most vigorous and prolific on lumpy mounds of surface soil interpreted to have been "beds" or "layouts" prepared to cushion falling trees. These "beds" apparently contained many *Whipplea* seeds. They were rich in organic matter and, as a consequence of the fresh disturbance, had a high rate of mineralization and high soil fertility. *Whipplea* appear to have responded vigorously to these conditions.

In contrast, when *Whipplea* is outplanted in subsoil on rehabilitation sites, its growth is suboptimal. The subsoil is much less fertile than A horizon layers for which *Whipplea* is adapted. *Whipplea* fails to achieve the high cover values needed for effective erosion control. A pebbly erosion pavement forms and, since there is little ground cover, there are few safe sites on or within the soil for seed storage. It is unlikely that *Whipplea* can replenish its seed population under these circumstances. In short, it is doubtful that *Whipplea* outplanted into infertile subsoil accomplishes either significant erosion control or vegetative restoration.

The bioassay experiments with fertilizer, compost, or both show the nutrient deficiencies of subsoil can be readily corrected. However, fertility treatments must be properly timed. Popenoe (1981) and Reed and Hektner (1983) observed that when rapid-release fertilizer is broadcast, timing plays a major role in survival of native species. Fertilizer broadcast in fall favored ruderal species. With fall fertilizer, ruderals grew rapidly, pre-empting space from native pioneers, including *Whipplea* and *Baccharis. Baccharis* and *Whipplea* germinate during winter and they were put at a competitive disadvantage. On the other hand, spring fertilization increased both the size and density of these natives. Broadcast fertilization should be timed to the phenology of the desired species.

Compost yields a gradual release of plant-available nutrients from organic matter decomposition. The process mimics that found in native A horizons and its benefits should persist also long enough to establish a good stand of *Whipplea modesta.* Organic matter can be viewed as a carbon substrate for saprophytic micro-organisms. Given the excess of carbon in compost, decomposers are limited by levels of other elements, particularly nitrogen. If levels of nutrients are increased through application of fertilizer, one may anticipate that decomposer populations will grow, converting the soluble nutrients into proteins and other organic compounds. These organic compounds will have become unavailable to higher plants, such as *Whipplea.* In the bioassay, we suspect that saprophytic organisms with compost acted to buffer levels of available nutrients. In treatments without fertilizer, *Whipplea* grew more vigorously in response to compost, probably due to the mineralization associated with increased biotic turnover. In treatments where fertilizer was added, *Whipplea* grew faster without compost, probably due to competition for the same available nutrients by a growing microbial population.

Redwood National Park has built a facility to produce compost and the park is now well along in putting it into operation. The composting operation has the potential to dramatically improve outplanting performance on some of the more difficult rehabilitation sites in the park.

MANAGEMENT RECOMMENDATIONS

1) Conduct trials to evaluate the effectiveness of re-establishing *Whipplea* by direct broadcast seeding from seed collected from plants.

2) Continue propagating *Whipplea* from cuttings. This has proven the most effective method so far for rapid re-population of bare soil sites in the park.

3) Fertile soil is needed to produce a vigorous stand of *Whipplea*. Treat surface soil as a special resource during all restorative, earth-moving operations. Avoid burying it under subsoil. Plant *Whipplea* only in A or upper B horizon soil or in deeper subsoil improved with compost, a slow-release fertilizer, or broadcast fertilizer applied in early spring. Substitute less demanding species for the most hostile, infertile sites.

ACKNOWLEDGEMENTS

Thanks are extended to Mary Hektner, Glenna Holgersen and Bud Hawkins for their help in obtaining data on specifications and successes with *Whipplea* contracts and purchase orders. Bonnie Griffith collected data on survival and growth of *Whipplea* tube stock. Gregg Riegel and Neil Sugihara collected field samples for the buried seed study and Gregg did releves to characterize the composition of the old-growth forest. Jack Lewis made valuable editorial comments to the manuscript. USFS Redwood Sciences Laboratory, Arcata, provided space for the bioassay. We are especially grateful to Jim Simmons of NOR CAL Nursery for sharing his experience and recollections on propagation of *Whipplea modesta*.

STAND COMPOSITION AND DIAMETER DISTRIBUTION IN SIXTY-YEAR-OLD SECOND-GROWTH COAST REDWOOD FORESTS

W.S. Lennox

ABSTRACT

A preliminary examination of tree species composition and diameter distribution 60 yrs following logging of coast redwood forests had been conducted. Nineteen 0.25 ac plots were inventoried. Three distinct upland coast redwood second-growth forest types were identified and described on a preliminary basis. The xeric upper slope type occupies upper convex slopes and ridges and is dominated by *Lithocarpus densiflorus* (tan oak) sprouts with a smaller number of *Pseudotsuga menziesii* (Douglas-fir) and *Sequoia sempervirens* (redwood, coast redwood). The dry-mesic type found on mid-slope sites is dominated by Douglas-fir, with a minor component of redwood and tan oak. A third type, occurring exclusively on small landslides, is dominated by redwood seedlings with a lesser number of Douglas-fir and tan oak. A lower slope non-landslide type is present but was not defined in this work. Basal area in all three types is about equal. Redwood basal area is dominated by stump sprouts in the dry mesic type, and seedlings in the xeric and landslide type. Redwood cover is presently lower than before logging of the pristine old-growth stands. Despite high mortality of suppressed trees, Douglas-fir is expected to remain the dominant conifer for the next 500 yrs.

INTRODUCTION

The objectives of this research were to describe the development of advanced second-growth forests following logging of forests dominated by *Sequoia sempervirens* (redwood, coast redwood) and to develop a classification hierarchy based on species and diameter distribution. These results will be used with other information from old-growth and other young stands to define successional patterns and yield management recommendations for second-growth forests on park lands.

The advantages of a classification system in defining forest vegetation mapping units has been recognized by many authors (Rowe 1961, 1971, Kuchler 1973). Jones (1969), Carmean (1975), and Daubenmire (1976) have developed classification procedures for existing forest communities which are providing the foundation for collecting and interpreting research results and, more importantly, are being used to extrapolate management techniques to appropriate new sites. The need for a hierarchial classification system that accommodates variation in existing vegetation has been recommended by Daubenmire (1966), and Viereck and Dyrness (1980) and as the basis for further systematic research of successional forest stands. Daubenmire and Daubenmire (1975) encourage a more intensive effort to be directed at defining ecological subsystems of redwood forests. This study is intended to provide such a classification of discrete homogeneous units within advanced second-growth coast redwood forests. In combination with a classification of 1 to 10 yr-old coast redwood clearcuts (Muldavin et al. 1981) and a coastal setting old-growth research natural area watershed (Lenihan 1983) a substantial effort at describing successional trends through classification is underway.

Stand density in relation to time has been described for both old-growth and second-growth forests including redwood (Harper 1977). Tree species composition and diameter distribution of an "even-aged" second-growth stand is significantly different than the old-growth stand that previously occupied the site. Regeneration of fast growing shade-intolerant species in second-growth stands is the reason their composition differs from old-growth uncut status (Seidel 1974). However, in time there is a trend toward dominance by more shade-tolerant tree species (Seidel 1974). The old-growth redwood forest was "all-aged", containing trees in an age range from germinating seedlings to mature canopy

Redwood National Park, P.O. Box SS, Arcata, CA 95521

dominants up to as much as 2,000 yrs of age. The plot of an old-growth "all-aged" forest (tree number per dbh class) is an inverse "J" shape (Husch et al. 1972) depicting the decreasing number of individuals in increasing size classes. In these old-growth redwood stands basal area and number of trees/ac presumably fluctuate about a constant with time. Contrary to this "equilibrium", basal area in developing second-growth stands increases with age while the density decreases. Tree basal diameter versus density for second-growth has a normal distribution, with the median dbh increasing while the modal number of trees decreases with the stand age (Meyer 1953, Husch et al. 1972). Density, size and time relationships for even-aged and all-aged stands are shown in Fig. 1.

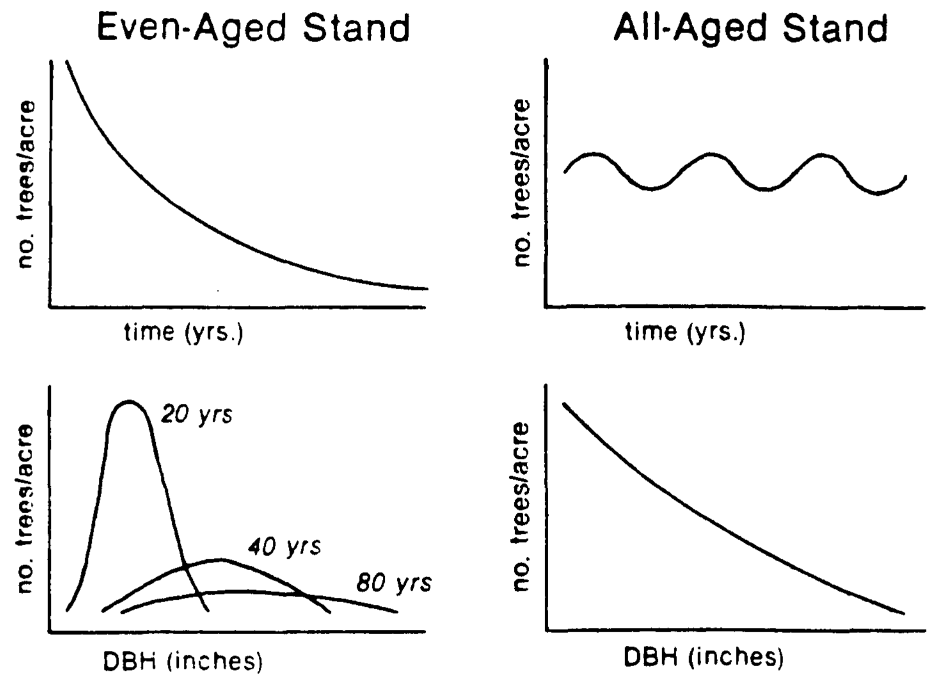


Figure 1

A second growth "even-aged" stand can be characterized by decreasing density and increasing basal area with time, while an "all-aged" old growth stand is characterized by a more or less constant density and basal area over time.

Coast redwood age data from a 30 ac plot sampled by Fritz (1929) at a low elevation interior site is a noteworthy documentation of the age distribution in an old-growth redwood stand. More recently, Veirs (1982) has combined both Fritz's age and size class data (Fig. 2) and described an additional 10 plots in these terms. Veirs' data from coastal lowland to interior ridge sites demonstrate that redwood successfully maintains more or less all-aged distributions with or without relatively low intensity fires. *Pseudotsuga menziesii* (Douglas-fir), *Tsuga heterophylla* (western hemlock), *Lithocarpus densiflora* (tan oak) and other redwood forest associates are present in distinct age class patterns reflecting the role of fire and other factors which influence establishment and mortality. Veirs concludes that the virgin upland coast redwood forest of northwestern California is a climax vegetation type.

In an old-growth forest, most young trees present at any given time have little probability of surviving to older age classes or canopy tree status. In second-growth forests this age class pyramid is

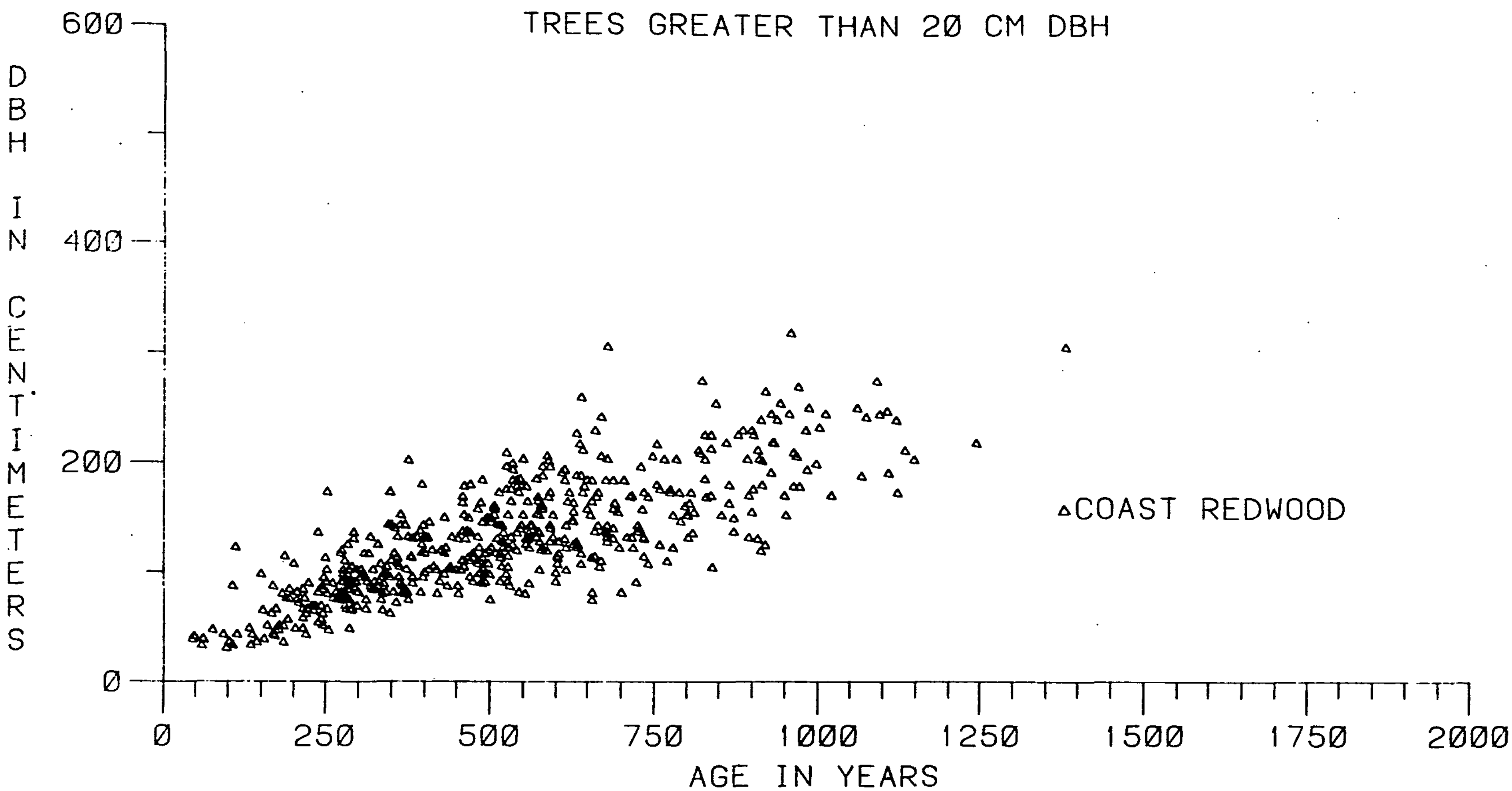


Figure 2

Age and diameter data for coast redwood trees from Veirs (1982). Based on unpublished data of E. Fritz from a 30 ac low elevation redwood stand. The few individuals of Douglas-fir and grand fir are not included. Trees less than 12 in dbh were not reported in the original study (see Fritz 1929). The all-aged character of the population is quite apparent.

replaced by a size class pyramid. Of the many seedlings established about the same time following logging or burning in a forest, only a relatively small number will reach dominance. The balance die suppressed. In some special cases whole second-growth stands may remain in an autosuppressed condition where there is little mortality and many very slow growing trees survive for long periods forming a stagnated stand (Diamond 1978).

Old-growth and second-growth forests have been described in terms of species composition, function, and structure (Franklin et al. 1981). Most differences can be attributed to four primary structural components of old-growth: 1) large live trees, 2) large snags, 3) large logs on land, and 4) large logs in streams. All of these elements can be present in second-growth redwood stands as an artifact of logging. A second-growth redwood forest is essentially a single age class of trees growing amidst these four structural elements of old-growth forests. The large live trees are represented by a few residual old-growth stems, the large snags by standing dead trees which existed before logging, and the logs in streams and on the slope are logs not removed during logging.

There is, however, no natural equivalent of clearcut timber harvesting in coast redwood stands (Veirs and Lennox 1981). Thus, predictions of future forest development on cutover parklands can only be made with the formulation of models based on data from second-growth stands.

Approximately 11,000 forested ac acquired in 1968 for the creation of Redwood National Park were subjected to timber harvest prior to park establishment. An additional 36,000 ac of cutover forest land was added to the park in the 1978 expansion. In addition, the three state parks that are included within the boundary of the national park contain 4,000 ac of second-growth, making an approximate total of 51,000 ac of second-growth redwood forest within the boundary of Redwood National Park (USDI 1982). About 39,000 ac of old-growth redwood forests remain within the 106,000 ac park.

There is a large percentage of redwood second-growth forest stands in the 1 to 30-yr age classes. The majority of the acreage of old-growth coast redwood was harvested after World War II, with the bulk of this harvesting being completed in the last 15 yrs. The first redwoods to be cut were in pure stands on the best growing sites. In the 1870s the vol/ac of coast redwood lumber cut was at its highest. As cutting progressed out of the lowlands and into the mixed stands on the slopes, more acreage had to be cut to yield the same volume of redwood lumber. As demand increased, more efficient logging methods were developed. By the early 1900s the cut was averaging 500,000,000 board ft annually. By 1950 the remaining uncut volume of redwood (including some second-growth) was 35 billion board ft down from 102 billion in 1909 (Leydet 1969).

STUDY AREA

All sampling was conducted in the Mill Creek drainage of Del Norte Coast Redwoods State Park included within Redwood National Park. The study area was located in northern coastal California on U.S. Highway 101 between Crescent City to the north and the Klamath River to the south. The climate is characterized as a Mediterranean-Marine, with moderate temperatures and an average 83 in of precipitation falling between September and April (Elford and McDonough 1974). Elevation ranged from 160 ft to 1,277 ft on slopes averaging 40%. Soils have been developed from sedimentary and meta-sedimentary rocks of the Franciscan Formation (Strand 1963).

Since acquisition by the California State Park System in 1929 after clearcut railroad, cable and tractor logging, these stands regenerated naturally and have not been logged or managed for future commercial use.

METHODS

Preliminary vegetation mapping based on apparent canopy texture differences was done using 1:62500 true color, high elevation U-2 and 1:5000 low elevation black and white aerial photographs. Five preliminary types were identified. This was followed by field reconnaissance to verify and supplement the types. Sampling to quantify these forest vegetation types utilized a combination of standard techniques from forestry and phytosociology and are similar to those used in other successful classifications (Dyrness et al. 1974, Mueller-Dombois and Ellenberg 1974, Pfister and Arno 1980).

Each sample consisted of a 0.25 ac circular plot (slope corrected). These were further divided, for the purpose of statistical testing, in two 0.125 ac halves by a line running perpendicular to the contour through the plot center. All tree measurements were taken in English units, rather than metric, to facilitate comparisons with existing forest mensurational data. For all standing trees with a measurable dbh the species, seedling or sprout origin, diameter (in 1 in classes), live or dead status, presence of basal sprouts less than breast height, and presence of bear damage was recorded. A releve (Benninghoff 1966, Mueller-Dombois and Ellenberg 1974) of all vascular plant species stratified by Raunkiaer life form (Raunkiaer 1937) using 10% cover classes was completed for each plot as a floristic description. The soil profile was described to a depth of 36 in. Age and height of Douglas-fir and redwood in the immediate vicinity of the plot were recorded to later determine the site quality for these species. Elevation, percent slope, aspect, slope position (ridgetop, convex, or concave), and a narrative site description completed the data taken at all plots.

All data was coded for analysis on the Humboldt State University Control Data Corporation CYBER 170 Model 720 computer. Polythetic-agglomerative cluster analysis (Clifford and Stephenson 1975) of the tree inventory using species and diameter class frequency of redwood, Douglas-fir, and tan oak was used to identify similar plots.

RESULTS

Results of the preliminary stand analysis are presented herein, while results of the site quality, soil profile, and releve data will be presented at a later date. From my interpretation of the cluster analysis, I identified a xeric, dry-mesic, and a landslide type, each having a distinct tree species composition and diameter distribution. Not all plots fell into the three groups identified in cluster analysis. Seven plots were classified as xeric, eight plots were classified dry-mesic, two as landslide and two plots represented single anomalous sites that were clusters unto themselves because they were unique in composition.

I have selected one plot from each type for presentation and comparison here. This enables the best description of the histograms which separately offer much information that would be lost in pooling the plots that comprise its type. All results presented are for 0.25 ac only and have not been extrapolated for the same reason to the more traditional 1.0 ac area.

Basal area of all tree species present per quarter acre ranged from 72.1 - 90.2^2 ft while the total number of trees per quarter acre ranged from 104 to 275 (Table 1).

Table 1

Number of Trees and Basal Area in the "Character Type" Plots (0.25 ac)

	Xeric	Dry-Mesic	Landslide
Number of Trees	193	104	275
Basal Area (ft^2)	90.2	85.0	72.1

Only tan oak, Douglas-fir and redwood are included in the character plot histograms. ***Castanopsis chrysophylla*** (golden chinquapin), ***Arbutus menziesii*** (Pacific madrone), ***Alnus oregana*** (red alder), ***Tsuga heterophylla*** (Western hemlock), and ***Acer macrophyllum*** (big leaf maple) were present in the plots but restricted to only one plot or type. While being an indicator of site environmental conditions, they are not as useful in stand comparisons as the tree species with 100% constancy between types (Tables 2 - 4). Sprouts of both redwood and tan oak are included in the following histograms and plot descriptions. The redwood and tan oak data are segregated into two groups: (1) principal trees (including single stemmed trees, or the principal stem of a multiple stemmed tree), and (2) sprouts of varying sizes, all of which are dominated by a principal stem.

Table 2

Number of Tan Oak Principal Stems and Sprouts and Percent Basal Area From Sixty-Year Old Redwood Second-Growth. "Character Type" Plots (0.25 ac)

	Xeric	Dry-Mesic	Landslide
Number of Trees	124	27	23
Percent Basal Area	33.9	1.7	8.7

Table 3

Number of Douglas-Fir and Percent Basal Area From Sixty-Year Old Redwood Second-Growth. "Character Type" Plots (0.25 ac)

	Xeric	Dry-Mesic	Landslide
Number of Trees	13	52	23
Percent Basal Area	23.3	61.4	46.0

Table 4

Number of Redwood Principal Stems and Sprouts and Percent Basal Area From Sixty-Year-Old Redwood Second-Growth Sprouts and Seedlings Combined. "Character Type" Plots (0.25 ac)

	Xeric	Dry-Mesic	Landslide
Number of Trees	18	25	219
Percent Basal Area	35.4	36.7	32.3

The xeric type character plot was located at 1,100 ft, sloping 23% to the south-southeast (Table 5). In number of stems tan oak dominated this plot with 150 of the total 193 trees contributing 35.5% of the total basal area. This was represented by 32 multiple stem clusters and 4 principal stems (diameters 3, 10, 11, and 12 in). The 13 Douglas-fir ranged from 7 to 31 in contributing 18.5% of the total basal area. Eighteen redwood were present as 12 free-standing stems and two sprout groups contributing 37.6% of the total basal area (Fig. 3, Table 6). Three madrone and one chinquapin completed the inventory. All species occurred in the one canopy layer averaging 85 ft in height.

Table 5

Environmental Description of the Three Character Type Plots

	Xeric	Dry-Mesic	Landslide
Elevation (ft)	1,100	760	670
Slope (%)	23	30	35
Aspect	SSE	SW	NE
Topographic Position	Ridge	Convex Upper Slope	Concave Lower Slope
Depth of A Horizon (in)	7	13	*

* -- buried A horizon

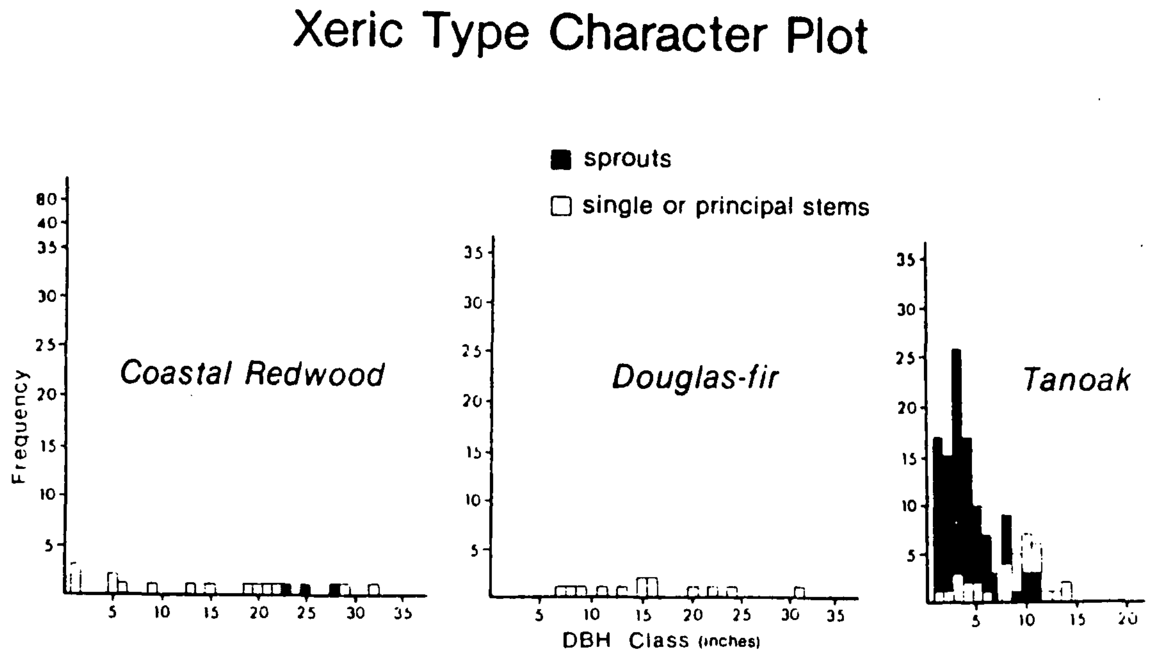


Figure 3

In numbers tanoak dominates this plot with 150 of the total 193 trees. Basal area of redwood and tanoak are nearly equal with 35.4% and 33.9% of the total respectively. Of the three character type plots presented, the xeric occupied the highest elevation and driest aspect.

Table 6

Xeric Type Character Plot Stand Table
Number of Stems with Measurable DBH and Cumulative Class Basal Area

DBH Inch Class	Tan Oak*	Tan Oak Sprouts	Douglas-fir	Redwood*	Redwood Sprouts	Madrone	Chinquapin
1	1/ .005	17/ .085		3/ .015			
2	1/ .022	15/ .330					
3	3/ .147	26/ 1.274					
4	2/ .174	17/ 1.479					1/ .087
5	2/ .272	10/ 1.360		2/ .272		1/ .136	1/ .136
6	1/ .196	7/ 1.372		1/ .196		1/ .196	1/ .196
7	3/ .801	3/ .801	1/ .267			1/ .267	
8	4/ 1.396	9/ 3.141	1/ .349				1/ .349
9	5/ 2.400	11/ .422	1/ .422	1/ .422			
10	7/ 3.815	3/ 1.635					
11	6/ 3.960	3/ 1.980	1/ .660				1/ .660
12	1/ .785						
13	1/ .922		1/ .922	1/ .922		1/ .922	
14	2/ 2.183					1/ 1.069	
15			2/ 2.454	1/ 1.227			1/ 1.227
16			2/ 2.738			1/ 1.369	
17							
18							
19				1/ 1.969			
20			1/ 2.182	1/ 2.182			
21				1/ 2.405			
22			1/ 2.640	1/ 2.640			
23					1/ 2.885		
24			1/ 3.142				
25					1/ 3.409		
26							
27							
28					1/ 4.276		
29				1/ 4.587			
30							
31			1/ 5.241				
32				1/ 5.585			
Number of Stems:	39	111	13	15	3	6	6
Basal Area (ft^2):	16.743	13.879	21.017	21.422	10.570	3.959	2.655
Basal Area (%):	18.5	15.4	23.3	23.7	11.7	4.4	2.9

* Includes principal stem of sprout group

The dry-mesic type character plot was located at 760 ft, sloping 30% to the southwest (Table 5). Douglas-fir was the dominant tree on this plot, contributing 61.4% of the total basal area with 52 trees in a normal distribution. Tan oak was present in a normal distribution ranging from 1 to 7 in. Nineteen tan oak sprouts contributed 0.92% of the total basal area while eight principal tan oak stems contributed 0.84% of the total basal area. Five principal stems of redwood contributed 15.0% to the total basal area (Fig. 4, Table 7). Redwood sprouts were distributed between the 2 and 22 in diameter class with 5 sprout groups representing 21.7% of the total basal area. The canopy at this site was stratified in two layers with tan oak and suppressed redwood and Douglas-fir occupying the lower strata (60-80 ft). Dominant and co-dominant redwood and Douglas-fir occupied the upper (110-130 ft) canopy strata.

Table 7

Dry Mesic Type Character Plot Stand Table
Number of Stems with Measurable DBH and Cumulative Class Basal Area

DBH Inch Class	Tan Oak*	Tan Oak Sprouts	Douglas-fir	Redwood*	Redwood Sprouts
1		1/ .005			4/ .020
2	2/ .044	5/ .110			2/ .044
3	2/ .098	12/ .558		1/ .049	
4	2/ .174	1/ .087			1/ .087
5	1/ .136		3/ .408		1/ .136
6			2/ 1.392		
7	1/ .267		6/ 1.602		1/ .267
8					1/ .349
9			6/ 2.532		
10			1/ .545		1/ .545
11			6/ 7.260		
12			3/ 2.355		1/ .785
13			3/ 2.766		
14			7/ 6.454		1/ 1.069
15			1/ 1.227		
16			2/ 2.738		1/ 1.369
17			3/ 4.728		1/ 1.576
18			2/ 3.534	2/ 3.534	
19			1/ 1.969	1/ 1.969	
20			2/ 4.364		
21			1/ 2.405		
22			1/ 2.640		2/ 5.280
23			1/ 2.885		
24					
25			1/ 3.409	1/ 3.409	1/ 3.409
26				2/ 7.374	
Number of Stems:	8	19	52	5	20
Basal Area (ft^2):	.719	.790	52.213	12.801	18.470
Basal Area (%):	.84	.92	61.4	15.0	21.7

* Includes principal stem of sprout group

Dry-Mesic Type Character Plot

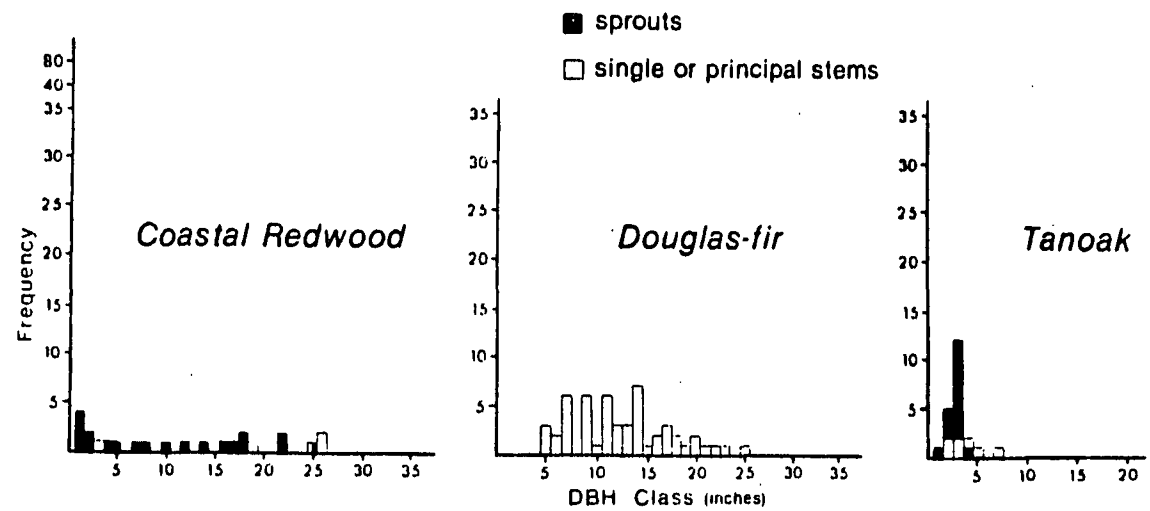


Figure 4

In both numbers and basal area Douglas-fir is the dominant tree species on this plot, with 52 of the 104 trees and 61.4% of the total basal area. The dry-mesic type occupies approximately 60% of the studied watersheds upland area, making it the best represented vegetation type.

Landslide Type Character Plot

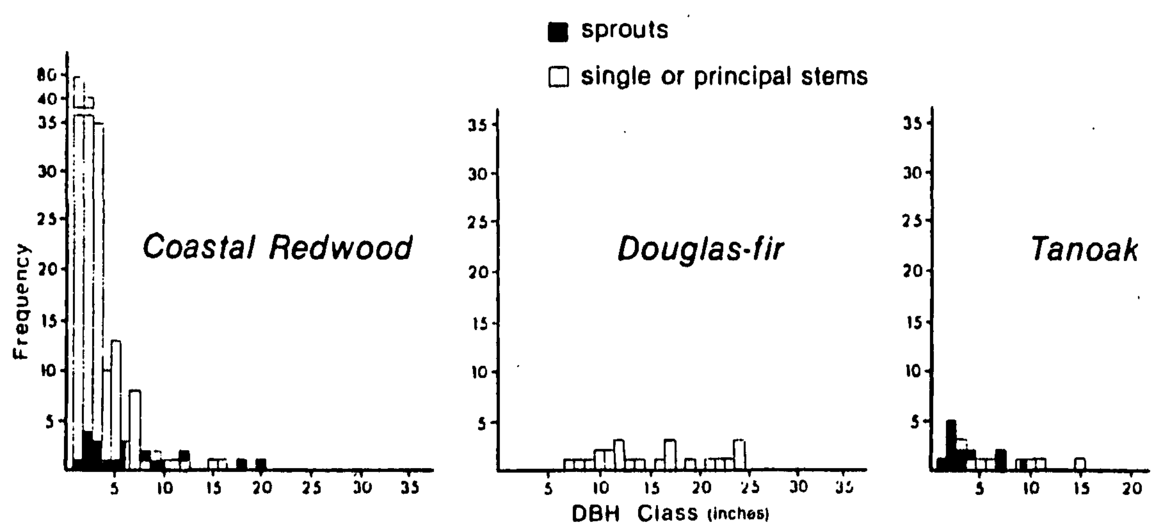


Figure 5

In numbers redwood dominates this plot with 219 of the total 275 trees. Douglas-fir dominates the basal area with 46.0% of the combined total. The landslide type is restricted to small local slipouts and landslides below the convex/concave break in slope.

The landslide type character plot was located immediately below the concave/convex break in slope, below an old railroad grade, on a small local slipout (Table 5). The surface was hummocky with a buried A horizon in the soil profile. Sloping 35% to the northeast, this was the lowest of the character plots with an elevation of 670 ft. Redwood was the dominant species with 219 of the total 275 stems. One hundred ninety-eight of the individuals are principal stems with diameters less than 6 in. Only five sprout clusters were present totaling 21 stems. Twenty-three Douglas-fir are distributed from 7 in to 25 in making up 46% of the total basal area (Fig. 5, Table 8). A minor component of tan oak contributed 8.7% of the total basal area. Seven alders ranging from 8 to 14 in accounted for 12.8% of the total basal area and completed the plot inventory. Redwood and tan oak in the 1 to 5 in classes were confined to a lower canopy level at 40-70 ft. Dominant and co-dominant individuals comprised the upper canopy level at 90-120 ft.

Table 8

Landslide Type Character Plot
Number of Stems with Measurable DBH and Cumulative Class Basal Area

DBH Inch Class	Tan Oak	Tan Oak Sprouts*	Douglas-fir	Redwood*	Redwood Sprouts	Alder
1		1/ .005		80/ .400	1/ .005	
2		5/ .110		40/ .880	4/ .088	
3	3/ .147	2/ .098		35/ 1.715	3/ .147	
4	1/ .087	2/ 1.740		10/ .870	1/ .087	
5	1/ .136			13/ 1.786	1/ .136	
6	1/ .196			3/ .588	3/ .588	
7		2/ .543	1/ .267	8/ 2.136		
8			1/ .349	1/ .349	2/ .698	3/ 1.047
9	1/ .422	1/ .422	2/ .844	1/ .422		
10	1/ .545		2/ 1.090	1/ .545	1/ .545	1/ .545
11	1/ .660		2/ 1.320	1/ .660	1/ .660	2/ 1.320
12			3/ 2.355	1/ .785		
13			1/ .922		2/ 1.844	1/ .922
14			1/ 1.069			1/ 1.069
15	1/ 1.227			1/ 1.227		
16			1/ 1.369	1/ 1.369		
17			3/ 4.728			
18						
19			1/ 1.969		1/ 1.969	
20						
21			1/ 2.405		1/ 2.405	
22			1/ 2.640			
23			1/ 2.885			1/ 2.885
24			3/ 9.426			
25						
Number of Stems:	10	13	23	198	21	10
Basal Area (ft^2):	3.420	2.918	33.216	14.136	9.172	9.210
Basal Area (%):	4.7	4.0	46.0	19.6	12.7	12.8

* Includes principal stem of sprout group.

Three landslides in the lower Redwood Creek basin dating 1861 (121 yrs before present) show a similar skewed distribution (S.D. Veirs, Jr., unpublished data) as those in the studied area 60-yr-old landslide type. In both instances redwood dominates the smallest size classes in both numbers and basal area while larger individuals are nearly absent. The Redwood Creek sites occupy the cooler-moister aspects at the bottom of the watershed and typical riparian species (big leaf maple, *Umbellaria californica* [California bay], red alder, and *Cornus cornuta* [dogwood]) are found there in addition to those which occur on the studied area landslides.

The plots that were unclassified due to being unique in composition were located on sites where the landscape had been drastically altered by logging. One plot was located on a ridgetop that had been leveled and used as a landing for logs. This plot supported a mixed stand of redwood and Douglas-fir with a very minor component of tan-oak, rather than a typical xeric stand dominated by tan oak sprouts. The other unique site was located on an incline where logs were dragged downhill to the railroad. This linear feature supports a stand of red alder, redwood and Douglas-fir. A lower slope non-landslide type is present but was not defined in this work.

CONCLUSIONS

Sixty yrs after logging of the original coast redwood forest cover on the study site the three forest type examples described in this paper differ substantially in character from uncut redwood forests. While the original native species are well represented, their proportion and density are much different. Typically, the old-growth stands, as described by Veirs (1982) in similar sites, have low densities of redwood and Douglas-fir in the overstory, ranging from approximately 14 and 3 trees/ac to 39 and 4 trees/ac or approximately 3:1 and 9:1, respectively. Douglas-fir trees more than 500 yrs old are well represented in the old-growth. This relative proportion and density is sharply different than that in the reported second-growth stands. In these the redwood to Douglas-fir density ranges from 101 and 210 trees/ac in the dry mesic type to 73 and 53 trees/ac in the xeric type and 887 and 93 trees/ac in the landslide type or approximately 1:2, 1.5:1 and 10:1, respectively. It is reasonable to assume that this relative over-representation by Douglas-fir in two of the three reported types will persist well into the normal life span for this species.

Although seedlings of the yr were present on rotten logs and in the soil, there was no observed regeneration that had reached the sapling size. Any hole left in the canopy by mortality in the smaller size classes is being filled by lateral canopy expansion of the dominant and co-dominant individuals. Veirs (1982) concluded that Douglas-fir in old-growth coast redwood forests is poorly represented or absent in the understory of redwood dominated sites, and may be classed as a long lived, fire-dependent, seral, canopy associate of redwood. Unfortunately, the post-logging history/management of the tens of thousands of acres of coast redwood timberland clearcut in the last 60 yrs is not the same. Older second-growth stands in private ownership have typically been re-entered for thinning and/or logging. These studied stands have not been re-entered after clearcut railroad and cable logging 60 yrs ago by the Hobbs-Wall Company. The result of post-harvesting management such as aerial seeding and pre-commercial thinning in second-growth stands weights them even more heavily with Douglas-fir and makes comparison with older second-growth less reliable. This should be kept in mind if this site is to be used as a location to predict the potential appearance of stands that are developing on the cuts made more recently. Pfister and Arno (1980) consider stands that are 70 yrs or older to generally display definite successional trends in which the potential climax trees can be predicted by evaluating the stand structure and relative shade tolerances of the species present. However, in coast redwood, 70 yr-old stands differ strongly from adjacent old-growth stands in species ratios and density. The shade tolerant redwoods present will most likely become canopy dominants. It would be misleading to assume that when the stand reaches an all-age climax, these trees would still be present.

There is no natural equivalent on which to base a prediction for the time involved for succession to replace the current even-aged Douglas-fir dominated canopy with an all-aged old-growth redwood forest.

ACKNOWLEDGMENTS

I wish to acknowledge the assistance of Michael Minden in the field work and data organization phases, and Stephen D. Veirs, Jr. for his many helpful comments and criticisms with the manuscript. Ron Knickerbocker and Susan Richey typed the manuscript.

VERIFYING FIRE BEHAVIOR MODELS WITH PRESCRIBED FIRES

J.W. van Wagtendonk

ABSTRACT

Expanded use of the National Fire Danger Rating System and the Fire Behavior Prediction System has led to increased interest in the verification of their internal models. These models were tested for prescribed fires burning underneath canopies in six fuel types in Yosemite National Park. Regressions of observed rates of spread on predicted rates of spread provided regression coefficients that ranged from 0.50 to 1.90. The range for flame length was from 0.58 to 6.14. Burning prescriptions based on the models have been adjusted for the variation in their predictive capability.

INTRODUCTION

Fire behavior prediction and danger rating systems are gaining in acceptance and use. The advent of custom programs for small calculators has put fire prediction capability in the hands of field personnel (Burgan 1979). Fire behavior officers use the Fire Behavior Prediction System (FBPS) based on the work by Albini (1976) to make on-site estimates of wildfire behavior. The National Fire Danger Rating System (NFDRS), on the other hand, is designed to make staffing decisions with regard to seasonal trends in fire potential conditions (Deeming et al. 1977). Both systems are based on the fire spread model developed by Rothermel (1972). Expanded use of the spread model has led to increased interest in its validation.

Andrews (1980) reexamined results from several studies that tested the fire prediction model in conifer slash, grass and southern rough. She found predicted rate of spread exceeded observed rate for 61 fires and was less than observed rate for 70 fires. For all fires, the mean error was 1.76 ft/min and the r^2 value obtained by a linear regression of predicted onto observed rates of spread was 0.89.

Fire spread models have been an integral part of prescriptions used for understory burning in Yosemite National Park for over 10 yrs (van Wagtendonk 1974, 1977). Since these models had not been validated for the fuel types typical of the park, an effort was undertaken to test the predictive capability of the models for prescribed burning applications. This paper reports on that effort.

METHODS

Fire behavior predictions and observations were made for 232 plots in areas representative of fuel types typically occuring in the midelevation forests of the Sierra Nevada in California. Thirty-two of these plots were studied by van Wagtendonk (1974), and the additional 200 plots were established on [illegible]0 different fires that were part of Yosemite's prescribed fire program (Botti and Nichols 1980). These plots were systematically distributed from random starting points in six different fuel types.

Forests dominated by ponderosa pine *Pinus ponderosa* Laws. constituted the first type. The ground fuels are primarily long pine needle litter and small branchwood. The mixed conifer-pine type is also dominated by ponderosa pine but has associated trees of incense-cedar *Libocedrus decurrens* Torr., white fir *Abies concolor* [Gord. and Glend.] Lindl., Douglas-fir *Pseudotsuga menziesii* [Mirb.] Franco, and sugar pine *Pinus lambertiana* Dougl. Long pine needles still make up the larger portion of the litter although the short-needled conifers contribute substantial amounts. Within the ponderosa pine and mixed conifer-pine types are areas where the forest floor is carpeted with bear-clover *Chamaebatia foliolosa* Benth. This highly-flammable, woody ground cover burns more intensely than either the long or short-needled conifers. These areas constitute the third type.

Yosemite National Park, El Portal, CA 95318

White fir is the principal species in the mixed conifer-fir type. Associated with it are sugar pine, incense-cedar, ponderosa pine, and red fir *Abies magnifica* A. Murr. Short needles predominate in the ground litter. The true fir type is similar in fuel characteristics and consists of nearly pure stands of either white fir or red fir.

Throughout all of the above fuel types, montane chaparral might be present in clumps or as extensive stands. Common montane chaparral species include greenleaf manzanita *Arctostaphylos patula* Greene, huckleberry oak *Quercus vaccinifolia* Kell., and mountain whitethorn *Ceanothus cordulatus* Kell. These plants seldom exceed 6 ft in height and are usually much closer to the ground.

The fuel on each plot was measured before and after burning using the inventory techniques developed by Brown (1974). Daily records of air temperature, relative humidity, wind speed, and 10 hr fuel moisture were kept at sites adjacent to each fire for at least 7 dys before ignition. The slope on each plot was measured with a clinometer.

Immediately prior to the fire passing over a plot, air temperature, relative humidity and mid-flame wind speed were measured. Rate of spread was determined as the plot burned by timing the fire front between stakes spaced at regular intervals. Flame length was estimated by comparing the average length to objects of known length (Rothermel and Deeming 1980). Head fires were used on 176 plots and backing fires on 56 plots.

RESULTS AND DISCUSSION

Observed Fire Behavior

Mean observed rates of spread ranged from 0.8 ft/min for true fir fuels to 11.7 ft/min for montane chaparral (Table 1). The fastest fire burned uphill in bear clover fuel with a rate of spread of 50.0 ft/min. Several fires were not able to spread at all under moist conditions. Flame lengths reached a maximum of 25.0 ft on one of the montane chaparral plots and averaged from 0.9 ft for true fir to 12.5 ft for chaparral (Table 1).

Table 1

Observed Fire Behavior for 232 Plots Burned with Prescribed Fires in Yosemite National Park

		Rate of Spread (ft/min)		Flame Length (ft)	
Fuel Type	Number	Mean	Std. error	Mean	Std. error
Bear Clover	16	5.1	3.1	1.7	0.3
Ponderosa Pine	78	2.1	0.3	1.2	0.1
Mixed Conifer-pine	58	1.5	0.3	1.0	0.1
Mixed Conifer-fir	50	0.8	0.1	1.0	0.1
True Fir	14	0.9	0.4	0.9	0.3
Montane Chaparral	16	11.7	2.5	12.5	2.1

Fuel Model Selection

Although Albini (1976) and Deeming et al. (1977) specify a fuel model for each of the fuel types tested, it was decided to determine a "best fit" model by analyzing several possible models for each type. Table 2 shows which models were used for each of the six types.

Table 2

Fuel Models Tested for Six Fuel Types for Rate of Spread Predictions for 232 Plots Burned with Prescribed Fires in Yosemite National Park

	Fuel Model													
	National Fire Danger Rating							Fire Behavior Prediction						
	B	C	F	G	H	T	U	2	4	5	6	8	9	10
Bear Clover		X				X	X	X					X	
Ponderosa Pine				X	X		X					X	X	X
Mixed Conifer-pine				X	X		X					X	X	X
Mixed Conifer-fir				X	X		X					X	X	X
True Fir				X	X		X					X	X	X
Montane Chaparral	X		X					X	X	X				

Predicted values for rate of spread and flame length were determined for each plot using the custom programs and the TI-59 calculator (Burgan 1979). In addition, the danger rating values for the spread component and the burning index were calculated. Input variables were taken from on-site weather measurements and from the nearest danger-rating station.

For backing fires, wind speed and slope were both set to zero (Rothermel 1983). Live fuel moistures were obtained from the woody and herbaceous fuel moisture calculations in the danger rating system. Fire behavior and danger rating predictions were made by using calculated values for live and herbaceous moisture contents.

Simple regressions were run for observed rates of spread as a function of predicted rates of spread for each of the desired fuel models. Additional regressions through the origin were then run using the same data. Finally, "t"-tests were used to see if the differences between the mean observed rates of spread and the mean predicted rates of spread were significantly different from zero. All tests for significance were at the 0.01 level.

The process for selecting the best fitting fuel model included several steps. First, from all the simple regressions, fuel models that had intercepts which were not significantly different from zero were selected. From those models, a further selection of those that had significant "F" values for the regressions through the origin was made. These were further reduced by selecting the regressions through the origin for which the differences between the observed and predicted means were not significantly different from zero. The two remaining regressions through the origin that had the highest values were then selected. Finally, the single regression through the origin that had the slope coefficient closest to one was selected.

The bear clover fuel type was best characterized by Fuel Model T in the NFDRS and by Fuel Model 2 in the FBPS. Both of those models are described as being appropriate for woody shrubs underneath conifer canopies. Fires burning underneath ponderosa pine and mixed conifer-pine stands were predicted best by Fuel Model U and Fuel Model 9. Model U was designed for closed stands of western long-needled pines. While originally designed for hardwood litter, Model 9 is also applicable to long-needled conifers (Rothermel 1983). Short-needled conifer fuels described by Model H and Model 8 provided the best fits for both the true fir and the mixed conifer-fir types. Montane chaparral fires behaved similarly to those predicted by Model F and Model 5. Open stands of mature California mixed chaparral are represented by Model F while brush stands which average 2 ft in height are described by Model 5.

Predicted Fire Behavior

The regression through the origin of observed rates of spread on predicted rates of spread provided regression coefficients for each of the six fuel types (Table 3). The coefficients for the NFDRS models ranged from 0.50 for mixed conifer-fir to 1.10 for bear clover. For the FBPS models, the coefficients ranged from 0.67 for mixed conifer pine to 1.90 for true fir.

Table 3

Summary Statistics for the Regression of Observed Rates of Spread on Predicted Rates of Spread for 232 Plots Burned with Prescribed Fires in Yosemite National Park

	National Fire Danger Rating			Fire Behavior Prediction		
Fuel Type (Models)	Regression Coefficient	Std. error Estimate	r^2	Regression Coefficient	Std. error Estimate	r^2
Bear Clover (T,2)	1.10	0.20	0.68	1.05	0.27	0.51
Ponderosa Pine (U,9)	0.90	0.12	0.42	0.91	0.10	0.51
Mixed Conifer-Pine (U,9)	0.97	0.12	0.54	0.67	0.08	0.56
Mixed Conifer-Fir (H,8)	0.50	0.09	0.41	1.56	0.24	0.45
True Fir (H,8)	0.60	0.15	0.57	1.90	0.40	0.64
Montane Chaparral (F,5)	1.04	0.20	0.64	1.59	0.31	0.64

Observed and predicted rates of spread for each fuel type are shown in Fig. 1 for NFDRS predictions and Fig. 2 for FBPS predictions. The solid line in each graph is the line of exact agreement (regression coefficient = 1.0) and the dashed line is the regression line. In most cases the two lines are in close proximity indicating a similarity between the predictive model and actual rate of spread. The degree of relationship is indicated by the r^2 values.

Figure 1

Observed vs. predicted rate of spread from the NFDRS for (a) bear clover, (b) ponderosa pine mixed conifer-pine, (d) mixed conifer-fir, (e) true fir, and (f) montane chaparral. The solid indicates perfect agreement and the dashed line is the regression line.

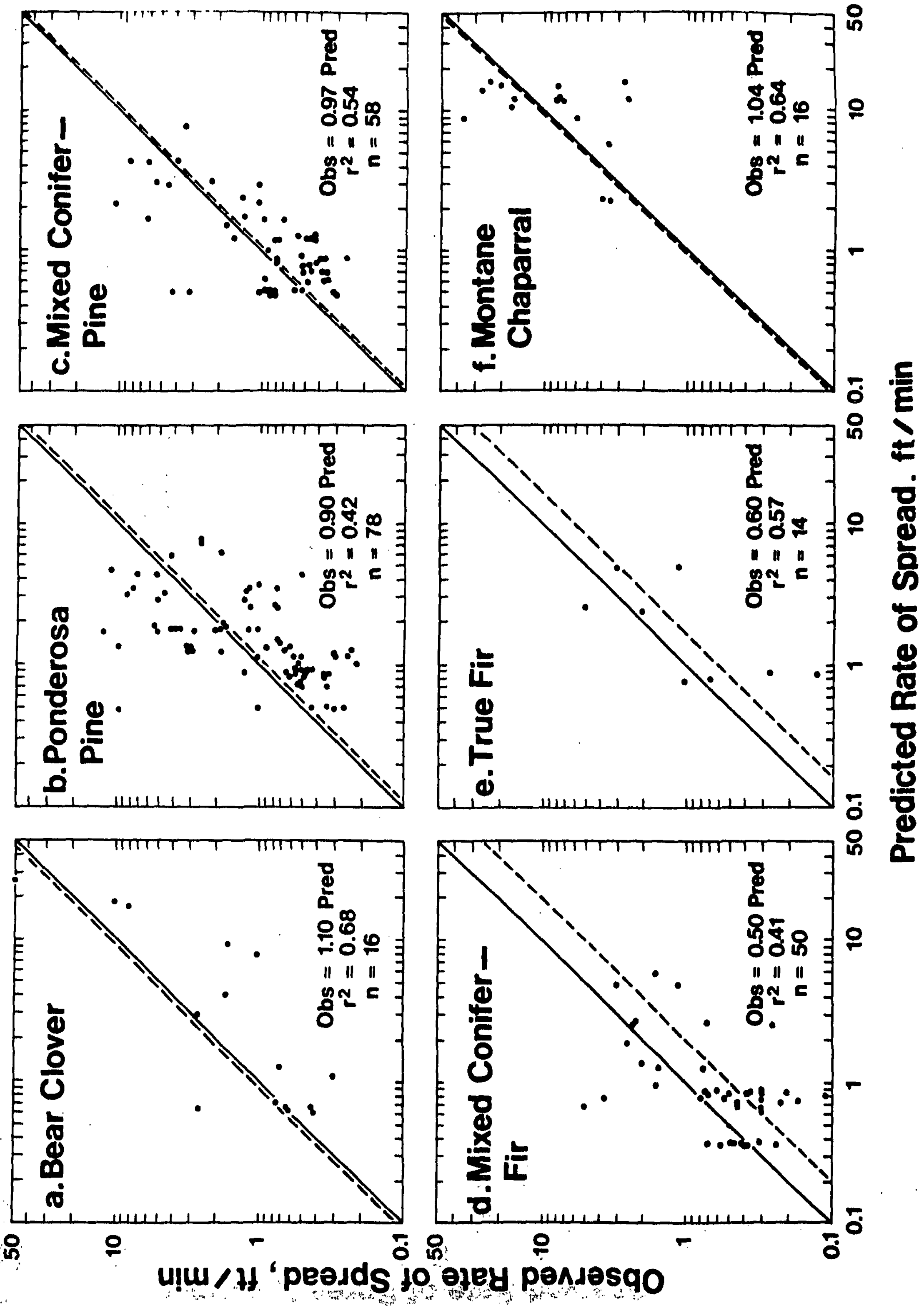
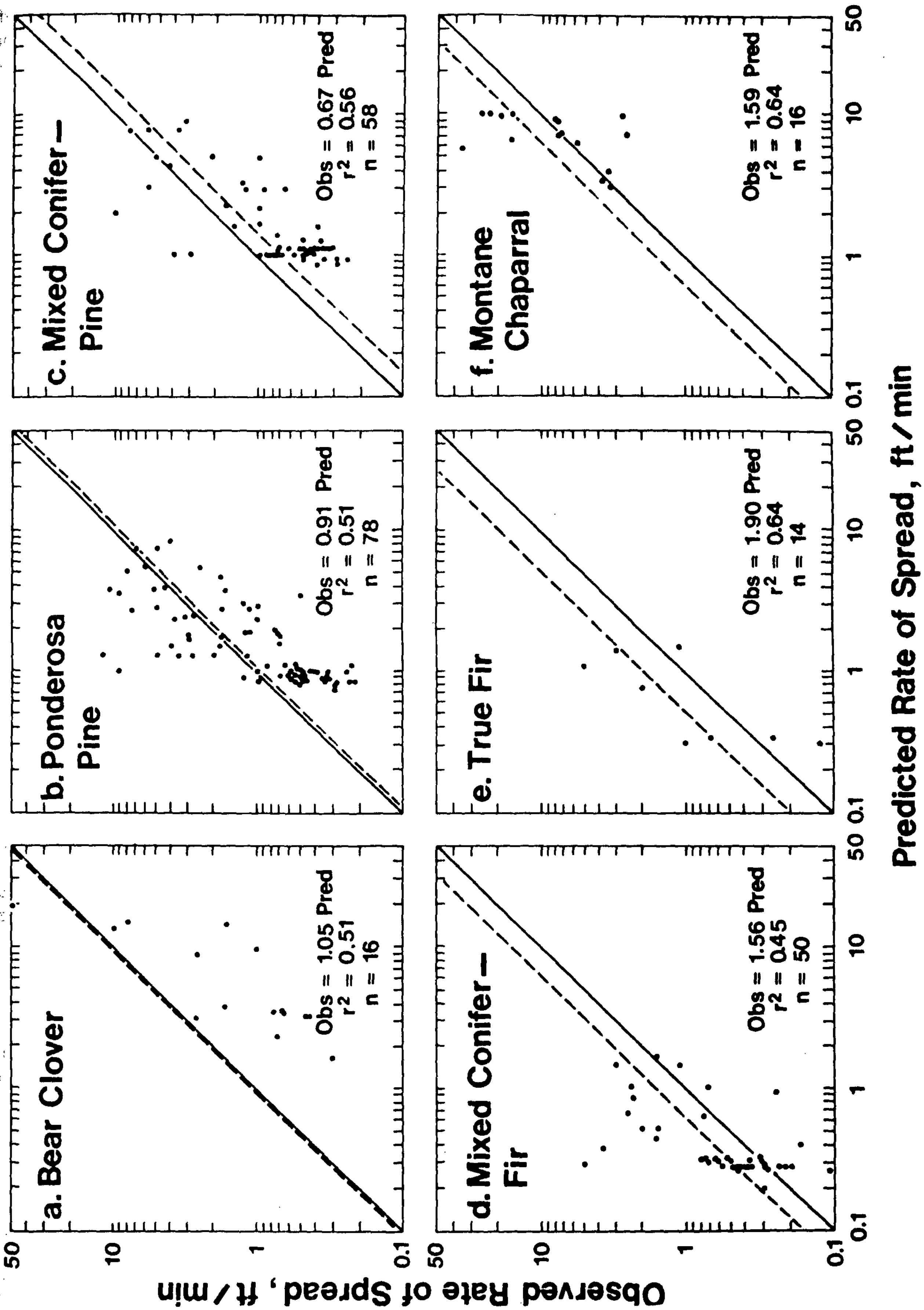


Figure 2

Observed vs. predicted rate of spread from the FBPS for (a) bear clover, (b) ponderosa pine, (c) mixed conifer-pine, (d) mixed conifer-fir, (e) true fir, and (f) montane chaparral. The solid line indicates perfect agreement and the dashed line is the regression line.



Regression coefficients for the regression of observed flame lengths on predicted flame lengths showed a greater variance than those for rates of spread (Table 4). This was attributed to the fires burning the montane chaparral plots with observed flame lengths from four to six times longer than predicted flame lengths. For this fuel type, fuel models B and 4 provided better flame length estimates. This could have been an artifact of ignition pattern since strip fires were used to ignite the burn. For the other fuel types, the flame length regression coefficients ranged from 0.58 to 1.13 for the NFDRS models and from 0.69 to 1.87 for the FBPS models.

Table 4

Summary Statistics for the Regression of Observed Flame Lengths on Predicted Flame Lengths for 232 Plots Burned with Prescribed Fires in Yosemite National Park

	National Fire Danger Rating			Fire Behavior Prediction		
Fuel Type (Models)	Regression Coefficient	Std. Error Estimate	r^2	Regression Coefficient	Std. Error Estimate	r^2
Bear Clover (T,2)	1.13	0.17	0.76	0.69	0.05	0.92
Ponderosa Pine (U,9)	0.72	0.05	0.73	0.83	0.06	0.70
Mixed Conifer-Pine (U,9)	0.74	0.09	0.53	0.72	0.09	0.51
Mixed Conifer-Fir (H,8)	0.72	0.09	0.56	1.87	0.26	0.51
True Fir (H,8)	0.58	0.14	0.56	1.69	0.42	0.56
Montane Chaparral (F,5)	4.53	0.71	0.73	6.14	0.94	0.74

MANAGEMENT APPLICATIONS

The ability of the rate of spread model to accurately predict fire behavior of low intensity fires is of practical use to fire managers. Fire behavior officers as well as prescribed fire managers can adjust model outputs to effectively predict fire behavior in wildland fuels. Burning prescriptions in use in Yosemite have been adjusted for the variation in the predictive capability of the models. Verification of the rating and prediction systems will give users greater confidence and will enhance interpretation of predicted fire behavior.

ACKNOWLEDGEMENTS

I would like to thank Steve Botti for his dedication to the Yosemite Fire Management Program and his commitment to collecting monitoring data on prescribed fires. Charisse Sydoriak and Jim Benedict collected the data, and Walter Sydoriak and Joe Coho entered the data and assisted in the statistical analysis.

SECTION III:

BIOLOGICAL SCIENCES – Faunistic Studies

FISH POPULATIONS OF ELEANOR RESERVOIR, YOSEMITE NATIONAL PARK

P.B. Moyle and D.M. Baltz

ABSTRACT

The fish fauna of Eleanor Reservoir consists of rainbow trout *Salmo gairdneri*, Sacramento sucker *Catostomus occidentalis*, and green sunfish *Lepomis cyanellus*. Probably none of these species are native to the reservoir watershed. In July 1981, the reservoir was extensively sampled with gillnets. The sampling revealed that: 1) the rainbow trout population was small and concentrated below the thermocline but individual trout reached large sizes (35 cm + SL); 2) the suckers have a large, healthy population that exhibits some surface feeding behavior, and 3) the green sunfish are the most abundant fish but are stunted in their growth. The sunfish may compete with small trout for food but serve as food themselves for large trout. Fisheries management options are discussed.

INTRODUCTION

Eleanor Reservoir, Yosemite National Park, is part of a complex water development project that generates water and power for the City of San Francisco. Eleanor Dam was built in 1917 across Eleanor Creek near the site of a natural lake. In 1956, Cherry Dam was constructed across nearby Cherry Creek, outside the park, creating Lloyd Reservoir, which was connected to Eleanor Reservoir in 1960 by a 1.8 km tunnel. Little is known about the fish populations in this system although it is likely that all the populations are the result of introductions by man, because of the abundance of natural barriers (waterfalls) to fish movement. Hubbs and Wallis (1948) provide evidence that rainbow trout *Salmo gairdneri* were first planted in Lake Eleanor (the natural lake) in 1877. Subsequently, a station was established on Frog Creek, a tributary to the lake, to capture spawning fish as a source of eggs for the propagation of trout that could be planted in other parts of the park. This station was later abandoned. In 1972, the California Department of Fish and Game (CDFG) sampled the reservoir and found that it contained a large population of Sacramento suckers *Catostomus occidentalis* as well as rainbow trout. In 1976 CDFG sampling of Lloyd Reservoir revealed the presence of green sunfish *Lepomis cyanellus* in the system.

In 1981, we undertook a brief investigation of the reservoir fish populations as part of a larger study evaluating the potential impact of a proposed pumping plant. This plant, proposed by Hetch-Hetchy Water and Power (City of San Francisco), would pump water from Eleanor Reservoir to Lloyd Reservoir, through the connecting tunnel during years when Eleanor Reservoir spills over the dam. The purpose of this paper is to present the results of our studies and to make some recommendations for fisheries management of the reservoir.

STUDY AREA

Eleanor Reservoir is located in the northwest corner of Yosemite National Park in the Tuolumne River drainage. It has a maximum surface elevation of 1,420 m (4,660 ft), a holding capacity of about 33.4 million m^3 (27,100 ac ft) and a drainage area of about 205 km^2 (79 mil^2 although there are some fairly extensive shallow areas (less than 5 m) which are usually exposed by late summer as the reservoir is drawn down. During our principal study period (29 June-14 July) the reservoir was full or nearly so, as inflow seemed to be nearly balancing outflow. The reservoir was highly transparent (Secchi depth, 10-15 m) and the surface waters were warm (22-24° C). On 18 August there was a well-developed thermocline between 8 and 11 m, with the temperatures below the thermocline being about 12° C. Surface temperatures by that time were only slightly higher (25° C) but Secchi depth had

Department of Wildlife and Fisheries Biology, University of California, Davis, CA 95616

dropped to about 9.5 m because of a bloom of phytoplankton. The water surface elevation was about 2 m below the surface of the dam and dropping rapidly as the tributary creeks had virtually stopped flowing. By 16 October, the thermal stratification was breaking up and surface temperatures had dropped to 12° C. The reservoir level appeared to be near that of the natural lake, although recent rains had caused the streams to start flowing again about a week earlier.

METHODS

All sampling was done with monofilament gill nets 30.5 m long x 2.4 m deep. Each net had five panels each of a different mesh size, ranging from 20 to 160 m in mesh size (stretch). Sets were generally for 8-10 hrs and the nets were usually either set in early morning or evening. A total of 39 sets were made, totaling 310 hrs of 'soak time.' An effort was made to sample as many habitats and depths in the lake as possible to give some idea of the principal fish habitats (Table 1). All fish captured were measured (fork and standard length) and a representative sample weighed. Scales were removed for age analysis from the area immediately beneath the pectoral fin on the left side, from a sample of each species. Scales were read at 23X magnification. The aging was verified and ages back-calculated using standard methods given in Tesch (1971). All green sunfish removed from the stomachs of trout were also measured (SL).

Table 1

Summary of Gill Net Catch Data from Eleanor Lake, July 1981

Time	Position Water Col.	No. Sets	No. Hrs.	Green Sunfish	Sacto. Sucker	Rainbow Trout	Total
Day	Bottom	6	46	0.00	0.89	0.87	1.76
Day	Midwater	8	53	0.08	0.44	0.15	0.67
Night	Bottom	8	81	4.43	1.80	0.09	6.31
Night	Midwater	8	95	2.34	1.04	0.19	3.57
Eve	Bottom	5	25	1.96	0.45	0.00	2.41
Eve	Midwater	1	4	21.30	2.00	0.00	23.30
Eve	Surface	3	9	0.00	0.44	0.00	0.44
All	8+ m	13	135	0.00	0.83	0.16	0.99
All	All	39	310	2.07	1.09	0.11	3.27

RESULTS

A total of 691 green sunfish, 336 Sacramento suckers and 37 rainbow trout were caught in the nets, for an average catch of about 2.0, 1.1, and 0.1 fish per hour, respectively (Table 1). More fish of all species were caught in the night and evening than during the day. Nets fished close to the bottom tended to catch more fish than those set in midwater or at the surface, the major exception being one set in midwater in a shallow bay (off Frog Creek) to document an observed off-shore movement of green sunfish in the evening. Trout were caught only in deep water below the thermocline during the day but were caught in shallower waters at night. Suckers were the most widely distributed species, appearing in nearly every set.

The average length at each age for the three species is presented in Table 2. The length/weight relationship for suckers was: log W = 2.86 log SL -4.50, while that for trout was: log W = 3.07 log SL -4.88. The length-frequency distribution for green sunfish (available from authors) indicated that the portion of the population vulnerable to the nets was dominated by small 3 and 4 yr old fish. A few large sunfish (90-110 mm SL) were also caught. They were not aged but were probably 6-7 yrs old. Smaller sunfish were observed in large numbers in shallow water. The length distribution of Sacramento suckers showed that the population was dominated by a strong year-class of 4 yr old fish, while the length distribution of the trout population showed it was dominated by 4 and 5 yr old fish. The catch of small green sunfish indicates that if smaller trout or suckers had been present in numbers, they probably would have been captured by the gill nets.

Table 2

Mean Back-Calculated Lengths (Sample Size) of Three Species of Fish From Eleanor Reservoir, July 1981

	Age (N)						
Species	I	II	III	IV	V	VI	VII
Sacramento Sucker	106(60)	142(57)	210(33)	267(21)	320(14)	375(6)	408(3)
Rainbow Trout	113(36)	178(36)	243(31)	306(18)			
Green Sunfish	28(48)	47(48)	57(30)	67(11)			

Stomachs from 15 rainbow trout were examined for food organisms. Ten stomachs contained green sunfish, three contained terrestrial insects such as beetles, leafhoppers, and wasps and two were empty. The green sunfish were of smaller size than those caught in the gill nets (44 mm mean SL vs. 60 mm mean SL). Stomachs of a few green sunfish were examined in a non-quantitative manner. Those with food in their stomachs contained either benthic invertebrates (mostly chironomid midge larvae) or terrestrial insects.

DISCUSSION

The growth rates of green sunfish in Eleanor Reservoir were slow compared to populations at lower elevations (Moyle 1976). The slow growth rates and large size of the population indicated that the fish were stunted, presumably from a combination of intraspecific competition and suboptimal temperatures. This green sunfish population may have been a major reason for the small size of the trout population. Green sunfish were most abundant in the productive shallow areas that are also likely to be favored by small trout, as well as around the mouth of the principal spawning stream for trout, Frog Creek. In both areas, green sunfish presumably compete with small trout for food and perhaps prey on them as well. However, it seems possible that the abundance of small green sunfish may have improved the growth rates of large (150 mm SL+) trout, as they were an abundant source of food. One of the trout captured (369 mm SL) contained 20 sunfish in its stomach, while two others (420 mm SL) contained nine sunfish each.

The sucker population, in contrast to those of the other two species, appeared "normal" in most respects compared to other sucker populations (N. Villa, unpublished ms.) Even the dominance of 1 or 2 yr classes, as observed in Eleanor Reservoir, was not particularly unusual (Moyle et al. 1982). This species is a bottom-feeding detritivore and insectivore that is capable of feeding in deep water inaccessible to green sunfish and on food neither trout nor sunfish can digest. Its large adult size and rapid growth when small helps to reduce the effects of predation by trout and birds (but not by otter). Its adaptability was indicated by the frequency with which we observed small schools on the surface, apparently sucking in pine pollen and other small debris that was concentrated by the wind near the dam.

MANAGEMENT RECOMMENDATIONS

Eleanor Reservoir at present does not offer much of a fishery. The green sunfish are mostly too small and the trout are too few. However, the records kept at the Frog Creek cabin indicate that some anglers, who know where and how to fish, catch an occasional 'lunker' trout. The suckers could be exploited but they are disdained by modern anglers despite indications that they were usually favored over trout by the Indians. It should be recognized, however, that the suckers and sunfish are an important source of food for the otters and for the mergansers, grebes and other fish-eating birds that are common on the lake.

If the National Park Service decides it is desirable to improve the trout fishery in the lake, it could be done by making annual or biennial plants of 100-500 rainbow trout of large enough size (250 mm SL+) to feed on green sunfish. It is unlikely that effects of their predation would be severe enough to decrease the foraging success of the birds and the trout could provide an additional source of food for the otters. We realize that Park Service generally does not stock fish in park lakes, but Eleanor Reservoir is a highly unusual situation. It is an artificial body of water connected to yet another such reservoir outside the park. The connecting tunnel was presumably the source of the green sunfish and perhaps the suckers as well. All three species now found in the reservoir are not native to the immediate area, although the suckers and trout are native to the drainage. All three species have self-sustaining populations so are unlikely to disappear naturally. Thus planting rainbow trout in the reservoir would not greatly increase the artificiality of the 'ecosystem'; however, it would make the trout fishing more attractive and potentially increase the number of people using the area.

ACKNOWLEDGEMENTS

Dennis Smith, Richard Reiber, Robert Burhans, Guy Drapeau and J. Noah Moyle assisted with the sampling and data analysis. The study was supported by Hetch-Hetchy Water and Power (City of San Francisco).

HEERMANN'S GULL (*Larus heermanni*) ON ALCATRAZ ISLAND IN GOLDEN GATE NATIONAL RECREATION AREA, CALIFORNIA

J.A. Howell

ABSTRACT

Alcatraz Island in Golden Gate NRA, California, is approximately 22 ac and receives over 750,000 visitors each year. Helicopters fly past the island every 3 min on high visitation days. With this public use pressure as a backdrop, Alcatraz is also the site of the first nesting pair of Heermann's gull *Larus heermanni* in the United States. Heermann's gull normally breeds in colonies in the Gulf of California, Mexico. They have also been reported in the Pacific on the San Benito Islands (28 20'N) in 1971. The first record of Heermann's gull nesting on Alcatraz (37 49'N) was in 1979. For three consecutive years eggs were laid but none hatched. The purpose of this study was to examine the effects of human disturbance on the Heermann's gull's nesting at Alcatraz. In 1981, 48.5 hrs of observation were made during 24 visits to the island. In 1981 and 1982 all nesting attempts failed.

INTRODUCTION

Heermann's gull *Larus heermanni* appears to be expanding its breeding range up the Pacific Coast from its historic breeding grounds in Baja, Mexico (Binford 1980, Howell 1982, Howell et al. 1983, Laymon and Shuford 1980, Sowls et al. 1980). Alcatraz Island in Golden Gate National Recreation Area is the site of the first breeding record of Heermann's gull in the United States. This biogeographic phenomenon is amazing because Alcatraz is 1,250 km (777 mi) north of normal Heermann's gull breeding areas.

Alcatraz is a 22 ac island in the San Francisco Bay. The island lies 1.6 km (1 mi) north of San Francisco and 2.4 km (1.5 mi) east of the Golden Gate. Daytime temperatures average 12° C (55° F) and are moderated by coastal fog and westerly winds through spring and summer. Alcatraz is a major attraction in the San Francisco Bay Area. Over 750,000 visitors come to the "Rock" each year. On busy days, helicopter tours fly by the island every 3 min. Management and research in this intensely used area is confounded by the fact that only one pair of Heermann's gull established itself on Alcatraz.

The discovery of Heermann's gull nesting on Alcatraz occurred in 1980. Reliable reports indicated that the first known nesting actually occurred in 1979. Preliminary data was gathered in June, 1980 in regard to nest and egg dimensions, clutch size, nesting behavior and hatching success.

METHODS

A brush blind was established on a terrace above the nesting area in 1981. The lower terrace was cordoned off and closed to all access except for a canvas blind established 9.0 m (30 ft) from the nest. Observations were made at all hours of the day from 0530 to 1800 hrs. In 1981, guided tours descended the west side of the island from the prison recreation yard to the terrace with brush blind, passing within 30 m (100 ft) of the Heermann's gull nest. The Heermann's gulls' reactions to the passing tours and helicopters were recorded. After a prolonged incubation period, one egg was retrieved and the contents examined for fertility.

Natural Resources Specialist, Golden Gate National Recreation Area, Fort Mason, Building 201, San Francisco, CA 94123

For the 1982 breeding season, the entire west side of Alcatraz Island was closed to tours. Behavioral observations were made from several blind locations. Helicopter disturbance was recorded and distances estimated with a calibrated target scale (Fig. 1). Aggressive encounters between Heermann's gulls and Western gulls were recorded in 1981 and 1982.

RESULTS

Response of the Heermann's gulls was recorded in 52 helicopter passes in 1981 and 1982. Of the 52 observations, 39 passes elicited no apparent reaction, nine resulted in raising the head and looking about, and four passes resulted in calling. The latter four cases occurred during very close (within 250 ft) approaches of noisy military or commercial helicopters.

The response of the Heermann's gulls to tours of people in the lower terrace was recorded on 40 occasions. The visitors had no apparent impact on the gulls; 17 occasions resulted in raising the head and looking in the direction of the tour, and six occasions resulted in birds leaving the nest for a short period (range = 30 sec to 2 min).

The Heermann's gulls' clutch sizes on Alcatraz were 3, 3, 4 and 0 for 1979, 1980, 1981 and 1982, respectively. No eggs hatched. The one intact egg that was examined exhibited no gross sign of fertilization.

Interspecific aggressive encounters occurred between the Western and Heermann's gulls on the island. Chi square analysis indicated a significant difference in Heermann's gull displacement of Western gulls from 1981 to 1982 (Table 1).

Table 1

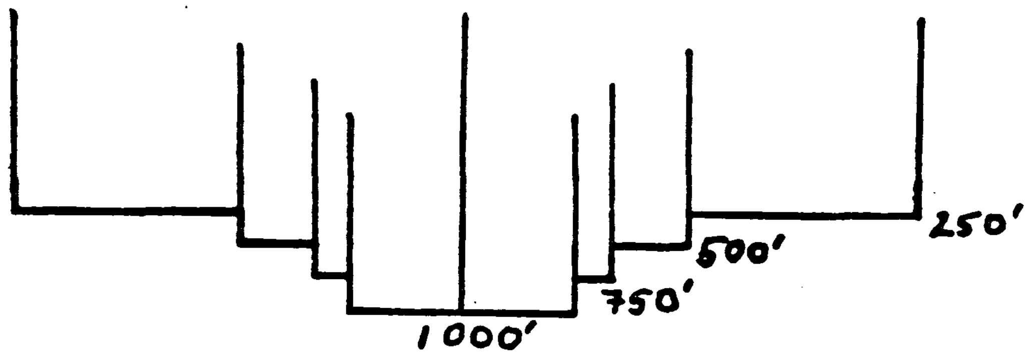
Chi-square Analysis of Heerman Gull—Western Gull Aggressive Interactions on Alcatraz Island, 1981-1982

Year	Heermann's win/ Western Displaced	Western win/ Heermann's Displaced	Total	Chi-square
1981	5	6	11	0.09 ($p < 0.90$)
1982	3	15	18	8.00 ($p < 0.005$)

DISCUSSION

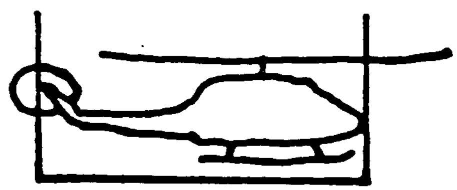
During the 1981 Heermann's gull nesting period, the lower terrace was closed and tours were routed past the nest site on the upper terrace. Even with these precautions the nest failed. The working hypothesis for the 1982 nesting season was that human disturbance by the tours, although subtle, might have interfered with courtship, resulting in infertile eggs. During the 1982 season, the entire west end of Alcatraz was closed. Two calling birds were present but pair formation apparently did not occur.

Disturbance data for helicopters and tours do not indicate that they are a major disturbance factor. However, Heermann's gulls have not been able to successfully nest on Alcatraz. An alternative hypothesis might be that the tours disturb the Western gulls more than the Heermann's gulls. With



Hold 24 inches

from eye



Length

Helicoptor Distance Scale
Nose to Tail Length 345 inches

disturbance, Western gulls lose their competitive advantage and the Heermann's gulls are able to establish a nest. In the absence of disturbance, the Western gull outcompetes the Heermann's gull and they cannot nest. The aggressive interaction data tend to support this hypothesis.

CONCLUSIONS

The competitive advantage hypothesis is attractive, but is difficult to document on Alcatraz with only one pair of Heermann's gull. Whether the birds will return in 1983 is uncertain. Given National Park Service mandates, and even with these drawbacks, this unique biogeographical event should be protected.

MANAGEMENT RECOMMENDATIONS

1) Restrict helicopter approach to no less than 500 ft, preferably 1,000 ft.

2) Continue tours from the prison recreation yard to the first terrace.

3) If the Heermann's gulls return in 1983, continue monitoring their behavior and begin documenting Western gull response to disturbance.

ACKNOWLEDGEMENTS

I extend my thanks to Bill Boarman and Bob Crabb who helped with some observations, and to the Alcatraz staff.

THE STATUS OF THE PEREGRINE FALCON IN YOSEMITE NATIONAL PARK: A PROGRESS REPORT

W.E. Davis and C.E. Asay

ABSTRACT

Research is currently being conducted to determine the present status of the Peregrine Falcon within Yosemite National Park. Research goals also include designation and evaluation of probable nesting areas within the Park and the development of management guidelines for monitoring Peregrine populations in the future.

Observations have been focused on the major cliff areas of the Merced, Tuolumne and Tenaya Creek drainages with special emphasis on historically active areas.

Prior to the onset of this project, one pair of Peregrines was known to be nesting within the park. During the summer of 1981, a second pair was discovered. Both nesting sites have been reoccupied in 1982. Future work will include continued surveying of potential nesting areas and the development of management recommendations.

INTRODUCTION

The decline of the Peregrine Falcon *Falco peregrinus anatum* in North America is well documented by Hickey (1969). Herman et al. (1970) described the decline in California; Thelander surveyed the state and found nine pair and estimated 25 pair, none of which were located within the Sierra Nevada (Thelander 1976).

The scarcity of Peregrine nesting sites within the Sierra Nevada was first indicated by Bond (1946) and later corroborated by Herman et al. (1970). Between 1949 and 1978 no nesting Peregrine Falcons were recorded in the Sierra Nevada. Thelander (1976) suspected that Peregrines were currently nesting in the Sierra Nevada in numbers "equal to, if not exceeding, those found in the Coast Mountain Ranges" (where most of the known occupied sites exist). He felt that the lack of Sierran nesting records was due to the relative inaccessibility of the area and to the difficulty in locating Peregrine Falcons.

Within Yosemite National Park, Peregrines were first reported breeding in 1926 (McLean and Rett 1926) then again in 1932 and 1933 (Adams 1939). Possible nesting was also reported in 1939 (Adams 1939) and 1949 (Wittreich and Garton 1979).

The discovery of Peregrines nesting in Yosemite Valley in 1978 stimulated the development of a Peregrine Falcon management plan for the park (USDI, NPS 1979). In 1979, a preliminary survey of historical and potential Peregrine Falcon nesting sites was conducted (Wittreich and Garton 1979) with no additional Peregrines being discovered.

The suggestion of recovery of the Peregrine in California and the hopes for a nest augmentation and release program for Yosemite involving captive-bred falcons indicated a need to continue the development of a comprehensive Peregrine Falcon management plan for Yosemite National Park. Important information on the status of the Peregrine in the park, the availability of suitable nesting sites and habitat, and methods for monitoring the Peregrine population within the park were needed. In 1981, a 3 yr study was begun to achieve the following goals:

1) to determine the present status of the Peregrine Falcon population within Yosemite National Park;

Graduate Group in Ecology, 2146 Wickson Hall, University of California, Davis, CA 95616

2) to designate and evaluate probable Peregrine Falcon nesting areas within Yosemite National Park; and

3) to provide park management with methods for monitoring Peregrine populations in the future.

This paper is a progress report on the research directed toward achieving these goals.

METHODS

The status of the Peregrine Falcon in Yosemite National Park is being determined by a site-specific search employing several appropriate searching techniques.

Study Areas

The ruggedness of the terrain and the size of the park make it impossible to search the entire area within the time frame of this project. Therefore, the search for Peregrines is being concentrated in specific areas that have been selected on the basis of historical nesting records and sightings (NPS files), and physical characteristics pertinent to Peregrine biology (e.g., major drainages).

The primary locations selected are large cliff areas located along the Merced River, the Tuolumne River, Tenaya Creek, and Illilouette Creek and also areas near Wawona and Tuolumne Meadows (Figs. 1, 2).

The areas are reached by automobile when possible, but most areas are accessible only by trail. Because of this, most research is conducted during extensive backpacking trips lasting up to two weeks.

Search Techniques

Visually searching for flying falcons and scanning cliffs for accumulated whitewash, combined with the use of audio and visual lures, are the principle techniques being used in the search for Peregrine Falcons in Yosemite National Park.

A falcon that is perched on a ledge of a large cliff is highly inconspicuous, even to the trained observer. Once the falcon has taken flight, however, it is much more easily sighted. Vocalizations by the falcon also provide the observer with evidence of its presence. It would expedite the search, therefore, if the searcher could somehow induce the falcon into flight or vocalization. To achieve this, we are playing recorded Peregrine Falcon calls and also prominently displaying a teathered live Great Horned Owl. Miller (1952) demonstrated auditory recognition in birds of prey and live Great Horned Owls have been used in trapping other predatory birds (Hammerstrom 1963).

Some field testing to determine the reliability of this luring technique has been accomplished during 1981 and 1982. The response to the lures of the more common Prairie Falcon *(Falco maxicanus)* was observed in several areas outside the park. Results at this time are inconclusive, but preliminary findings indicate that the luring technique may give us some advantage over only visual scanning. Since Peregrines are known to be very rare in the study area, we feel any advantage provided by the luring technique is valuable and worth the effort required to backpack with a large tape player and a live Great Horned Owl.

Recognizing the possible dangers involved in studying sensitive raptor species, we are exercising suitable precautions (Fyfe and Olendorff 1976).

The designation and evaluation of probable nesting areas and the compilation of management recommendations involve the application of the results of the current status study as well as the utilization of information from numerous other sources.

RESULTS

Nesting activity within the Sierra was confirmed in 1978 when Peregrines successfully fledged at least one and possibly up to three young from an eyrie on El Capitan in Yosemite National Park (Wittreich and Garton 1979). In 1979, only an adult male was observed at the nest site, and no young were fledged. The site was again active in 1980 and two young were fledged. In 1981, three nestlings

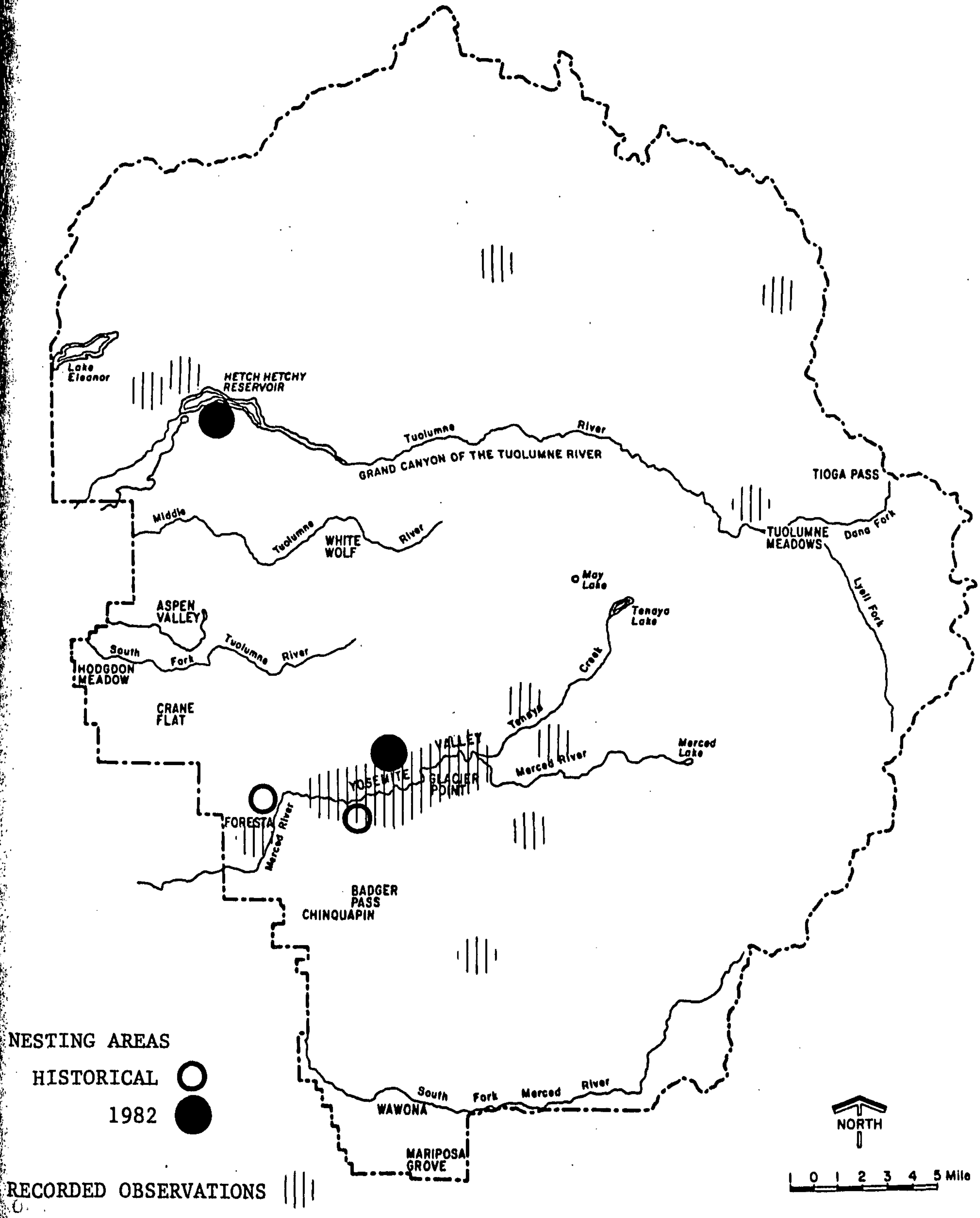
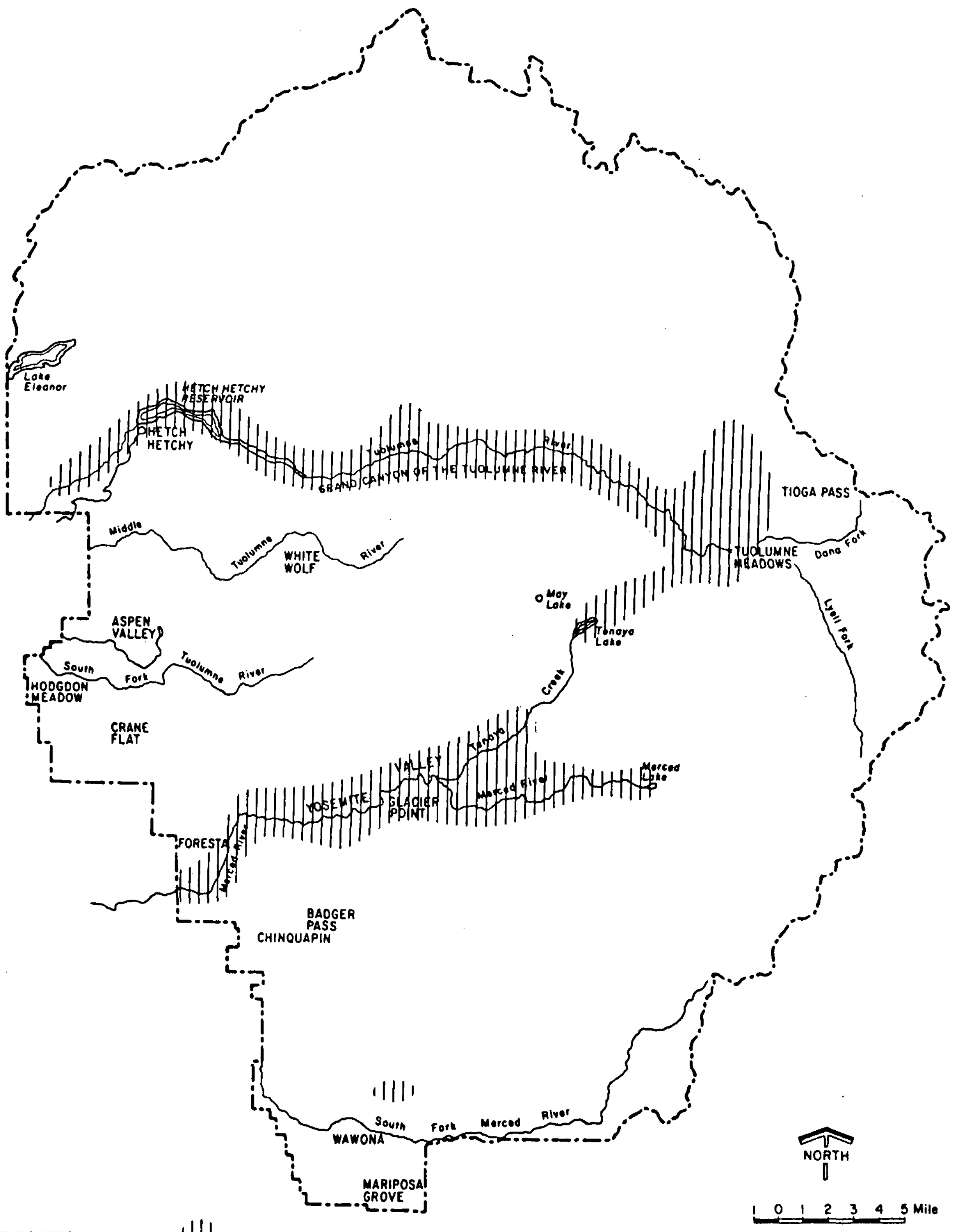


Figure 1

Recorded Peregrine Activity Within Yosemite National Park—1926-1982



OBSERVATION AREAS ||||

Figure 2

Areas of Observation During 1982 Selected on the Basis of Historical Records and Physical Characteristics

were produced. One immature male Peregrine was found at the base of the nesting cliff and was subsequently cared for by the Santa Cruz Predatory Bird Research Group after it was determined to be incapable of survival in the wild. This bird is now being kept for captive breeding purposes. The other two young fledged from the site.

In 1982, this nest site was manipulated by members of the Santa Cruz Predatory Bird Research Group because detrimentally thin eggshells were predicted. Four eggs were removed and, after artificial incubation, three hatched. Two other young were placed in the El Capitan eyrie and both birds subsequently fledged.

During the summer of 1981, we found another active site within Yosemite National Park in the vicinity of Hetch Hetchy Reservoir. Records indicate that two Peregrines were observed within 5 km of this site in 1949 (Jacobs 1949) and another observation was recorded near the site in 1978 (Wittreich and Garton 1979).

Between June and late October of 1981, we observed both immature and adult Peregrine Falcons at this site. We were unable to positively document the presence of both male and female adults by viewing them at the same time, however, separate observations indicate that both an adult male and female were present. Also observed was one immature Peregrine, identified as a female.

The reproductive success of this site in 1981 is unclear, for it is uncertain whether this immature bird was fledged during 1981. When first discovered on 25 June 1981, the immature female could fly well but spent much time perching and producing begging calls. Eggshell fragments collected from the suspected eyrie in early August were identified as Peregrine, but were not believed to be from the current season (Ramey 1981). Also, the immature bird we observed had missing and/or broken feathers, and one brief observation of both brown and black feathers on the back indicated possible molting. If the immature bird that we observed was not a fledgling, but instead a year old bird, then it is possible that this site was active and reproductively successful in 1980 but not 1981. Thelander (1976) reported that during the following nesting season, immature Peregrine Falcons are often seen at the site from which they fledged.

On 12 April 1982, we again observed a pair of Peregrines at the newly discovered site. These birds were determined to be an adult male and adult female. Copulation was first observed during the third week of April. The birds were determined to be incubating at a different eyrie (not the suspected 1981 eyrie) on 7 May. Hatching date was noted as 10 June. On 27 July, two adult Peregrines and two fledged juvenile Peregrines were observed.

CONCLUSIONS

Since the beginning of this project, 122 man days have been spent in the field within Yosemite National Park searching for or observing Peregrine Falcons. All areas containing historical eyries have been closely observed and most areas with recorded Peregrine sightings have been visited.

One new active nesting site has been discovered, and this is only the second known currently active site within the Sierra Nevada. The other active nesting site, also occurring within Yosemite National Park, is on El Capitan.

The process of designating and evaluating potential nesting areas is continuing and information is being compiled to complete a set of management recommendations on monitoring the Peregrine Falcon in Yosemite National Park.

ACKNOWLEDGEMENTS

Thanks to Charles van Riper III, Jeff Keay, Brad Cella, Brian Walton and Dave Harlow for their continued advice and support. Glen Browning, Bob Davis, Thom Curdts and Russel Tucker provided invaluable field observations.

MANAGEMENT OF PARATUBERCULOSIS IN TULE ELK IN CALIFORNIA

D.A. Jessup, P. Gogan,[1] B. Abbas,[2], and D. Behymer.

ABSTRACT

Paratuberculosis was diagnosed in three tule elk *Cervus elaphus nannodes* in the winter of 1980 and the spring of 1981. The diagnosis was based on gross necropsy and histopathologic findings and on isolation of *Mycobacterium paratuberculosis* from tissues and feces. Fecal culture and acid-fast stains of fecal smears proved to be more effective than complement fixation in diagnosis of the disease.

INTRODUCTION

Paratuberculosis has been reported in numerous captive wild species, including white-tailed deer *Odocoileus virginianus* (Libke and Walton 1975), roe deer *Capreolus capreolus* (Hellermark 1966), European red deer *Cervus elaphus* (Vance 1961), moose *Alces alces* (Soltys et al. 1967), aodad *Ammotragus lervia* (Boever and Peters 1974), mouflon *Ovis musimon* (Katic 1961, Boever and Peters 1974), camel *Camelys bactrianus* (Katic 1961, Thoen et al. 1977), bighorn sheep *Ovis canadensis* (Thoen et al. 1977), reindeer *Rangifer tarandus* (Katic 1961), Japanese sika deer *Sika nippon* (Katic 1961), water buffalo *Bubalus bubalus* (Katic 1961), yak *Bos grunniens* (Katic 1961), gnu *Connochaetes albojubatus* (Katic 1961), and llama *Lama glama* (Appleby and Head 1954).

Reports of clinical paratuberculosis in free-ranging wildlife are few and incomplete, except for a recent report of six cases involving a herd of Rocky Mountain bighorn sheep and a Rocky Mountain goat *Oreamnos americanus* on Mt. Evans, Colorado (Williams et al. 1979). We document three clinical cases of paratuberculosis in a herd of tule elk *Cervus elaphus nannodes* recently established on land previously used by dairy and beef cattle. Subclinical infection was diagnosed in a fourth animal.

At Point Reyes on the coast of central California, the National Park Service maintains a reservation of approximately 100,000 ac on a peninsula jutting into the Pacific Ocean (Fig. 1). Several of the original dairy farms throughout the area are operated through lease arrangements with the Park Service. Two species of exotic deer, axis deer *Axis axis* and fallow deer *Dama dama*, were introduced into the area during the 1940s. Since their introduction, the exotic deer population has increased to the extent that control measures are necessary to maintain populations at carrying capacity. Although *M. paratuberculosis* had been isolated from feces of normal axis and fallow deer at Point Reyes, none was clinically affected with paratuberculosis (Riemann et al. 1979). Tule elk were introduced onto the peninsula in 1978 in accordance with state laws granting them full protection and mandating relocation of tule elk onto historic ranges. Contact between exotic deer and tule elk has not occurred.

The three affected tule elk were born at Point Reyes National Seashore after relocation of a herd of 14 adult elk to the narrow end of the peninsula, separated by fencing from dairy farms. Two were born in March 1978 and one in March 1979. Due to ongoing litigation, beef cattle remained on the elk range for over a year, severely competing for feed. Copper deficiency and starvation resulted in the deaths of several adult elk, and reproductive rates were greatly reduced until cattle were removed. Although transient diarrhea is a common spring phenomenon in wild ruminants, two 2-yr-old elk had diarrhea through the summer and into the fall of 1980. Because California law protects tule elk, it was decided to immobilize and test affected animals and as many others in the herd as possible.

Wildlife Investigations Laboratory, California Department of Fish and Game, 1701 Nimbus Rd., Suite D, Rancho Cordova, CA 95670

[1]Department of Forestry and Natural Resources, University of California, Berkeley, CA 94720

[2]Department of Epidemiology and Preventive Medicine, School of Veterinary Medicine, University of California, Davis, CA 95616

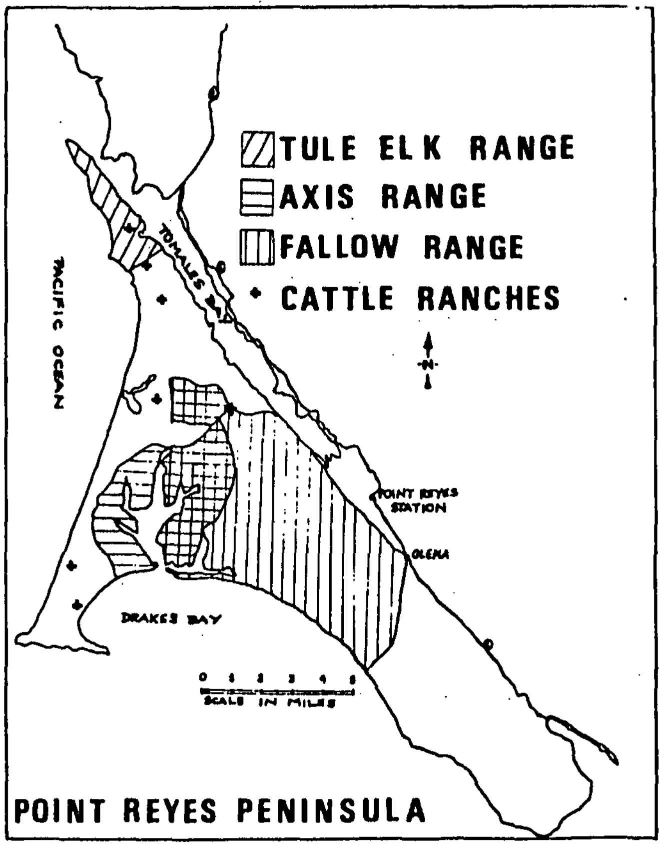


Figure 1

Map of Point Reyes National Seashore, showing locations of exotic deer, dairy cattle, and tule elk. Black-tailed deer use the entire peninsula.

METHODS

A combination of 4 mg of etorphine and 35 mg of xylazine was administered via dart syringe to ...nimals. Venous blood samples and fecal samples were obtained from 12 individuals. Animal 1 was ...ented for necropsy on 25 November 1980, and provided the initial diagnosis. Animals 2 and 3 ... euthanized in extremis in March and May 1981, respectively. Feces from each live animal and ...enteric lymph nodes from each necropsy were stained by the Ziehl-Neelsen method. ...presentative tissue specimens were fixed in buffered 10% formalin, routinely processed, and stained ... hematoxylin and eosin and Ziehl-Neelsen stains. Blood samples were allowed to clot, then ...gerated and separated for serum. Sera were tested for antibodies against *M. paratuberculosis*, using ... complement-fixation test. Fecal and tissue specimens were washed in 0.3% benzalkonium chloride, ...utlined by Merkal (1971). A 1.0-ml aliquot of each fecal suspension or tissue homogenate was ...ulated onto slants of Herrold's egg medium with mycobactin and onto 1 slant without mycobactin ...rkal 1971). Incubation times ranged from 12 to 14 wks at 37° C. Diagnosis was based on ...roscopic examination of clumps of acid-fast bacilli from colonies subinoculated to additional slants ... had mycobactin dependence. A culling program was instituted. Under this program, tule elk ...wing signs of persistent diarrhea were to be shot and removed from Point Reyes for necropsy.

RESULTS

Initially, clumps of acid-fast organisms were identified in the feces of the clinically affected animals. *Mycobacterium paratuberculosis* was eventually recovered from these animals, as well as from a fourth animal that appeared normal and had a fecal smear negative for acid-fast bacteria. Complement-fixation testing revealed little difference between fecal culture-positive and fecal culture-negative animals. Two of 10 fecal culture-negative animals had no reaction; the rest had suspect reactions of 1:8. Animal 2 retested at necropsy had a titer of 1:32. *Mycobacterium paratuberculosis* was recovered from feces and mesenteric lymph nodes of all three affected animals, and from liver and gut sections of animal 2. Affected animals had similar gross and microscopic lesions. All three animals were emaciated, had fecal pasting of the hocks and perineum, and had rough, light-colored, brittle coats. All animals had subserosal edema of the jejunum and ileum and attaching mesentery. Afferent lymphatics from this region were enlarged, beaded, and cream-colored. Mesenteric lymph nodes draining this area were firm and, on cross section, white proliferative patches were noticed. The walls of the jejunum and proximal ileum were extremely thickened and rugose, and the mucosal surfaces were reddened (Fig. 2). Multiple 1 to 2-cm light-colored areas were present throughout the liver of animal 2.

Microscopic examination of the lamina propria and submucosa of the jejunum and proximal ileum revealed extensive infiltration by large, pale, foamy eosinophilic epithelioid mononuclear inflammatory cells. The distal ileum and cecum were less severely affected. Acid-fast organisms, usually within macrophages, were evident in the lamina propria and submucosa (Fig. 3). Multinucleated giant cells were in the submucosa and mesenteric lymph nodes. Although granuloma formation was a prominent feature of the inflammatory response, casesation, necrosis, and mineralization were not seen. Small granulomata were scattered through the liver of animal 2 in a pattern suggesting vascular metastasis. Culling was not necessary in 1982, as no symptomatic elk were reported.

CONCLUSIONS

Spores of *M. paratuberculosis* can survive for more than 1 yr (Jubb and Kennedy 1970), and cattle on the premises during or shortly before elk relocation seem the most likely source of infection. How important a role marginal nutrition during the first year of life played in susceptibility to infection should become evident as future generations of tule elk are born at Point Reyes without competition with cattle. It should be noted that tule elk are a highly inbred subspecies of elk. Immunologic competence of tule elk has not been tested nor compared with that of other races of elk or domestic animals. The clinical and pathologic features of paratuberculosis in tule elk most closely resemble the disease in domestic cattle. Microscopically, mineralization or caseation was not evident in the intestinal wall or lymph nodes, as described in affected domestic sheep (Kluge et al. 1968, Nisbet et al. 1962). Giant cell formation, as reported in cattle, was abundant in the intestinal wall and in lymphatic tissues. Although naturally occurring paratuberculosis has not been reported in free-ranging elk, it has been reported in several closely related species and has been transmitted experimentally to elk (E.S. Williams, pers. comm.).

The initial recommendation to cull all elk at Point Reyes and to restock that range after a suitable period of time was rejected. The alternative, culling only affected individuals, carried with it the inherent risk that those individuals would serve as a source for continued infection. In cattle, infection usually occurs during the first six months of life, but is not manifested as disease until approximately 2 yrs. Adults are refractory to infection. The three affected individuals showed signs of disease at almost precisely 2 yrs of age. Only one animal of that age class survived through the spring of 1982. It appears that culling of affected individuals, environmental dilution and a very small susceptible age class may have combined to eliminate paratuberculosis disease from tule elk at Point Reyes. This will be confirmed only by several generations of 2-yr-olds without signs of disease. Adjacent cattle and deer remain as potential sources for reintroduction of paratuberculosis.

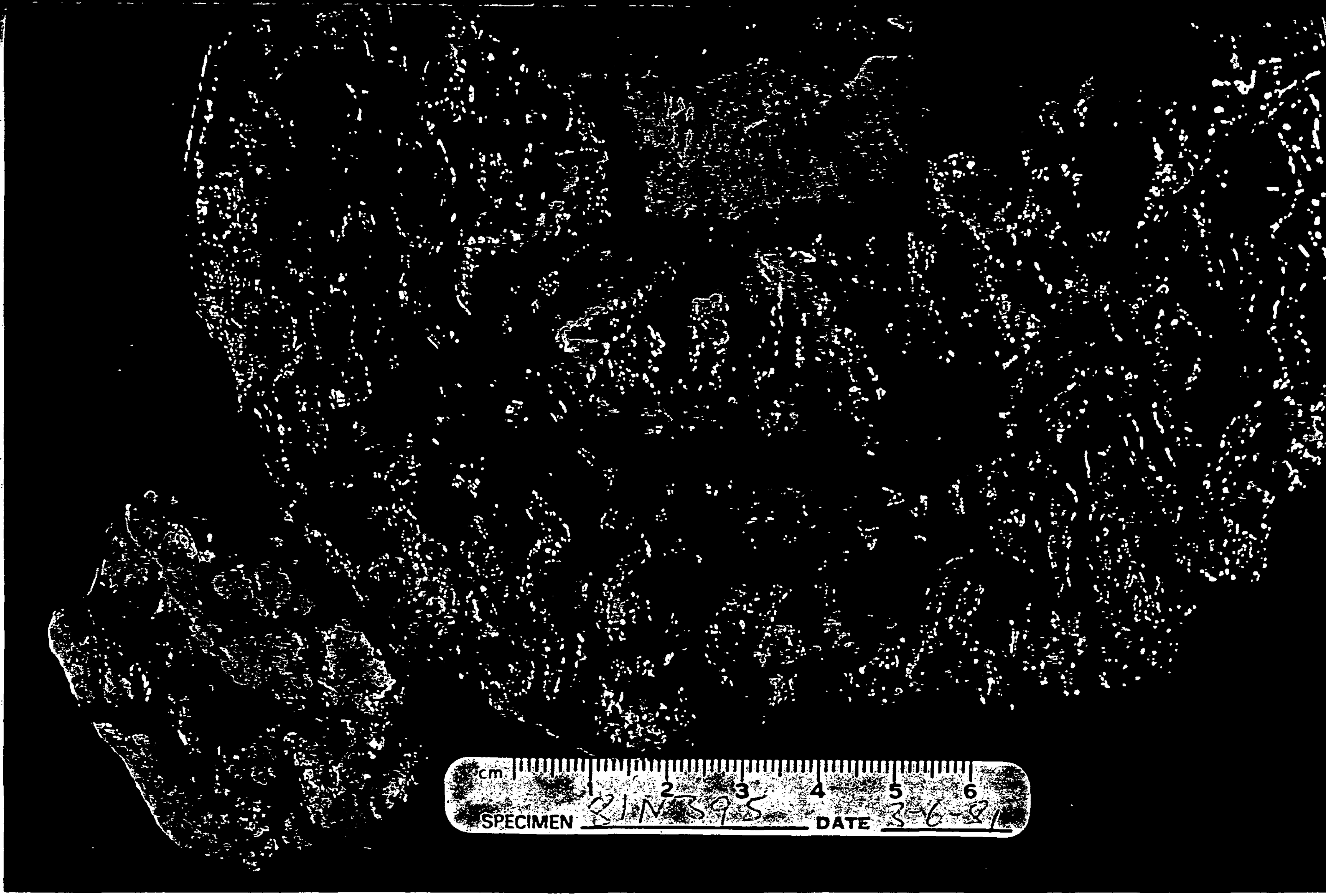


Figure 2

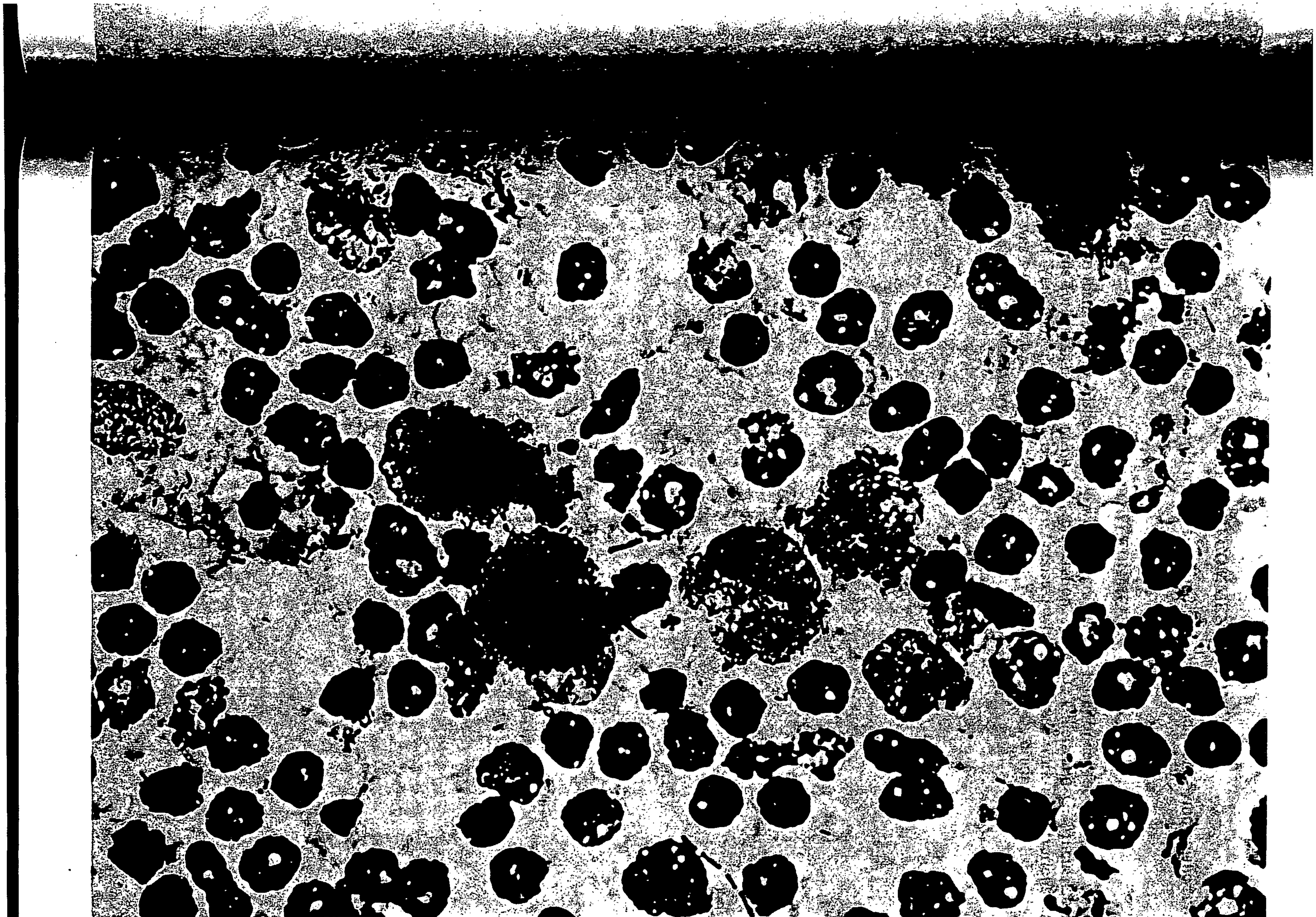


Figure 3

Ziehl-Neelsen Stain of Intestinal Wall Showing Acid Fast Organisms Within Macrophages

MANAGEMENT RECOMMENDATIONS

As much as possible, tule elk should remain separated from cattle and deer. Symptomatic animals should be culled.

ACKNOWLEDGMENTS

We wish to thank Ann E. Fisher for help with the graphic art, Karen Jones for laboratory support, and Sue Records for assistance in manuscript preparation. Drs. D. Gillett and G. Mitchell of the Department of Veterinary Pathology, U.C. Davis, assisted with pathologic work-up of various cases. This work was supported by Pittman-Robertson Project W-52-R21 and was originally published in the Journal of the American Veterinary Medical Association.

STEREOPHOTOGRAMMETRY IN WILDLIFE RESEARCH AND MANAGEMENT

D.E. Grubbs and J.N. Hatzopoulos[1]

ABSTRACT

Animal photogrammetry was first attempted more than 70 yrs ago. While it has received wide medical application and had occasional application in agriculture, remote animal measurement has gone unnoticed in fields that might benefit from it most. In light of recent developments in optics, photography and engineering we have begun to develop methodology that would permit a manager or researcher to quickly appraise important aspects of an animal's morphology without capturing, handling or otherwise disturbing the animal. We are able to predict animal weight with a precision of 5% or better from photographs alone. Such precision would be of value in projects where pharmacological intervention is required, but more importantly, we expect further work to yield protocols of use in predicting nutritional status, pregnancy, litter size and other features of interest to the wildlife manager. The use of inexpensive zoom lens-equipped 35mm cameras and polaroid equipment also look promising.

INTRODUCTION

Animal mensuration of one form or another frequently governs the success or failure of wildlife research and management. The applications range from the purely pragmatic—measurements taken to assure a proper dose for a tranquilizer—to ones that are more academic—measurements that might reflect the nutritional plane of free-ranging animals relative to the condition of their range. Of special value are methods that permit wildlife researchers or managers to appraise important aspects of an animal's morphology without requiring the worker to capture, handle, or otherwise disturb the animal. Developments in optics, photography and engineering have resulted in advances in photogrammetry that make it especially well suited for such applications. It suffers at present in that its promise is not widely appreciated in the disciplines that might benefit from it most, and from the fact that traditional photogrammetric methods require costly camera equipment, a stereoplotter the size of a small car, a degree in photogrammetry, and a great deal of leisure for the photographic analysis. We have been working in Engineering and Biology at California State University in Fresno to overcome these limitations in hopes of widening the scope of its applications.

METHODS

Animal photogrammetry is not new. It was first attempted more than 70 yrs ago (with equipment constructed incidentally by Carl Zeiss). It has had wide medical application, contributing to everything from reconstructive surgery (Wright et al. 1974) to the analysis of athletic performance (Walton 1977). While there has been interest in photogrammetry in agricultural science (Brinks et al. 1964), applications in zoology have been rare. The limitations of the methodology have simply made other forms of measurement more practical.

Traditional stereophotogrammetry is precise—but then it should be. It is essentially a slice by slice, three-dimensional reconstruction of the object that was photographed (Fig. 1). Few wildlife applications actually require such precision. Photogrammetry can be performed with modest equipment by technicians with minimum training and quite quickly. For zoological applications we have been using radial line techniques which are translations of linear dimensions on a stereo pair of photographs into linear dimensions on an imaginary image plane parallel to the original shutter plane. The geometry

Department of Biology, California State University, Fresno, CA 93740
[1]School of Engineering, California State University, Fresno, CA 93740

his technique is shown in Fig. 2. While the contour maps of true stereophotogrammetry provide ater precision, we can achieve estimates of three-dimensional quantities, such as weight, within 5% uracy without dealing with three-dimensional data.

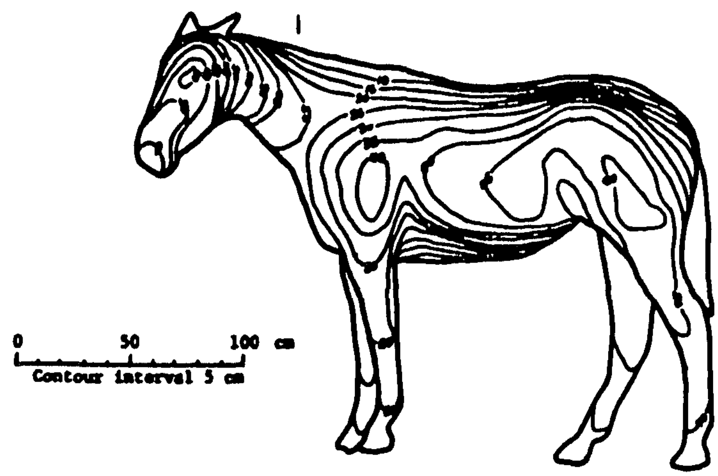


Figure 1

A Contour Map of a Horse from the CSUF Department of Animal Science

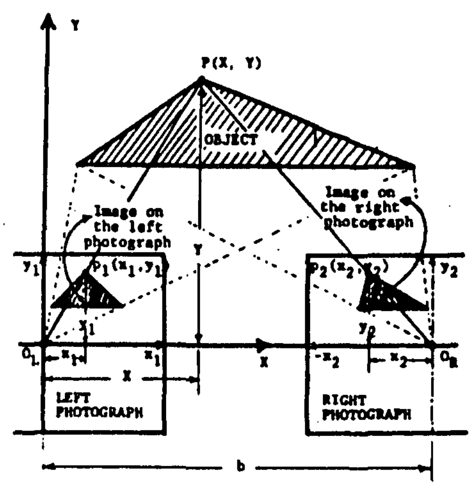


Figure 2

Interrelationship of Stereophotographs and Orthogonally Projected Object to the Image Plane

In practice, the animal is photographed with a stereo pair of cameras mounted on a rigid bar such their axes are parallel. Although we have used Wild-P32 metric cameras, common 35 mm ras are adequate in theory, and the mounting can be performed at modest cost by an engineering The photos are developed, enlarged, taped to a desk and all of the data are acquired with a ruler. eometry is such that the cameras may be equipped with zoom lenses, and we hope to test such and polaroid camera backs to speed processing in the near future.

The radial line method is easiest to visualize with reference to our pilot studies, in which we ed it on horses of known weight in our Animal Science department. Four linear dimensions (a, b, nd d in Fig. 3) proved adequate, but additional dimensions may be included if necessary. The ensions were computed from the image coordinates of points one through five using a small rammable calculator. A multiple regression equation was then derived that yielded a prediction of ht from the four dimensions.

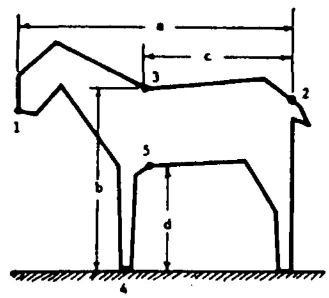


Figure 3

Location of the Measured Points on the Horse

The application of radial line techniques to this problem was described by Hatzopoulos (1983). methods are similar to those of Beard et al. (1974).

In summary, the known quantities for the computational analysis are the base line, b (which is the ance joining the respective centers of the two stereocameras at the moment of the exposure) and photographic coordinates measured directly on an enlarged paper print. The unknown quantities are rdinates like X and Y. Considering a coordinate system with its origin located at the principal point he left photograph O_L, the object space coordinates of point P are X and Y, while its image rdinates on the left photograph are x_1 and y_1, and x_2 and y_2 on the right photograph. From similar ngles

$$\frac{X}{x_1} = \frac{Y}{y_1} \tag{1}$$

$$Y = \frac{(y_1)}{x_1} \, . \, X = \lambda_1 \, . \, X \tag{2}$$

ilarly,

$$\frac{X - b}{x_2} = \frac{Y}{y_2} \tag{3}$$

$$Y = \frac{(y_2)}{x_2} \cdot (X - b) = \lambda_2 \cdot (X - b) \tag{4}$$

expression for X is obtained by combining (2) and (4) as follows:

$$X = \frac{\lambda_2 \cdot b}{\lambda_2 - \lambda_1} \tag{5}$$

Equations (2) and (5) are used to determine the object space coordinates X, Y of any point P ith measured image coordinates (x_1, y_1) on the left photograph and (x_2, y_2) on the right photograph. careful examination of the formulas (2) and (5) reveals that the image coordinates are involved in e computation of the object space coordinates in a ratio form of λ_1 and λ_2; however, if they are xpressed in the same measuring units (meters, inches, etc.), the object space coordinates are dependent of those measuring units. The units of the object space coordinates are the same as the its of the baseline b.

After computing the coordinates of points 1 through 5, linear distances a, b, c, and d are mputed applying the Pythagorean theorem. The computational analysis is completed by determining e coefficients of a multiple regression equation; a prediction equation of the form

$$X_1 = b_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 \tag{6}$$

here: X_1 is the dependent variable (the animal weight in this study):
X_2, X_3, X_4, X_5 are the independent variables (the linear distances a, b, c, d) and;
b_1, b_2, b_3, b_4, b_5 are unknown prediction coefficients.

RESULTS

The method was tested with the cooperation of the Department of Animal Science at CSU Fresno hich provided several sets of mares and their foals. The horses were photographed and weighed at 15 y intervals over a two month period. Image coordinates and linear distances were computed as scribed above, and three multiple regression equations were derived for horses and foals (set 1), als alone (set 2), and mares alone (set 3). Linear dimensions and residual weights (the difference tween an animal's actual weight and the weight estimated using the regression equation) are shown in ble 1. A statistical analysis is presented in Table 2 and the three sets of regression coefficients are ed in Table 3.

Table 1

Refined Measurements and Processing Results

Horse Name	Date	Linear Distances (Meters) a	b	c	d	Weight (lbs)	Residuals (lbs) 1st Set	2nd Set	3rd Set
Fair Lady Offspring	3/27	1.106	1.103	0.517	0.729	164.0	-25.5	-5.1	-
	4/10	1.164	1.095	0.561	0.682	192.0	22.3	18.0	-
	4/24	1.267	1.146	0.673	0.746	225.0	36.9	1.0	-
	5/8	1.151	1.124	0.678	0.710	265.0	-46.8	7.5	-
Poco Lady Offspring	4/10	1.220	1.092	0.618	0.646	264.0	15.3	-0.7	-
	4/24	1.312	1.133	0.678	0.687	295.0	11.0	-10.3	-
	5/8	1.308	1.161	0.685	0.688	319.0	53.4	-14.7	-
Nigties Bar Offspring	3/27	1.028	0.998	0.482	0.617	180.0	-87.9	-14.1	-
	4/10	1.163	1.068	0.565	0.632	225.0	20.3	8.5	-
	4/24	1.258	1.092	0.631	0.635	267.0	37.5	9.3	-
Fair Lady	4/10	2.319	1.571	1.223	0.815	1241.0	-25.9	-	-15.4
	4/24	2.408	1.589	1.033	0.833	1250.0	3.8	-	-2.5
	5/8	2.363	1.569	1.203	0.804	1260.0	-20.8	-	-26.1
Poco Lady	4/24	2.423	1.593	1.161	0.817	1250.0	34.8	-	11.5
	5/8	2.363	1.578	1.244	0.812	1217.0	24.8	-	23.1
Nigties Bar	3/27	1.728	1.528	0.766	0.788	1117.0	14.7	-	2.7
	4/24	2.213	1.483	0.852	0.771	1139.0	-33.2	-	-3.0
	5/8	2.362	1.513	1.155	0.789	1169.0	-34.8	-	9.8
Root mean square error (RMS)							35.7	10.4	14.6
Prediction error as a percentage of the mean weight							5.3%	4.3%	1.2%
Multiple correlation (R)							0.997	0.976	0.960
Minimum value of significance for R at $P \leqslant 0.05$							0.70	0.90	0.96

Table 2

Statistical Analysis

	Processing Set No.	Linear Distances a	b	c	d	Weight (lbs)	Minimum Value of Significance for Correlations P ⩽ 0.05	P ⩽ 0.01
Means	1.	1.695	1.302	0.818	0.733	668.8		
	2.	1.234	1.101	0.609	0.677	239.6		
	3.	2.272	1.553	1.080	0.804	1205.4		
Standard deviations	1.	0.548	0.228	0.265	0.071	482.5		
	2.	0.156	0.044	0.070	0.041	48.3		
	3.	0.214	0.037	0.169	0.019	52.3		
Simple correlations of distances and weight	1.	0.96	0.99	0.92	0.89		0.47	0.60
	2.	0.39	0.60	0.86	-0.29		0.64	0.76
	3.	0.77	0.86	0.78	0.84		0.71	0.84
Partial correlations of distances and weight	1.	0.39	0.97	-0.21	-0.81			
	2.	-0.52	0.62	0.83	-0.84			
	3.	0.67	0.60	0.00	-0.17			

Table 3

Regression Coefficients

Processing Set No.	b_1	b_2	b_3	b_4	b_5
1	-1252.50	125.23	2483.97	-96.72	-1971.64
2	-163.01	-61.64	578.36	560.19	-737.26
3	-406.22	119.75	1108.82	0.84	-477.111

DISCUSSION AND CONCLUSIONS

A complete discussion of the statistical implications of our pilot study has been presented by Hatzopoulos (1983). Note in summary, however, that the largest prediction error, expressed as a percentage of mean weight, is 5.3%. This is well within the precision required in most wildlife applications. Smaller errors may be achieved using the regressions derived for foals alone (set 2) and mares alone (set 3). While this is a quantification of the obvious—foals are not miniature mares—it illustrates the need to derive mathematical protocols for the animals to which it will be applied. It will have to be calibrated on bears if it is to be used on bears and calibrated on elk if elk are the focus of a study. We are hoping to test the methods on exotic animals in zoos to determine the extent to which a protocol derived for animals of one morphology is transferable to animals of another.

Note also that the calibration procedures yield correlation coefficients between dimensions and weight and that some dimensions are better predictors than others. Dimension d is not very useful as an index of foal weight for example. This is not surprising in light of the fact that horses are born ready to run, with disproportionately long legs relative to their adult morphology. More important, however, is that the initial photographic analysis allows the worker to test all possible dimensions and to select from them those that best estimate the variable of interest. In our case dimension b alone is a respectable predictor of weight and it is a dimension that remains rather constant regardless of posture and alignment of the subject relative to the cameras.

This analysis may also reveal specific dimensions indicative of specific states of interest. For example, Severinghaus (1981), recently developed regressions for weight loss and estimated weights-to-no-return for deer. Photogrammetric study might readily detect whether terminal weight losses would be achieved, allowing for timely intervention where indicated and practical.

MANAGEMENT RECOMMENDATIONS

At this stage in its development, this project probably falls outside of the research directives of any individual Park unit. However, we are eager that those of you that might benefit from it know of its promise. We would be interested if this procedure would appear to be of value to research projects, and we would appreciate invitations to test our methods on wild animal subjects.

ACKNOWLEDGEMENTS

We would like to acknowledge the School of Engineering at California State University, Fresno for its support and the grant under which this research project was performed. A special thanks is extended to Dr. James D. Matheny, Dean of the School of Engineering. We would also like to thank Dr. G. Heusner from the Animal Science Department, Dr. F. Nader from the School of Engineering, Mrs. Mary Swanson of the Fresno Zoo for scientific support, and Mrs. Mary Gibson for typing the manuscript.

SECTION IV:

SOCIAL SCIENCES

UNDERWATER ARCHAEOLOGICAL INVESTIGATIONS OF GOLD RUSH ERA STEAMSHIPS ON THE CALIFORNIA COASTLINE

J.P. Delgado

ABSTRACT

San Francisco was the site of intensive urbanization and industrialization during the 19th Century. Trade and commerce depended upon a fleet of sail and steam vessels, many of which eventually were wrecked near San Francisco. The various shipwrecks in the area comprise a unique and significant study collection of vessel types and cargoes. Due to threats from erosion and collection activities a program of survey and analysis has been proposed for sites in the legislated boundaries of Golden Gate NRA, San Francisco. Research was initiated with the S.S. *Tennessee* (1848), a significant steamship wreck, through an interdisciplinary approach utilizing scientists, archaeologists, and historians. Comparative studies are underway at the S.S. *Winfield Scott* (1850) in Channel Islands National Park and are being considered for the S.S. *Samuel S. Lewis* (1851) in the Point Reyes/Farallon Islands National Marine Sanctuary, California. Additional wrecks will be considered for study. These studies have the potential of revealing much about infant steam technology, trade, and urbanization of the Pacific Coast of the United States.

INTRODUCTION

Prior to 1848 California was an isolated province, separated by land and sea from her successive governments' seats of power. Madrid, Mexico City, and Washington, D.C. were months away from the sparsely populated agrarian territory. Under Mexican rule (1822-1846) ports of entry included San Diego, Santa Barbara, Monterey, and San Francisco, each of which boasted equal opportunities for trade. After the American conquest of California during the Mexican War of 1846-1848 and the subsequent annexation of California as a Territory of the United States, San Francisco began to gain prominence due to its great inland harbor, which afforded endless opportunities to shipping. The discovery of gold in California in January of 1848 confirmed the primacy of San Francisco Bay as a West Coast center for trade and commerce as thousands of vessels sailed for San Francisco, which, with its natural position of an entrance to the great rivers that pierced California's interior, became the gateway to the gold fields. By 1849, incoming vessels had more than doubled the population of the small town of San Francisco and nearly one thousand ships rode at anchor in the bay (Lewis 1949, Lotchin 1974, Caughey 1975, Holliday 1981).

The influx of vessels sailing to San Francisco remained constant throughout the early years of the gold rush. The number of sailing ships peaked after 1850, with a predominate number of steamships now making the trip regularly as steamship lines were established and the famous "clipper ships" began to make their appearance. Steamers were to ultimately control West Coast shipping with their reliable and dependable schedules. Not dependent upon the winds, tides, or currents, as were sailing ships, steamers though at times slower than clippers, were hailed as the links that tied the frontier territory of California with the established mercantile and industrial houses on the Eastern seaboard of the United States and Europe. Fifteen steamers joined the Gold Rush in 1849, to be followed by dozens more in the 1850s. The Pacific Mail Steamship Company, and later its competitors, regularly plied the California coast between San Francisco and Panama City, touching at various intervening ports. The narrow Isthmus of Panama proved to be the quickest and easiest means of getting to California until the completion of the transcontinental railroad in 1869, and throughout the 1850s steamers and sailing ships carried the bulk of passengers, mail, cargo, and gold via the "Panama Route" (Wiltsee 1938,

Golden Gate National Recreation Area, Building 201, Fort Mason, San Francisco, CA 94123

[Ke]mble 1943, Rasmussen 1970). This trade made possible the quick urbanization and industrialization [in t]he 1850s of San Francisco, California, and ultimately the Pacific Coast.

[Wi]th The hectic pace of shipping required to keep trade flowing, as well as generally unsafe sailing [co]nditions, with no lighthouses to mark dangerous harbor entrances, inadequate and at times inaccurate [sa]iling charts and directions, and mariners unfamiliar with the coast led to hundreds of shipwrecks [(S]hanks and Shanks 1976, Hagwood 1982). The shattered hulks of the many sail and steam vessels [th]at litter the beaches and offshore waters of California have been called "footsteps in the sea" [(M]arshall 1978). The term is not inappropriate. Clusters of shipwrecks in certain geographical areas tell [mu]ch about the importance, safety, and role of the individual ports. It is not surprising, then, to note [ov]er three hundred shipwrecks in and around San Francisco Bay alone, some as early as the *San [Ag]ustin,* which went aground and broke up 30 mi north of the Golden Gate while surveying the [coa]stline in 1595 (Aker 1965). However, the number of wrecks which occurred prior to 1848 were [fe]w, since most met their fates after the Gold Rush. These wrecked vessels, of all types, sizes, rigs, [re]gisteries, and ages, comprise a unique study collection. The collection, *in toto,* reflects the [d]evelopment of Pacific Coast ships and shipping for over a century. As such it deserves a careful [p]rogram of survey, identification, analysis, and preservation. Such programs are not unknown. The [N]ational Park Service's Submerged Cultural Resources Unit (SCRU) has conducted surveys in National [Pa]rk Service areas at Gulf Islands National Seashore, Biscayne National Monument, Isle Royale [N]ational Park, and is in the process of completing a survey at Point Reyes National Seashore in [C]alifornia (Lenihan 1974, Murphy et al. 1980, 1983). Surveys have been conducted in California waters [b]y the Corps of Engineers near Los Angeles (Hunter and Pierson 1980) and for the State of [C]alifornia's Fort Ross State Historic Park (Foster 1983). Individual searches for specific vessels have [b]een legion in other states. The successful professional effort which culminated with the discovery of [th]e historic U.S.S. *Monitor* is one example (Sheridan 1978). In California, most individual vessel [se]arch projects are the domain of wreck divers, treasure hunters, and salvors.

METHODS/RESULTS/DISCUSSION

A proposal has been developed for a comprehensive submerged cultural resource survey to locate [sh]ipwrecks at and near the entrance of San Francisco Bay within the waters encompassed by the [au]thorized boundaries of the Golden Gate National Recreation Area. The survey, which would be [co]nducted by park professionals with input and assistance from the NPS Submerged Cultural Resource [U]nit, would follow the basic outlines of the Point Reyes National Seashore Survey (Christopher et al. [1]982). The methodology of the survey will be conducted along conventional lines. Survey vessels [eq]uipped with locational devices and sophisticated electronic survey equipment such as side-scan sonar [a]nd magnetometers would locate "targets" which would then be investigated by divers or (in areas too [d]eep for divers) mini-submarines. Historical research would be conducted in advance to locate wreck [r]eports in newspapers, archives, diaries, reminiscences, and the records of the United States Life-Saving [S]ervice. This information would be used to assess possible shipwreck locations and to identify the [p]otential historical and archaeological significance of specific wreck sites. Once specific shipwrecks are [lo]cated, a limited program of documentation and analysis—a visual inspection of visible remains, the [p]reparation of site maps, photographs, and possibly some test excavation in conjunction with an on-site [m]agnetometer survey would be completed (Arnold 1977). A preliminary assessment of the extent and [in]tegrity of the wreck site would then follow. If conditions warranted further investigation, and the [s]uspected significance of the site was high, then additional research would be conducted to conclude [w]ith the nomination of the site to the National Register of Historic Places. The final result of the [su]rvey, then, would be a listing of all submerged cultural resources within the boundaries and [m]anagement responsibility of the Golden Gate National Recreation Area, a prioritization of these [r]esources based on their suspected eligibility for inclusion of the National Register of Historic Places [(as] determined by historicity, extent, integrity and archaeological values) and detailed individual site [r]eports and National Register nominations. The final report would include management [r]ecommendations and strategies for the protection of these fragile resources.

It is realized that the costs of such a venture are prohibitive. Adequate documentation of an individual wreck site may cost in excess of $100,000 (Delgado and Bennett 1981). When dealing with an area as large as the submerged lands of the Golden Gate National Recreation Area (over 2,000 ac) with many suspected shipwrecks, the time, outlay, and costs would be considerable. The goal is not, however, unrealistic. A utilization of existing resources (United States Coast Guard or Navy vessels, National Park Service survey equipment, and maritime archaeologists) with donations of equipment and money from private interest groups, such as was done at Point Reyes National Seashore when a private maritime archaeological group joined the effort, and cooperation with State and Municipal bodies may distribute the cost. Cost effective management would be achieved if the submerged cultural resource effort also included the equally important task of submerged natural resource survey and identification. When the survey effort is finally launched, it is realized that the task will take years to complete. When accomplished, however, it will serve as a model for the management and protection of significant submerged resources which although out of sight are not out of mind.

In the meanwhile, work has progressed with one known shipwreck within the authorized boundaries of the Golden Gate National Recreation Area. The S.S. *Tennessee,* a steamship built in New York in 1848, served on the Panama Route between 1849 and 1853, when she was wrecked 4 mi north of the Golden Gate in a fog. Her passengers, mails, and much of the cargo were landed safely, but the 1,200 ton vessel, her provisions, fittings, equipment, and some cargo were a total loss. The *Tennessee* is a significant vessel worthy of individual study. An early American steamer of transitional design (from sail to steam propulsion), she was involved in the pioneer years of the urbanization and industrialization of the Pacific Coast. This period, sparked by the California Gold Rush, matured after the conclusion of the Gold Rush period in 1855. The *Tennessee's* demise during the active phase of this first burst of urbanization and her survival as an archaeological resource containing material culture from this period, which can, when eventually collected under proper archaeological procedures, provide a unique perspective of the times, the people, and the events which she participated in, makes her a very important resource.

A research design for this project has been drawn up and plans for its implementation as a joint venture of the National Park Service and a non-profit private group, the S.S. *Tennessee* Project, Inc., achieved fruition in 1981 (Delgado and Bennett 1981). The project involves a coordinated effort between scientists, historians, archaeologists, and professional divers to document the site of the wreck of the S.S. *Tennessee.* An interdisciplinary approach is being utilized to reach an understanding of the nature of the wreck's significance, extent, and environment. Geological features, coastal processes, such as sand movement, weather, tides, and currents, and natural resource identifications of tidal zone and benthic organisms will be conducted in cooperation with the United States Geological Survey, the National Park Service, the State of California Bureau of Mines and Geology, and the California Academy of Sciences. Of specific interest are environmental factors influencing the distribution of wreckage and the preservation of material culture at the site. Detailed historical research in archives located locally and abroad is being conducted. Ship's plans, engine room drawings, menus, provisioning lists, cargo manifests, and passenger and crew accounts have been collected for the interpretation of archaeologically collected information and materials. The chance for "cross-checking" the veracity of the written record through the archaeological materials has not been overlooked, nor have the more obvious benefits of archaeologically documenting minute details that often do not merit mention in the written documents or plans of the day. The methodology of the project calls for as little disturbance or destruction as possible. Magnetometers will be utilized to investigate the range and scope of metallic wreckage, as suggested by Clausen and Arnold (1976). Side-scan sonar and sub-surface interface radar will also be used. Limited test excavations will then follow, both underwater and dry land, where surf-borne wreckage was deposited. Limited excavation of the beach areas has already begun; to date four hundred artifacts have been recovered and are being analyzed.

At the same time, plans were formulated for a comparative study of the shipwrecked remains of the S.S. *Winfield Scott,* an 1850 steamship which served on the Panama Route from 1851 to 1853, when she wrecked through an error in navigation on Middle Anacapa Island off the California Coast, in waters now encompassed by Channel Islands National Park. The remains of the *Winfield Scott* have been subjected to salvage and collection activity since the 1880s. Intensive diver intrusions began once again in the early 1970s and continue to this day, prompting Channel Islands National Park officials to suggest that a determination of the wreck's National Register status be made and protection activities stepped up in cooperation with the State of California, which has jurisdiction over the wreck. In order to assess the extent and integrity of the *Winfield Scott's* remains, a program of research similar to the *Tennessee* Project was proposed. In April of 1982 the first phase of the project, a preliminary mapping of visible wreckage, was carried out as part of a joint effort by Channel Island National Park and Golden Gate National Recreation Area staff. In addition to the obvious benefits of individual study of this wreck, the opportunities offered for a comparative study of historical and archaeological data are significant. It is realized that each wreck site can present a biased interpretation through the selective processes of historical documentation, material culture represented in the ship prior to wrecking, and the survival or lack of survival of the cargo, fittings, vessel, provisions, and personal items. To further the benefits of comparative study, plans are now being made to include within the study another steamer, the S.S. *Samuel S. Lewis,* an 1851 screw steamer which also wrecked in 1853 and whose remains lie on Duxbury Reef within the boundaries of the Point Reyes/Farallon Islands National Marine Sanctuary 15 mi north of San Francisco. The study of these three wrecks will doubtless provide much new information and would possibly revise current interpretations about the Panama Route, early steamships on the Pacific, and the processes of West Coast urbanization and industrialization derived from purely documentary sources.

CONCLUSIONS

Shipwrecks are much more than collections of relics scattered on the seabed. They are unique archaeological resources worthy of protection, particularly when they are within the authorized boundaries of National Park Service areas or National Marine sanctuaries, as are the *Tennessee, Winfield Scott,* and the *Samuel S. Lewis.* Particularistic interpretations of data pertaining to types of material cultural items, vessel construction, and early steam propulsion systems may be obtained at one level of investigation; additionally anthropological inferences can be made regarding the people who built, operated, worked, lived, and died on the vessels and the society they were a part of (Muckelroy 1978, D. J. Lenihan 1983, and Murphy 1983).

MANAGEMENT RECOMMENDATIONS

National Park Service, State of California, and local managers of submerged lands should take into account the submerged cultural resource potential of their areas and take the necessary steps to document, assess, and protect these unique and fragile resources. NPS managers of coastal areas have a challenge and a responsibility to identify their submerged cultural resources and exert responsible custodianship over them. In these times of fiscal restraint, the best means available to achieve this goal may be a regional effort utilizing resources, equipment, and personnel from each park. An intra-park program would equally distribute the costs and logistical burdens for mutual benefits.

ACKNOWLEDGEMENTS

The advice and support of Daniel J. Lenihan, Chief of the Submerged Cultural Resource Unit, Larry Murphy, and Toni Carrell, also of the Submerged Cultural Resource Unit, Robert Bennett, of the S.S. *Tennessee* Project, and Roger Kelly, Regional Archaeologist, Western Region, is greatly appreciated.

PROGRAMMING VARIABLES FOR DELINEATING PARK VIEWSHEDS IN SENSITIVE AREAS

K.J. Dawson

ABSTRACT

'View-It' is the computer graphics program presently utilized by the Department of the Interior and the U.S. Forest Service to map viewsheds (seen and unseen areas) in highly scenic natural landscapes. Sensitivity levels (patterns of recreational use) and scenic quality ratings presently determine which areas are placed under special management for protection of the visual resource. Viewing distance (seen area limits) is presently programmed arbitrarily, with little allowance for the duration and seasonality of atmospheric clarity or the foreground details of the surface landscape (topography is the primary data input). Discussion centers on recent research emphasizing the programming of atmospheric clarity, vegetation screening, and structural screening (both natural and man-made).

INTRODUCTION

Visual resource management is a growing concern in the stewardship of California's public lands, particularly in those areas where development pressure is threatening the scenic integrity of our more important natural environments (national parks, national monuments, wilderness areas, natural areas, and areas of critical environmental concern). Therefore, methodologies have been developed by the departments of the Interior and Agriculture to inventory and protect scenic resources in specific response to the Federal Land Policy and Management Act of 1976. The primary requirements of the act are stated in Section 102(8): "The public lands will be managed in a manner that will protect quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resources, and archaeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use."

Within the Department of the Interior, National Park Service lands are assumed to be under uniform management for resource protection but, in reality, development and recreational use are zoned into areas where scenic resources are usually considered but at times degraded. Although decision making on visual resource management in national parks is not uniformly applied, the informal process tends to follow the more formalized methods of the Department of the Interior's Bureau of Land Management (Fig. 1). The visual resource management program of the Bureau of Land Management (BLM) has three primary functions: the inventory and evaluation of visual resources on all BLM lands, the scenic mitigation of proposed developments under the multiple-use planning philosophy of BLM, and the support of design expertise through the monitoring of visual impacts and disseminating information on the value of visual resources (Ross 1979).

METHODS

In the BLM visual resource management system, landscape features (vegetation, water, etc.) and elements (form, line, color, and texture) are assessed along with landscape character (variety, harmony, and contrast) to provide a generalized idea of scenic quality. Because the staff surveys of scenic quality can add prejudices in assessment, regional and individual attitudes are inventoried so that visual sensitivity can be added as a balanced inventory. Sensitivity levels are determined in two ways: recreational use levels from survey areas are tabulated and interviews and workshops are held to determine user attitudes (Fig. 2b). The last part of the BLM evaluation phase focuses on distance

Department of Environmental Design, University of California, Davis, CA 95616

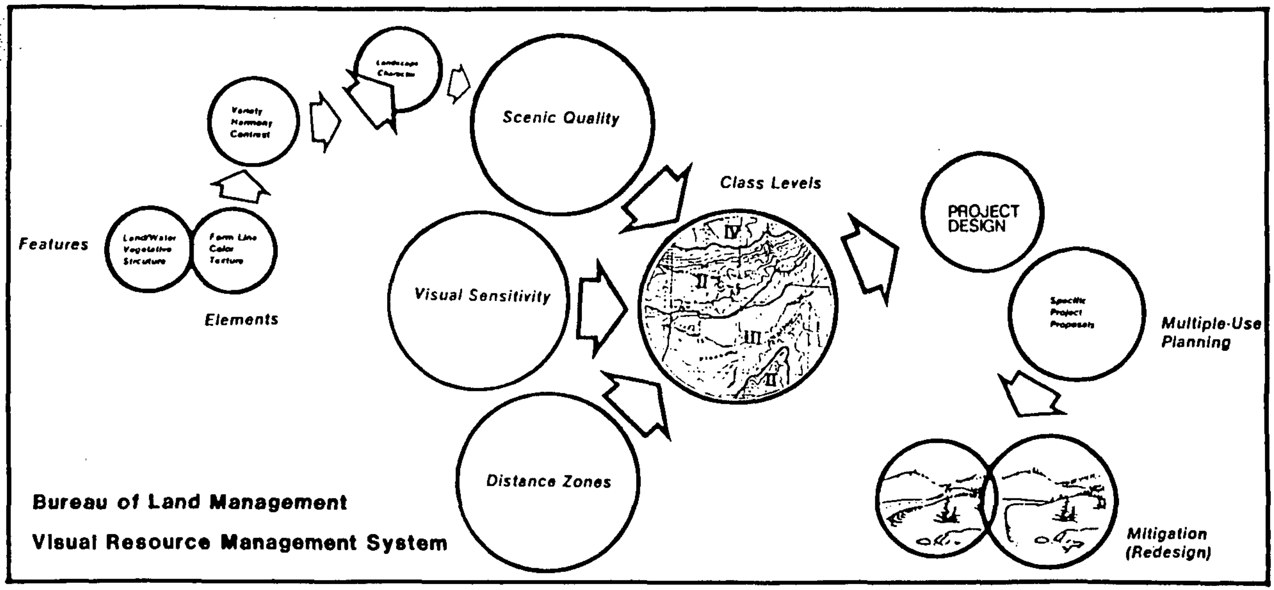


Figure 1

The Federal Land Policy and Management Act of 1976 requires that the scenic resources of the public lands be inventoried and that the natural integrity of those resources be protected. Shown above is a simplified version of the visual resource inventory and management system of the Department of the Interior's Bureau of Land Management. Features and elements of landscape character are assessed in terms of scenic quality. Scenic quality, sensitivity (use and perception), and distance zones are then combined to yield landscape management classes. Multiple-use planning are then designed or mitigated based on visual quality objectives.

zones. Distance of landscape elements and character may be magnified or diminished on observer distance from the evaluated scene. In the instance of the BLM system, distance is mapped as foreground, middleground, background, or seldom-seen areas (Fig. 2a). The combination of scenic quality, sensitivity, and distance zones lead to landscape management classes for the Bureau of Land Management which highlight areas for protection, improvement, rehabilitation, or development.

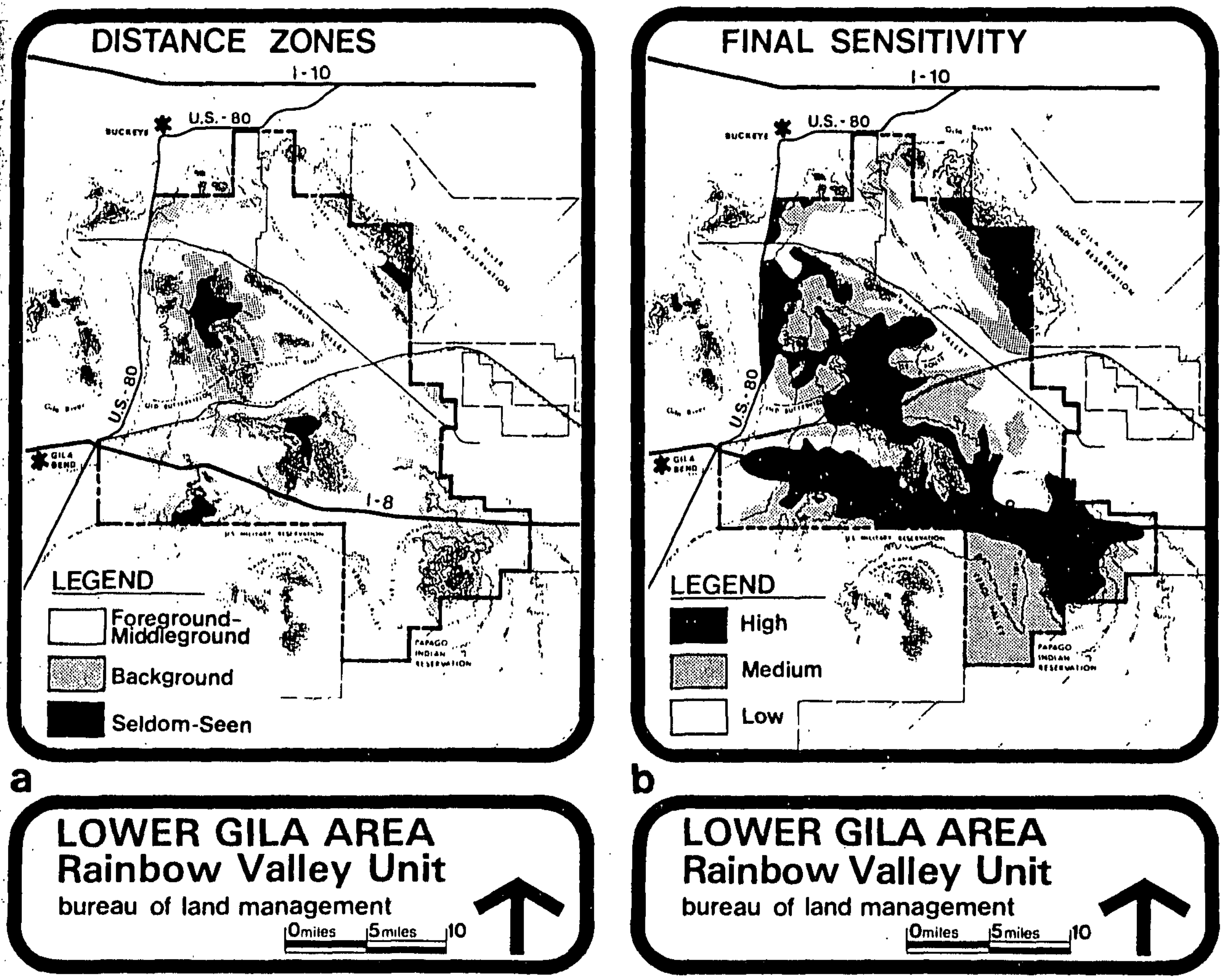


Figure 2a,b

Distance zones and sensitivity levels are very important variables in programming the significance and type of views to be assessed. Overlaying information from scenic quality, distance zones, and sensitivity is fundamental to determining management options (Dawson and Fryling, 1981).

RESULTS

Computerized techniques have been developed for mitigating development projects in conflict with visual resource management goals. VIEWIT is a computerized technique for delineating viewed areas from single observer points or from a continuous series of observer points (Fig. 3). VIEWIT utilizes elevation information from contours digitized on defense mapping agency computer tapes. The topography grid system, when converted to a standard United States Geological Survey 7 ½ Min Quad Map, has an area per grid cell size of 3.1 ac. It is fairly simple to attain a 7 ½ min format because the DMA information has been interpolated from a 1:250,000 scale UCGS map. Each DMA tape file represents one-half of each 1:250,000. Unfortunately, the 1:250,000 scale files have 200 ft grids which need to be converted to 333 ft by 400 ft rectangle grids to attain the 2.1 ac format. The conversion is accomplished using the TOPAS computer program COPYNCIC.

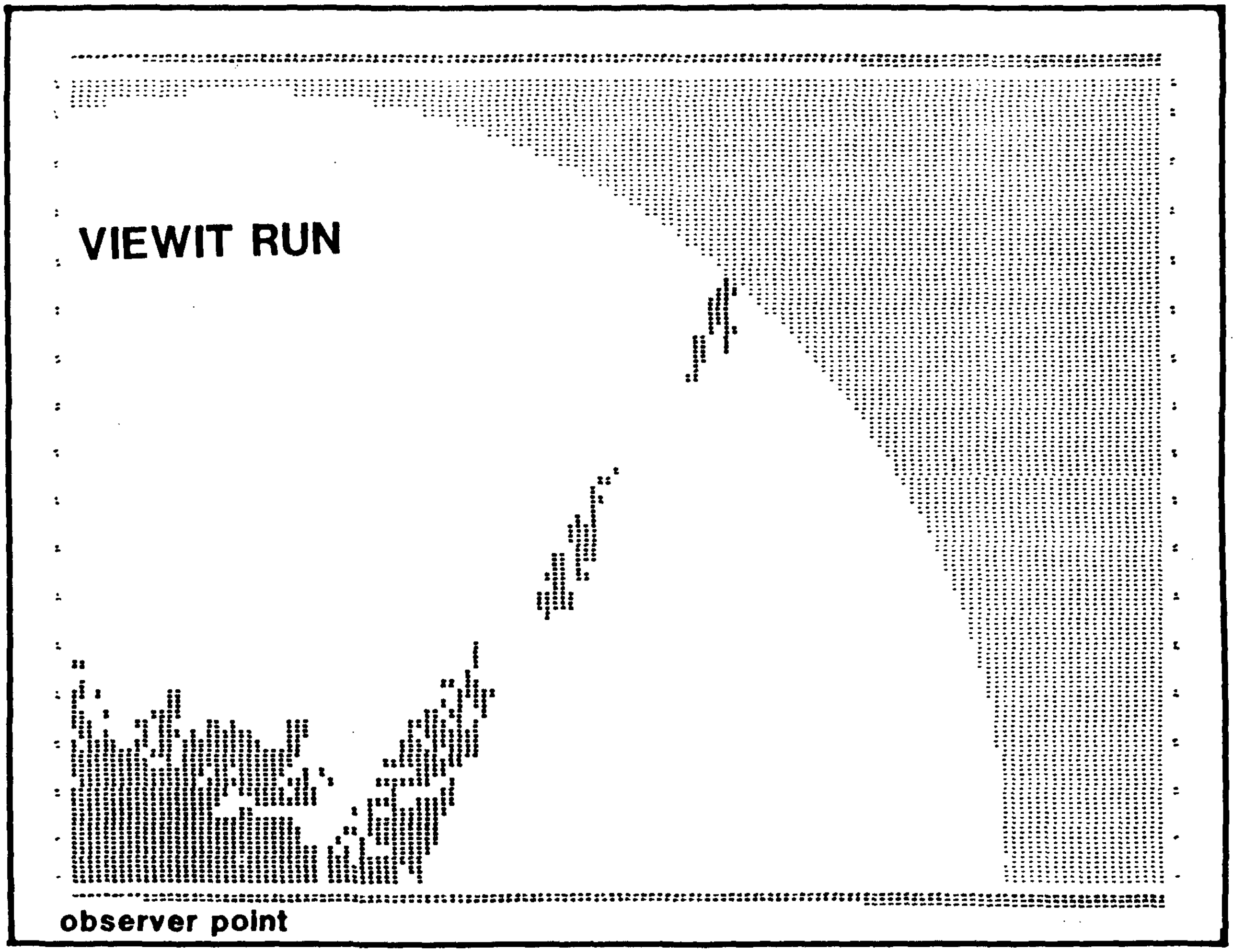


Figure 3

Computerized plotting by VIEWIT program, from a landscape control point at Cache Creek, Jackson, Wyoming (Litton, 1973). This is a single observer point, from the lower left, scanning visible areas. Circle quadrant represents programmed limit of survey. Each cell represents 3.1 acres on elevations established by interpolation for 1:250,000 single USGS maps recorded on defense mapping agency tapes.

VIEWIT has a general storage capacity of four total quads which generally covers a large area but at times can be inadequate. Additionally, joining of east-west maps and map halves (because of latitude and longitude curves in relation to grids) requires the use of of a Univac Text Editor and because of the column format of storing data, the TOPAS programs SCANDTIS and ARRAY must be used to join north-south maps and map halves. To produce one map file of DMA quad coordinates, the use of the TOPAS program PRINT is necessary. To fill the storage capacity through the creation of four-quad print-outs, the STAR*GRID Program (PSW*VIEWIT.DMA) is necessary (Travis et al. 1975).

DISCUSSION

One of the biggest problems VIEWIT has is the inaccuracy of topography information on the DMA tapes. The use of the 1:250,000 information is necessary on the tapes because not all of the country is mapped at the 15 min or 7 ½ min scale. The gross scale of the 1:250,000 scale maps often leads to truncated ridges or loss of definition in slightly rolling plains (Araki 1979).

Another drawback of VIEWIT is the lack of programming for vegetative screening, structural screening, and degraded visibility (Fig. 4). Litton (1973) has identified vegetative and structural screening as primary factors in explaining discrepancies between hand mapping of visual resources and VIEWIT mapping. Visibility is a complicated issue for VIEWIT because it is a traditionally difficult item to input. Litton (1968) has often pointed out the visibility orientation of terrain viewing to sun angle throughout the daytime: north facing slopes tend to be obscured at midday by shadows of backlighting, south facing slopes with front and side side lighting show up more clearly at midday, west slopes are best viewed in afternoon hours, and east slopes are best in morning light. Additionally, contrast of form, line, color and texture often determines whether objects will be seen. Beyond these guidelines, visibility information could be programmed based on probability of viewing distance and clarity, but is not.

Viewing distance is presently programmed arbitrarily by simply selecting a distance limit to be considered. The distance limit is the radius of a circle drawn around the observer point as shown in Fig. 3. Another set of options for visibility analysis include weighting options for aspect and distance in relation to observer. Methods for determining aspect in relation to observer position have been well developed beyond the one-dimension of VIEWIT into three dimensions. Such a product is PERSPECTIVE PLOT, a program that complements the magnitude of VIEWIT (Tlusty 1979). Within perspective plot, grid cells that are oriented toward the observer are more visible than areas oriented away (Fig. 5).

CONCLUSIONS

There has been much discussion of the value of visibility monitoring stations at the larger national parks and possible uses to which the information might be put. In California, we now have approximately 65 weather stations collecting data on particulate concentrations, meteorology, and visibility with the only major problem in data quality coming from long-term historical trends. In California, the most important elements of visibility are relative humidity, temperature, and special weather events (coastal and tule fog as examples). From 1950 to 1966, visibility deteriorated in California, but gradual improvement was noted from 1966 to 1975. The California/Nevada border experiences some of the best visibility in the nation with a median of close to 70 mi (Fig. 6). Los Angeles and the lower San Joaquin have, at best, 10 to 15 mi. Minimum visibility in Southern California usually occurs during late spring and summer (down to 5 mi) while the Central Valley and Bay Area suffer the most in late fall and winter (6 to 7 mi).

Because of the degraded air quality in most of the major metropolitan areas of California, our national parks are the bastion of the extended view. Issues such as visibility and meteorological relationships, spatial visibility patterns, seasonal visibility patterns, diurnal visibility patterns, visibility/aerosol relationships, and historical visibility trends are central to the future stewardship of our public lands. Visibility information in our national parks not only needs to be increased but, in addition, the information must be better programmed into visual resource management methods, such as VIEWIT, to assure that the experience of today is available in the future.

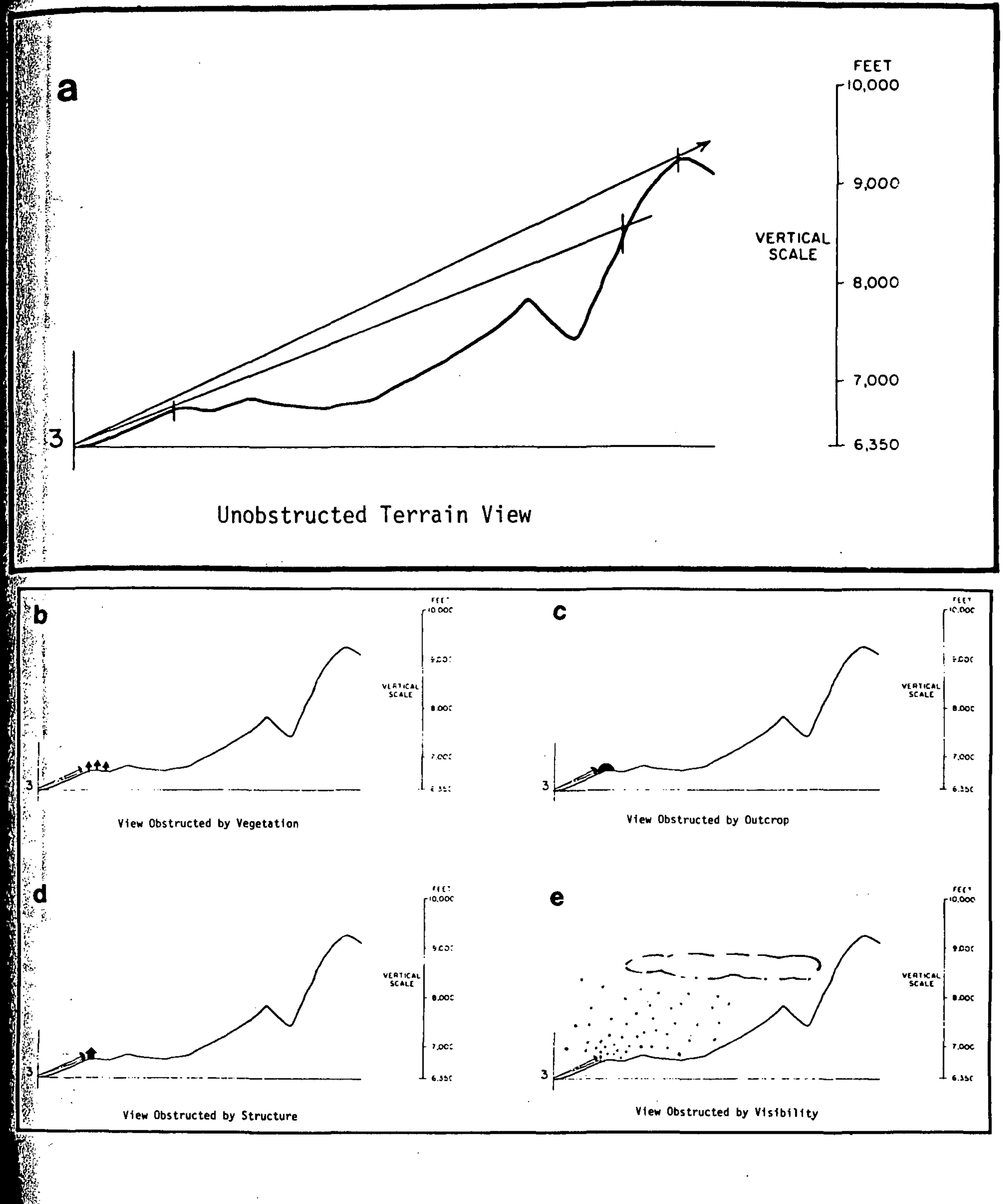


Figure 4a, b, c, d, and e

Shown at top (a) is an unobstructed terrain view from a single observer point. This type of terrain input is typical of VIEWIT programming. VIEWIT must be used in combination with PERSPECTIVE PLOT to input other programming variables such as vegetation (b), site specific topography (c), or structures (d). Formalized atmospheric visibility (e) is a much needed input that is dependent on increased monitoring and new programs to successfully assess view duration and probabilities.

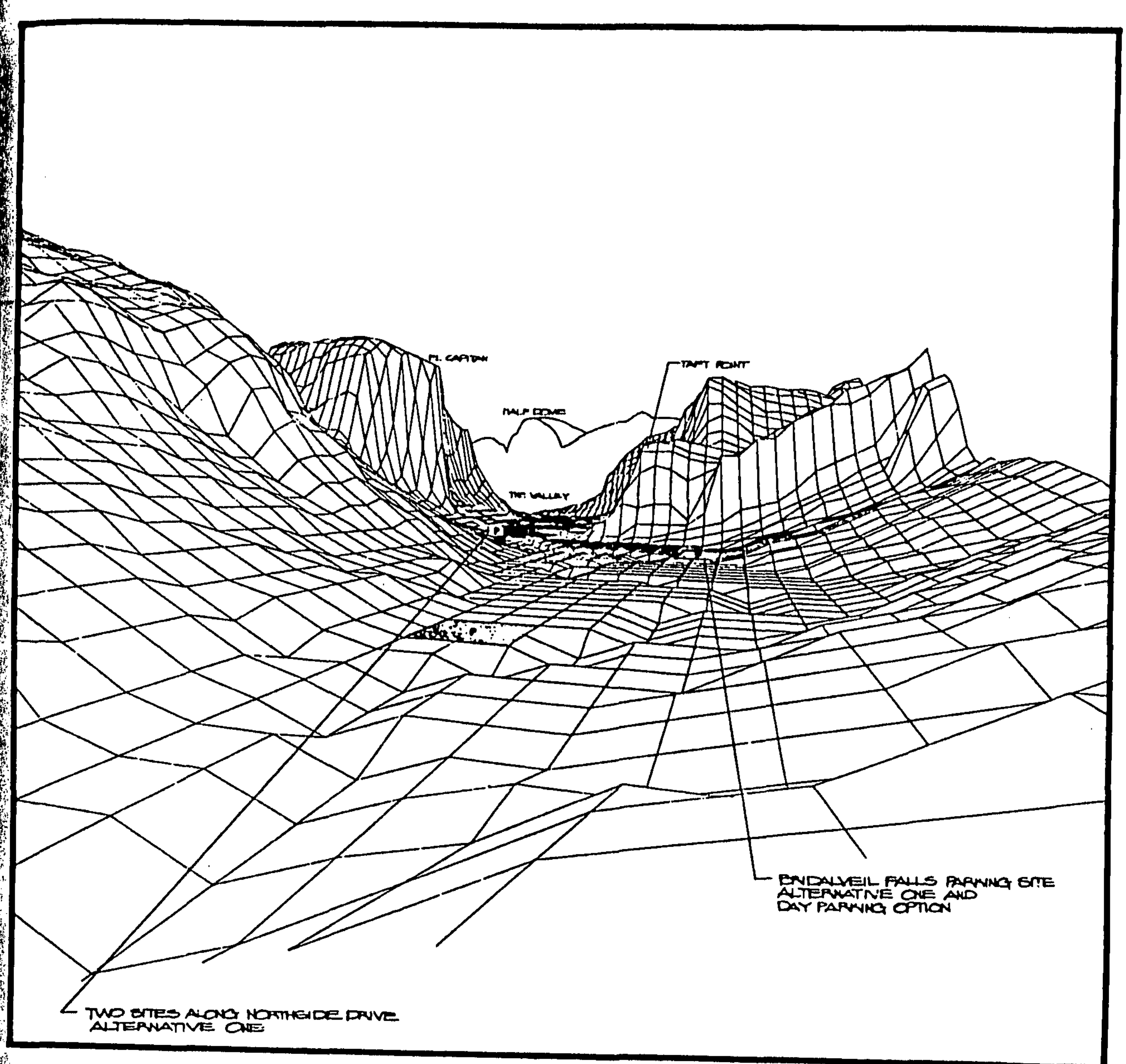


Figure 5

PERSPECTIVE PLOT is a computer program enabling three-dimensional assessments of single observer points in relation to topographic orientation. The example above is a visual analysis study of three alternative parking areas in relation to the scenic overlook at Wawona Tunnel in Yosemite National Park. What is clearly demonstrated are the variables of distance and aspect (cell orientation) to visual impact (NPS, 1978).

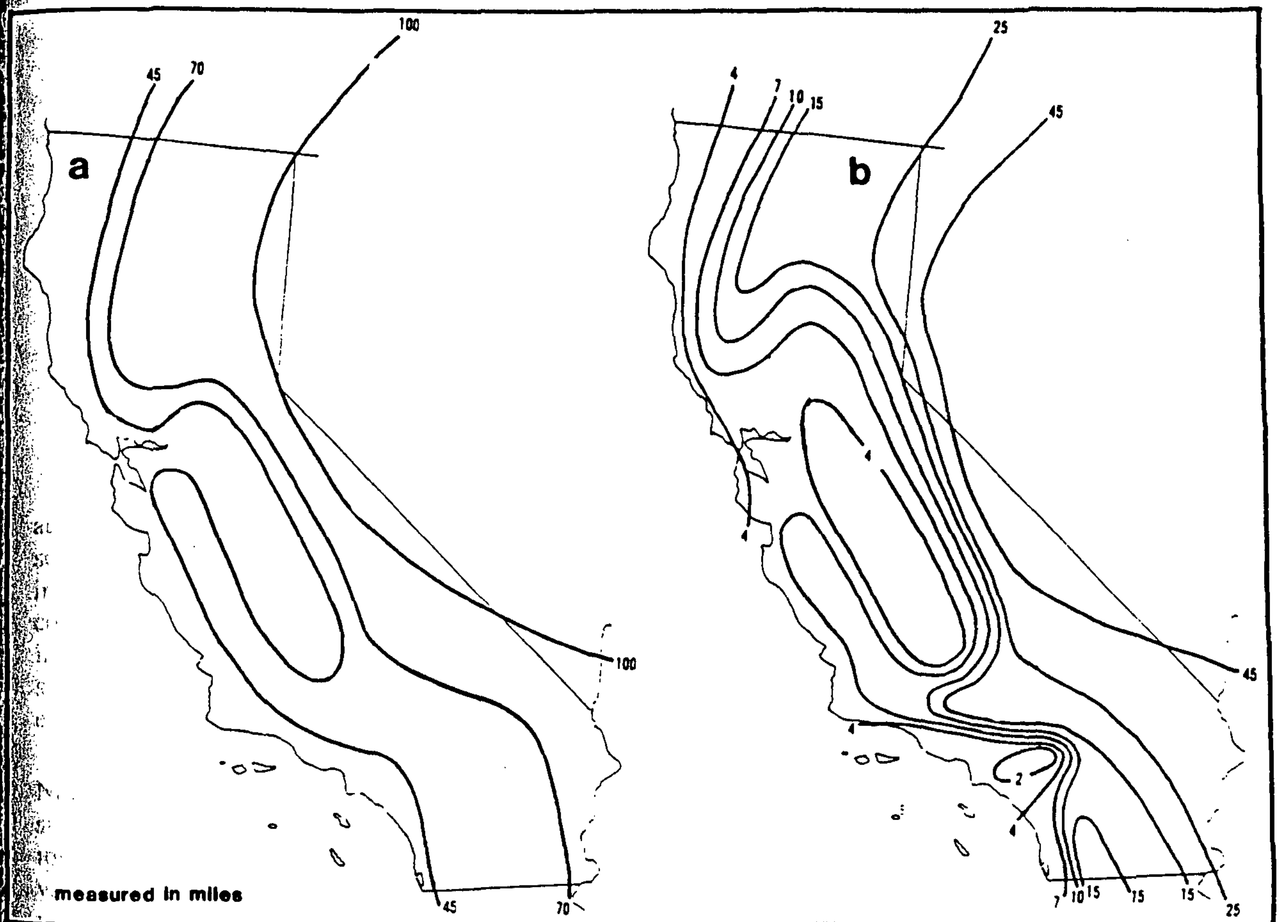


Figure 6a, b

Atmospheric visibility information is increasingly being researched and defined in California leading to the hope that data banks of information may soon be available for programming into view simulations. Generalized information such as best 10th percentile visibilities for 1974-76 (a) or worst 90th percentile 1 PM visibilities for 1974-76 (b) are rapidly increasing in specificity (Trijonis, 1980).

TOWARD A "NATURAL HISTORY" OF PEOPLE IN YOSEMITE NATIONAL PARK

D.A. Robertson and D.S. Wilson[1]

ABSTRACT

By custom and policy wild animals are taken to be "at home" in Yosemite National Park and people to be intruders. This set biases policy and interpretation, taints art and tints experience. We have begun to study "park people," residents as well as visitors, as MacCannell (1976) did tourists and Tinbergen (1961) did gulls, in order to discover *their* world, how they fit into it, how they interact, what they value, and how they indicate to others and symbolize for themselves what they make of the Park. It has been an exercise in non-intrusive field study and is interdisciplinarity between the social sciences and humanities mainly, but enriched by concepts and information from the natural sciences.

In large part this paper represents an early report on research, a description, as it were, of an "exploratory dig" and some of the preliminary findings. While we have come to some conclusions, we have discovered more questions to be studied than solutions to problems.

INTRODUCTION

Naturalists go into the field to look and listen, take notes and specimens, and ultimately compose accounts of what they have found. While now and then they tease a subject to see how it will react and so learn something of its perceptions and values (Fabre 1949, Tinbergen 1958), usually they try not to influence the life they observe, preferring to watch it unfold at its own pace and play out unanticipated complexities. They are good at learning from the works (dams, hives), signs (scratches, scents), and litter (scat, castings) left by animals. Their ultimate goal is to enter imaginatively into the life of the subject, to see the world from its perspective, and to participate with it in a larger mutual drama which enriches their world and illuminates the world of the subject.

Our mode of study has been, first of all, naturalistic. In the course of many trips to Yosemite National Park over the past 3 yrs, we have explored places, met visitors, come to know residents, surveyed the art and literature, and returned to our studies to tease out a few distinctions and grope toward an insight or two. We have taken park people as we have found them, in context, working, vacationing, enacting preferences, telling tales, passing on warnings, enduring the rain, and hiking the trails. We have been sorely tempted to modify slightly their world to catch their response to puzzlement, but so far we have restrained ourselves.

In this project we have had an advantage denied to the classical naturalists. We not only identify sympathetically with our subjects, but we have at different times been park people of one type or another ourselves: tourist, camper, backpacker, day-hiker, climber, Park Service campfire speaker, teacher of sketching or photography, editor or illustrator of Yosemite poetry (Dwyer 1982, Wilson 1978). Whatever threat to objectivity such participant observer status may entail, counterbalancing that danger is our participation in the emotional and symbolic life of park people. To be "in on" that life as actors entangles us in webs of interconnected meaning and value that are, as a rule, too subtle to be seen by outsiders and that are, as a rule, too complex to be reported in interviews.

Department of English, University of California, Davis, CA 95616
Department of American Studies, University of California, Davis, CA 95616

METHODS

Our mode of study has also been semiotic (Sebok 1978), or "textual". Whatever park people do or make we treat as "texts" of what they make of the Park and make of themselves in the Park. We "read" these texts critically, tracing out themes, noting harmonies and dissonances, attending to figures and motifs, and searching for underlying patterns. We attempt to explicate the texts singly and to appreciate more fully the import of one text by comparing it to others. A good deal one discovers in Yosemite speaks of being made by park people (e.g., roads, buildings, sewers, power grids) but does not very clearly tell what the making means. We have given some attention to the methods used by archaeologists to "decode" the import of material artifacts.

Our ultimate aim is to enter the world of park people, to see Yosemite National Park from their perspective, and to spell out some of the implications of what we find for policy making. Our study is ethnology, in that it is concerned with a people; it is ethology, in that it deals with the animal *"Homo sapiens yosemitiensis"*; and it is semiological, in that it deals with signs and stories. Both ethnosemiotics (MacCannell 1979) and ethosemiotics describe what our collecting, comparing, and reading the texts of Yosemite park people amounts to.

RESULTS AND DISCUSSION

While our findings are preliminary they are suggestive. In brief: 1) we find that the ecological story told by the Park Service in pamphlets, signs, and ranger walks, and upon which revisions in the General Plan is based, is biased by its largely unacknowledged reliance on rhythms and dramatic plotting inherited from Protestant Christianity and glossed by post-Transcendentalist naturalists like John Muir; 2) we further suppose, though this needs to be studied, that this bias is ethnically and generationally relative and does not represent what the Park means to numerous users, and even a good many employees; 3) we have seen signs that sub-groups of park people have developed alternative stories of the Park which sustain and rationalize their unsanctioned uses, such as feeding the deer and playing hacky sack in the parking lots; and 4) that certain of these responses to the Park require a new critical vocabulary if they are to be understood in all their human intricacy and vitality and not dismissed as "out of place", "uninformed", "frivolous", or "wrong-headed" behavior.

The Park Story

We have tried to determine the basic story, or myth, of Yosemite told by Park Service representatives, written into its brochures, and underlying its policies. It seems to us that the plot of this story is as follows: In the beginning was a balance of nature, a harmony of all Yosemite's flora and fauna brought about by the counterbalancing forces of nature. All plants and animals in the valley at this time belonged there. Yosemite was a natural paradise. The only cause for concern was that the balance of nature was fragile. Then so-called "white men" disrupted the ecosystem with settlements, sheep, and tourism. Unlike the arrival of other species in Yosemite in the course of its long history, the arrival of human beings was not natural. They did not belong. Prophets arose to denounce the presence of people in paradise and to decry the marks they left upon the landscape. These same prophets warned of the doom to come, and sure enough, today we have the crisis they predicted; over two million visitors a year enter the Park and threaten to unbalance the scales of nature in a drastic and unredeemable way. It would be better, so the story goes, were people to stay away altogether, or failing that, come only in small numbers, leave soon, and leave no trace of their sojourn behind.

This secular tale parallels chapter for chapter the sacred story cherished by Christians of original paradise, eventual corruption, and final restoration to purity, whether in individual biography as in birth, sin, and rebirth, or in ecclesiastical history where, for Protestants at least, the primitive church became corrupt in Rome and was purified by the Reformation.

The upshot of this overlap of ecological and Edenic narratives is the casting of Yosemite as the Eden of the New World, but an Eden that is more wilderness than garden, and that thickens the plot. A garden is a kind of park and implies ease, abundance, beauty. It belongs to that complex, scholars call "soft primitivism" (Panofsky 1955). Wilderness, on the other hand, fits into the "hard primitivism" complex and implies struggle, scarcity, and awesome (rather than pretty) landscape. In the Bible wilderness serves as a surrogate Eden at times, for Eden after all is a one-time place, out of this world for all practical purposes since it is barred against errant humanity. East of that Eden farms and cities lie, but out back of them, deserts. In these wildernesses prophets find renewal, even rebirth, and saints find trials. Wilderness fills-in, as it were, for the Eden they cannot go back to and start over from again. It is a place to go-out-to as a way to get-back-to a unity with the cosmos people find they have lost. The secular "wilderness experience", then, is the functional equivalent of the "state of grace" Christians so value. Being in the wild is like being "in Christ." Going into Yosemite, then, is much more than a matter-of-fact excursion to those who subscribe to these narratives.

The function of scientists in the context of this tale of pristine origins, of despoilation, and of restoration is to understand how the balance of nature was arrived at in the beginning and how, in the present, it can be restored. They are experts in the mechanics of paradise. Their work with the ecology of fire is a good example.

The function of the Park Service is threefold: 1) like the prophets of old, they alert the people to the destruction already done, warn of disasters imminent if drastic steps are not taken, and preach repentence; 2) like engineers, they apply the knowledge gained by scientists to the problems of restoring paradise to its original condition; and 3) like priestly custodians of the holy, they guard it from profanation, explain its laws, and dispense the powers of paradise to the laity.

Signs of the Park Story

A good example of the priestly office of the Park Service is the selection of visitor signs along the John Muir Trail that leads from Happy Isles up the Merced canyon into the High Sierra Yosemite wilderness. As a spiritual quest the real beginning is not so much at Happy Isles but the turn eastward off California's north-south axis, Highway 99. As pilgrims, we motor across the flat San Joaquin Valley and up through the Sierra Foothills, past a town with the symbolic name of El Portal to a real entrance station. The dark tunnel of rock just beyond it signals that the world we are entering is no ordinary one. Through that passageway are new realms of physical, emotional, and spiritual possibility that we can, if we are willing, be initiated into.

The next 6 mi are negotiable by car—down a one-way road past stations where we can stop momentarily and view the major "power places" of the Park, like El Capitan and Yosemite Falls. Eventually we arrive at Curry Village, where we must park the car and board public transportation. Only National Park Service-owned shuttle buses are allowed on the next mile of the trail. They take us deeper into the forest to the Happy Isles station. From here on we must walk. A sign directs us to Happy Isles; once there another points across a bridge over the Merced to the trailhead. Now we receive the first unambiguous indication of where we are headed. A sign reads, "Entering Yosemite Wilderness". Certain rules are laid down, certain prohibitions imposed: "No pets allowed on trails". A domesticated animal has no place in the wild. It will keep at a distance the untamed creatures we need to become acquainted with. Besides we most readily learn wilderness lessons if alone. Also here at the trailhead are the first intimations of danger ahead. This hike may be hazardous: "WARNING--DANGER. ICE AND ROCK FREQUENTLY FALL ON TRAIL. HIKERS ASSUME THEIR OWN RISK."

The next stage of our journey is from the trailhead up to the bridge below Vernal Fall. The most important of many signs along the way contains a quote from the trail's namesake, John Muir. It tells of our ultimate destination: "As long as I live I'll hear waterfalls and birds and winds sing. I'll interpret the rocks, learn the language of the flood, storm, and the avalanche. I'll acquaint myself with the glaciers and wild gardens, and get as near the heart of the world as I can." And where is the heart of the world? In the wilderness. Another sign reads: "Each step along this trail is a step away from the road . . . a step closer to wilderness." To arrive there we must awaken senses dulled by urban living: "Search with more than eyes. Fragrant laurel leaves . . . Can you find them? Listen . . . to water sounds changing with each step." We must also understand the underlying structure of the Yosemite wilderness, how it came to be and is always changing, how the past, present, and future are part of one intelligible process. Science, more particularly, geology is our instructor in these matters. Successive signs explain with charts and pictures "Yosemite's Rounded Scenery", "Patterns in Angular Scenery", "Master Joints", and "Crumbling Mountains".

Once out on the bridge we can look up river and see the effulgent Vernal Fall. The sign on the bridge is divided into four parts, four ways of seeing the Vernal Fall gorge. We can record it with a camera: "Vernal Fall through a camera's eye . . . Vernal's moments are captured." We can look into its past through the geologist's eyes of Francois Matthes: ". . . the ice stream tumbled in magnificent chaos down the great stairway, whose great steps are now marked by the Nevada and Vernal falls . . . Broken into fantastic blades and pinnacles . . . the cascading portion of the glacier must have presented the appearance of a tumultuous cataract frozen into immobility." We can become as little children and enter the wilderness seeing with eyes curious and wondering: . . . "I see things that do surprise me! The Water slashing, rushing, crashing over the fall round the bridge and granite rocks. Down through the valley it goes day and night. It's always there carrying with it stones and tones." Most important of all we must see through our own eyes: "Through your eyes . . . You briefly encounter this natural scene. Yet your senses may record this moment to be remembered your entire life."

Over the bridge the stakes increase. Signs broadcasting danger abound: "CAUTION—slippery rock surface." "STAY ALIVE—It is dangerous to climb on rocks next to the river. They are slick wet or dry. Deaths have occurred here." "STAY ON TRAIL." "EMERGENCY TELEPHONE."

We are leaving civilization behind. A final restroom and water fountain are provided. A quote from Muir states the essential doctrine of the wilderness, the interrelatedness of all things: "When we try to pick out anything by itself, we find it hitched to everything else in the universe." Shortly we come to the final sign: "You have taken the first step to wilderness. The next step is through the mist to the top of the fall. But wilderness does not lie that close. Steps to wilderness increase, as more people reach out for solitude. Continue . . . if you are prepared."

In the early days wilderness began in the valley proper. But with the coming of tourists *en masse* wilderness retreated up the canyons. Now it can be reached only by proceeding through the valley and up the John Muir Trail into the high, back country. As we read the final sign, we understand fully what our goal is: an experience in and with Wilderness, with a capital W. Our progress up the trail is an initiation into wilderness as a state of heart and mind, presided over by ranger priests who instruct us in what to see, feel, and learn along the way.

In this story of Wilderness Lost the Yosemite Miwok play the role of a *tertium quid*. Although human by genus and species, the fact that their culture did not seriously disrupt the balance of nature casts them as natural and makes them seem more at home in Yosemite than their "white" cousins of the same genus. In this sense they are on the side of the animals. Because of their ambiguous mythic status, the Park Service has had difficulties in knowing what to do with them and about them. It works under the legal mandate to return the Park to conditions extant prior to the arrival of human beings. But does this directive mean "before the arrival of any human beings" or merely "before the arrival of 'white' human beings"? The recent, 1982, revision in interpretation appears to cast the Indians as part of history more than of natural history, and so fallen like the rest of us.

Alternative Park Stories and Vocabulary

But there is more Park than fits into this Paradise Lost-Paradise Regainable myth (Wilson 1977). Jewish tradition supplies a myth upon which to hang alternative interpretations of Yosemite. In the beginning the Law was written down by Moses. In the course of history new laws arose as social conditions changed. These laws were at first transmitted orally, and so were known as the Oral Law. The Oral Law did not supercede the Written Law, or Torah, nor depart from it, nor was it a falling away from the old, true standards. Rather it supplemented the Written Law, added on to it, made it more full and more applicable to changing times. Eventually the Oral Law too was written down as the Mishnah (literally, the Second Law), and as the centuries went by new oral laws were added onto it. Some of these were in turn codified, and the cycle went on. The modern Jew does not sense history as a series of pure times followed by impure ones followed by returns to purity, but as a series of additions, each of which is necessary, right, and true, enriching rather than tarnishing the past. While tension may exist between different codes, that tension is not dissolved by choosing one as the true and labeling others as heresay. All are passed down as holy. Jewish tradition as a whole, then (and Roman Catholic also) is a vast accumulation of additions, abutments, and juxtapositions. It is a syndetic story instead of a synthetic one.

These two terms, *syndetic* and *synthetic*, are technical concepts developed by Armstrong (1975, 1981, 1982) in his study of African art. Synthetic stories are like Aristotelian plots: they have definite beginnings, middles, and ends. Beginnings are connected with middles and middles with ends by a continuous series of causes and effects which are rationally coherent. Thesis necessitates antithesis and together they eventuate in a satisfying synthesis. Syndetic stories are quite different. They begin *in media res*, proceed by the abutment of one stage of the story up against the preceding one, and continue on *ad infinitum*. Novels, symphonies, sonnets, and plays tend to be synthetic. A museum, a library, a succession of *Encyclopedia Americana* yearbooks tend to be syndetic.

What would a syndetic reading of the Park sound like? There would be no Beginning but a long regression of stages going back to some indefinite time in the past. It would be impossible to label one of these as better than the others, much less as paradise. Things have come to the Park and things have gone. Once there were no bears, and then bears arrived. Their arrival did not cause Yosemite to fall from some plane of perfection; it just made Yosemite different. Yosemite without bears, Yosemite with bears—both stages are accepted and the story of Yosemite is thereby the thicker. (Notice how much this sounds like *Ecclesiastes*, one of the great syndetic books in world literature.) At one time there were no people in Yosemite; then people arrived. The migration of people into the Park was as matter-of-fact as bear migration into it. Arrival of people did not ruin a perfect place; people just made it different. Yosemite without people, Yosemite with people—both stages are accepted and the story of Yosemite is all the fuller.

Once this park-full-of-people is taken for granted instead of deplored, two things follow. One has to do with attitudes toward people in the Park. They no longer need to be classed as alien species and taken to be intruders. The Park Service might even take them as enriching the environment the way bears and manzanita do and worry less about erasing sign of their inhabitation of the Park.

The second thing is that people might then be studied as part of Nature. In the course called "People as Park Animals" we taught for the Yosemite Natural History Association last summer, we took some steps in that direction. Some were false starts, but two approaches seem worth pursuing. One of these is economic, in the sense that Thoreau meant in the first chapter of *Walden*, namely, the way of being at home in the world. While few members of our species "make a living" in the valley, millions make a home of it, gather and spend, do domestic chores, worship, play and work for awhile. Surely something important to healthy human living is taking place, and speaking of Yosemite as economy gives us a way of investigating the matter. For example, what is it about Yosemite that makes it such a healthy place for human beings to vacation? What transactions occur between place and people? What factors make for a healthy Yosemite economy, and which bring on a depression, as it were? Some of the answers to these questions may seem, and may be, obvious. Yosemite is such a popular vacation spot because it is so beautiful. Yet what about the dislocation and anxiety that many people experience while there? The place is amazing in the root sense of that word. People easily get turned around in it and have difficulty getting from one place to another, whether on roads or on paths. We suspect that the transaction of amazement is integral to Yosemite economy.

Talk of what is happening inside people while they are in Yosemite leads to a second approach we think may be fruitful. We have labeled it ethological. We want to study park people, residents as well as visitors, as Tinbergen (1961) did gulls and MacCannell (1976) did tourists in order to discover their world, how they understand themselves as fitting into Yosemite, how they interact with the environment and with each other, what they value, and how they indicate to others and symbolize for themselves what they make of the Park. Right off one discovers that it would be better to talk of park peoples instead of park people. Correlatively we need to speak of Yosemites, for subsets of the population experience and inhabit different parks.

One can discover what the Park means to some users by studying their texts: reading their books, auditing their lectures, viewing their pictures, and inhabiting their buildings. Other groups must be studied more indirectly. The graffiti deposited in toilets, the signs posted on bulletin boards, the carvings knifed into wooden railings, the poses struck on Stoneman Bridge, the clothing worn at the Ahwahnee, remarks overheard and grimaces observed, all let the alert observer in on what others care about at the Park.

Meanings are often located spatially, and one way to get in on these meanings is to cross boundaries of one sort or another. Wheeling bikes across the bridge which connects Housekeeping with Lower River Campground, (B. and D. Wilson) ran the gauntlet of a dozen young employees, lounging against the rail and ragging each other but not us or other pedestrians as a rule. Then we stopped, took some pictures, and then went back across the bridge. This time we had comments made to us which, when we ignored them, were repeated together with vocal observations about our not having responded. We inferred that in photographing Housekeeping and them on the bridge we trespassed in a way that more matter-of-fact pedestrians did not, and thereby violated some code of *their* Park.

Or again, walking through Park Headquarters, on the one hand, and the Curry Company offices, on the other, brought different reactions from the inhabitants. No Park Service person indicated that walking around, peeking into offices, and studying announcements on the bulletin board trespassed on Ranger space in any way. Several Curry Company people indicated, however, by stares, by repeated glances, and finally by direct inquiry, that they felt more protective of their corridors, bulletin boards, and offices. In other words, Park Service people took Park buildings to be as public as Park grounds, whereas Curry Company personnel sharply distinguished public space from indoor, private enterprise space.

Women differ on how safe Yosemite is for them. Some discount the danger of rape and other violence; some assign the danger to night-time only; some distinguish between valley and backcountry. The point is that the Park is a different place to one alert to threat. David Brower is fond of saying that crowding in the Park, which he dislikes, decreases as the square of the distance from the road and as the cube of the distance above it. His male wisdom fails to take account of the fact that some males use the Park as a hunting ground.

It seems to us that few visitors experience Yosemite as wilderness. It is to them a human-made as well as nature-made place. Experiencing Yosemite Falls is the combinations of parking in a lot reminescent of shopping centers, walking on an asphalt path, heeding or not heeding signs that mark the boundaries of the safe, gazing at a natural river while standing on a human bridge, and employing a highly sophisticated instrument to record impressions.

We also think that only a limited number of visitors have the kind of pure and grand experience wilderness is supposed to produce. Most encounter is appositionally, syndetically: in little bits and pieces that accumulate but do not add up to a conversion-type experience nor lead to a conversion to the Wilderness-Lost gospel preached by the Park Service and Sierra Club. Syndetic experiences, each one of which may be little in itself, take on greater meaning by being repeated, by becoming rituals. We think that one reason Yosemite is such an ecological niche for vacationers is that it has not one falls, but five major ones and a host of minor ones, not one towering cliff but one after another. Most tourists seem, in fact, to make a ritual out of seeing them one after another. Our impression is, moreover, that among Yosemite tourists is a high percentage of repeaters, many of whom have been coming to the valley for decades in a ritual that is strikingly analogous to religious retreats. The Curry Company seems to have sensed this fact, for many of the activities they sponsor are ritual-like: the tour buses, talks at Curry Village and the Lodge, and the Bracebridge Dinner.

Tourists like to take mementos of their vacation home with them. The power these objects have is almost never related to their intrinsic merit but to the power of the experiences they invoke. So people purchase inexpensive items from the Curry Company concessions. For decades champions of Yosemite-as-wilderness have lamented the tasteless curios purveyed by the Curry Company. To them cheap objects of poor taste are indicative of cheap, shallow experiences. We believe this may be wrong. The value of these objects depends upon their invocational power, in the same way that the power of an heirloom depends not upon its commercial value but upon the person to whom it once belonged. Park Service denigration of Curry curios is strikingly similar to Prostestant repulsion at plastic, Roman Catholic icons. The power of Yosemite mementos is *analogic,* to borrow another term from Armstrong (1981). They gain their power from sharing the shape and being of the realities they symbolize. It may be that the appeal of the firefall, beloved by the vast majority of park people and deplored by the preservationists, should be understood in terms of its analogicity.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

As this paper began as an interim report, it will end as a call for further study. We see a number of projects worth doing and wish to propose several which are immediately practical and have implications for policy. 1) Native Americans have occupied an anomalous status within American culture since colonial "nature reporters" first reported on them (Wilson 1978). Presently interpretation of Indian culture in Yosemite has experienced a remodelling, and both interpreters and visitors appear to be divided on what ought to be done. Formerly, the women who "inhabited" the "village" behind the Visitor's Center wore skins and enacted the life of pre-contact Miwok people. This year (1982) they have been "moved" into a post-contact, late nineteenth-century world and use iron pots, live in shacks, grind coffee as well as acorns, and wear flour-sack dresses. They act out the life of "historical" Native Americans much as Euro-Americans at Wawona act out the roles of pioneer settlers. Whether Native Americans ought to be pure beings in an Edenic setting or post-contact beings in a historical setting ought not be decided in absence of a thorough semiotic study of the story they tell, of what the actors feel and believe, of what visitors experience, and of the way the presentation articulates with other presentations of nature and history in the Park.

2) The many different peoples of Yosemite deserve attention. Students trained in field studies of peoples could easily begin to assemble competent ethnographies. Such studies would produce a library of information which naturalists, in preparing talks and walks, might consult as they now consult field guides, *Nature Notes,* and the slide library. One thinks, for example, of the folklore manuscript from 1955 on the tradition of calling "Elmer" (now-a-days "Wilbur") at night in the campgrounds. Or again, one can imagine a living history exhibit of Euro-American camping from the 1950s, with the historically appropriate gear, clothing, hair styles, and small talk, to complement the pioneer village at Wawona and the Miwok village in the valley. The Oakland Museum has pioneered settings of recent everyday life in its Hunter's Point exhibit.

3) Much of the photography, literature, and art of Yosemite has been done in the spirit of an "aesthetic of virtuosity" (Armstrong 1981), informed by the synthetic mode, and presented in the tone of the preacher. Basic ethno-aesthetic research into the literary, iconic, folkloric, and material manifestations of the expressive impulse of park peoples needs to be done. For example, as we have suggested above, the invocative quality of the goods sold in the shops is due for a reappraisal. It appears from preliminary studies that the souvenirs may well speak more eloquently to and for the customer than the works sold as art do.

4) What park people make while they are in Yosemite provides a direct sort of testimony of their beliefs and values. What they lose or discard, in turn, may speak as concretely, though indirectly, to the questions, "What do park people make of the Park", and "What do they believe they need to make themselves at home in it". Perhaps the richest single site for a "dig" we found was the Lost and Found Trailer. All the lost items retrieved from the campsites, the lodgings, and the trails end up there, stored in bins and labeled as to month. The plenitude and variety of goods is astounding. People familiar with the methods of above-ground archeology and with the "garbology" pursued by some field workers, could discover there a whole monograph's worth of information on the values of park peoples.

ESTABLISHING A COMMUNICATION PROCESS FOR APPLIED RESEARCH

D.R. Field

INTRODUCTION

Regardless of the discipline involved, the person conducting the inquiry, or the setting in which the inquiry occurs, the principles of science when employed to answer a question are universal. It is appropriate, however, to distinguish types of research activity. These distinctions are not made with regard to the activity of science, but rather the social origin of the scientific inquiry and the goals for which the results of the research are commissioned (Johnson and Field 1981). A brief comparison between basic and applied research serves to illustrate the point.

First, basic research has as a primary goal the creation of knowledge to advance disciplinary theory and understanding of a phenomenon under investigation, while applied research has as its primary goal the creation of knowledge for problem solving. In short, applied research is mission oriented. Second, the impetus for basic research is intellectual curiosity, a gap in knowledge or the personal interests of the scientist, while the impetus for applied research is a policy issue, a management or client problem, or program evaluation (Johnson and Field 1981).

The foundation of scientific inquiry for the National Park Service is applied science and it is the obligation of all who do research in parks to embrace this tradition. Certainly for those scientists (government and university) under contract to the Service, an applied orientation with its requisite responsibilities is essential. Both orientations toward scientific inquiry, however, are found within the National Park Service science program represented by scientists employed by the Service and those universities and independent scholars who do research in areas managed by the Service. Most basic research is undertaken by university and independent scholars with non-National Park Service funding who do research in areas managed by the Service utilizing parks as research laboratories.

At the heart of applied science is the formation of a partnership between management (client) and scientist. That partnership rests upon communication throughout the research endeavor—from establishing a research agenda to the presentation of the results of research (Fig. 1). Previously, we have reviewed the key elements of applied science (Johnson and Field 1981). This paper explores a communication process which underlies the applied science tradition and which is essential to the integration of research results within the park management decision making process. The paper is developed around the following themes: 1) establishing a research agenda, 2) defining the research question, 3) conducting research, and 4) reporting the results of science.

METHODS

Establishing a Research Agenda

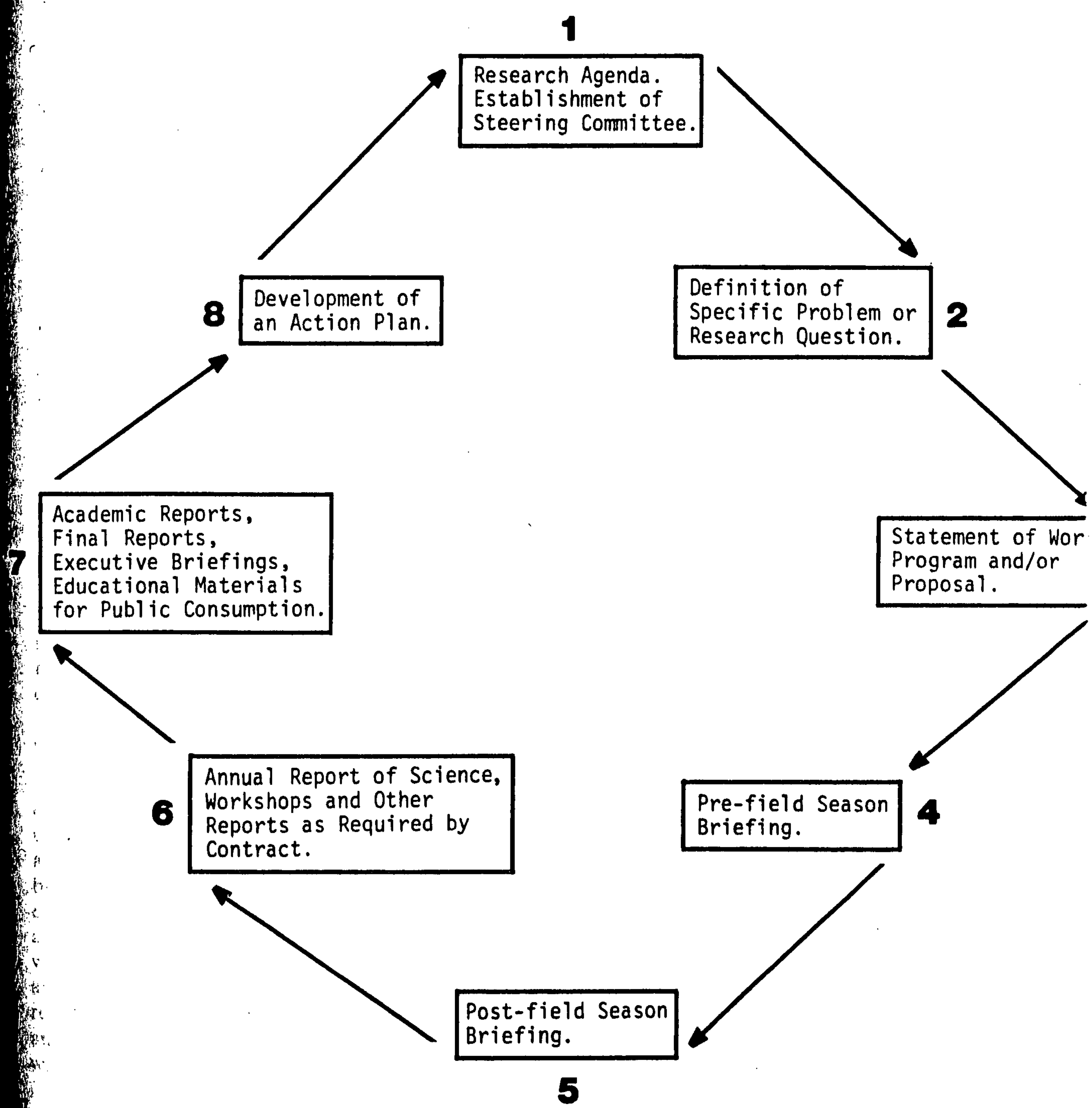
The first characteristic of applied science is the joint interaction of the client and the scientist in the definition of a research program. The responsibility for defining a research agenda lies with the management of the National Park Service. Management has exercised this responsibility for defining research objectives by establishing resource management plans.

Between 1972-1974, research/resource management workshops were held in each park in the Pacific Northwest Region. These workshops were jointly chaired by the Superintendent of the park involved and the Regional Chief Scientist. Depending upon the nature of the National Park Service area (natural, cultural, or recreational), an interdisciplinary group of scientists was asked to join park management personnel such as interpreters, maintenance staff, planners, and rangers to formulate a

Regional Chief Scientist, Pacific Northwest Region, National Park Service and College of Forest Resources, University of Washington, Seattle, WA. 98195

Figure 1

Steps in the Communication of Science To Park and Resource Managers



research plan which documented existing knowledge, and established research needs. The first resource management plans resulted.

The current generation of resource management plans reflect upon these earlier efforts but specify resource management problems or issues and prescribe necessary research to address these problems. Resource management problems requiring scientific knowledge are placed in priority order. Criteria for establishing a priority list vary depending upon the type of area (natural, cultural/historical, or recreational), specific legislation appropriate to the area, health and safety considerations, etc.

With a limited appropriation available for National Park Service science programs, choices must be made over which research projects are funded. If either scientists or managers made a decision on projects independently, the priority list would reflect incomplete analysis, perhaps be "skewed" toward long term research projects, or short term "crises" oriented projects or, political or legislative initiatives.

The resource management plan provides a consistent logical process to evaluate these projects, and assess how these various projects will be achieved. Because of the plan, accumulation of knowledge about resources is being recorded and gaps in knowledge for decision making is documented.

The resource management planning process, while not perfect, provides a basis for decision makers and scientists to initiate research, monitor social and biological change, and resolve problems. These documents with their research agendas will be modified as research projects are accomplished and information is infused within a resource management program. A constant updating of research needs will necessitate regular interaction between scientists and managers as to what a new agenda should be.

The process, likewise, provides a forum for discussion about the role of science in park management and resource management. Through interaction of management and scientists, an appreciation has developed for the limitations of science to solve all management problems and the constraints of management to incorporate science into the decision making process. However, not all areas of scientific inquiry supporting park management are covered and additional planning elements are required to provide a holistic approach to scientific needs.

For example, neither the resource management plan, interpretive plan or visitor management plan adequately documents social science research that is required to understand human behavioral issues associated with National Parks. To compensate for this, a steering committee comprised of local park personnel, regional office scientists and university scientists can be formed to identify research needs, define research questions and prioritize potential projects in a comprehensive social science research plan. Ideally this committee would also monitor the communication and application of research results.

Similarly, the resource management plans did not adequately address fire management policies for the three parks in the Puget Sound basin. Under the direction of the fire ecologist, a document was prepared in concert with management which outlines a fire research program for these parks over the next 5 yrs. Eventually, the resource management issues and associated research recommendations emerging from both of these documents will be incorporated into resource management plans.

The Research Question

The interaction of management and scientist does not end with a plan. Both must be involved in establishing the specific research question to be investigated. While management poses a problem for examination, the problem must be converted to a research question. A partnership in this stage of the applied research process is essential for several reasons. Many management issues cannot be answered by scientific inquiry, and only through communication and, perhaps, education by the scientist in terms of what is or is not a researchable question, can we determine if scientific inquiry is appropriate. There are numerous examples in land management agencies where science has been commissioned for the wrong reasons and results of science rejected for the wrong reasons. At times, the failure of manager and scientist to communicate has led to expensive and relatively long-term research, when a literature review and a state-of-the-art assessment by a scientist would do, or research requested which cannot answer the question. In my own field of sociology, we have over 10 yrs of research on carrying capacity which clearly demonstrates that values and attitudes of parkgoers are necessary but not sufficient indicators to assessing human response to different levels of population density in a recreation setting. Yet such an emphasis upon attitudes and values in carrying capacity research persists.

Scientists and managers have a responsibility to each other to clearly articulate the reasons for requesting research, whether or not research is appropriate and if so, clearly stating the research question and the expected results based upon the way the research question is posed.

Conducting the Research

Once the research question has been formulated and agreed upon, the partnership forged between manager and scientist begins to grow in earnest. There are limitations to research contributing to the solution of management issues which are inherent in the activity of science itself. These limitations should be addressed and understood by manager and scientist alike. Three issues in particular should be addressed in the early stages of the research project: 1) the timing and pacing of the research activity itself, 2) research design, and 3) variable selection.

Does the timing and pacing of the research activity match the client's problem solving time schedule? Often data are requested requiring a longitudinal design (2, 3 or 5 yrs) when a project must be completed within 1 yr. Social scientists prefer sophisticated sampling designs and survey research, such may not be practical or required. Participation observation, time budget studies, and unobtrusive measures may be sufficient to provide the kind of information and accuracy desired. Often scientists must modify the research; design in the field in response to existing conditions. Similarly, the time frame in which a decision must be made, and funds available, guide the selection of the research design which can be employed. But unanticipated events can alter well thought-out research plans. Finally, the selection of variables to study are sometimes dictated by whether or not resource management teams can prescribe action to mediate a problem. Attitude and value research once again serves to illustrate the point. Managers, through planning and design, regulations, permit systems, etc., can modify behavior of individuals but have little or no ability to change attitudes or values.

Communication between scientist and management during the research process keeps both informed of the progress being made. A mistake often made by scientists conducting research in national parks is assuming that once a contract is awarded, communication responsibilities about the research are less important. Pre-field season briefings and briefings during a field season keep management informed of progress and modifications in research plans. The critical period of uncertainty for management is at the end of a field season and before the first interim report—communication at this stage of the process enhances credibility, support and confidence for the project. A close-out interview at this time reviewing work accomplished and the next step in the research program reinforces the partnership between management and scientists.

RESULTS AND DISCUSSION

Reporting the Results of Science

Scientists generally recognize their responsibility to publish the results of research. The manner in which the results are reported however, has been changing during the past 10 yrs. Traditional publication responsibilities to the academic community remain; but the need to disseminate scientific information to special interest groups and the general public has increased. Scientists are being asked to serve in a "technology transfer" role explaining what the research means, identifying alternatives for management actions suggested by the research and helping to design resource management programs based upon research results. Reporting the results of science has taken on new meaning, for a diversity of audiences, requiring alternative means for accomplishment.

Several questions further illustrate the point. Will the research address a political question, be utilized within the public involvement process or in the preparation of an environmental statement or social impact assessment? Will the scientist be expected to testify in a court of law or represent the agency in a public hearing?

Thus, communication continues in the preparation of reports. While scientific journal articles, dissertations and master's theses maintain the scientific credibility of the researcher, management often requires separate reports which prescribe how the research answered the question posed and what are the alternative actions which management can consider to solve a problem. Executive summaries and action documents noting implications and alternatives are essential for management action plans (Fig. 2).

Does the research lend itself to a popular report or brochure for dissemination to the public? Can a slide/tape program be prepared to communicate the results of the research? Scientists should think in terms of a multifaceted science publication/reports program for management, the public and the scientific community as depicted in Fig. 2. The wider the distribution of scientific results, the wider the audience who gain an appreciation for the role of science in park management. Numerous interpretive naturalists and communication experts within and outside the National Park Service are more often than not willing to help the scientist in translating science into a popular publication or program.

CONCLUSIONS

The integration of research into resource management decision making more often depends upon the manner in which the research is undertaken and communicated to park management than the subject area under study. This paper has explored a communication process which underlies an applied science perspective and which is essential for the application of science problem solving. This communication process facilitates the formation of a partnership between manager (client) and scientist where both are involved in the decisions relative to what research is to be undertaken, how and in what order research issues will be addressed and in what time frame.

The partnership will face numerous challenges in the future. Perhaps the most important area for discussion involves the question as to what research will be required in the next 20 yrs to preserve the social and biological integrity of a National Park system. Managers and scientists should seriously consider the formation of a think tank, a Strategic Planning Task Force (SPTF) to chart a course of action which will provide necessary information for management of park landscapes in conjunction with resource management activities around parks.

During the remaining two decades of this century, the competing demands for scarce resources will accelerate. Managers and scientists must be concerned with integrated resource management. They must consider events taking place within and outside the park, such as commercial development, hydroelectric power development, forestry products, fisheries management, mining, agriculture, visitor use and tourism, regional urbanization, and rural population growth. There must be increasing awareness that parks are not islands unto themselves; rather they are integral components of a larger natural and social system, subject to the myriad of external or internal forces and should be managed accordingly.

Some have argued that park ecosystems are becoming distinct, biological islands. This conceptualization has merit for assessing the ecological change taking place within a park, species and habitat relationships, etc., ***but the distinctiveness arises because of the ecological interdependency within the region in which the park is located.*** To consider such issues, however, will require an expanded scientific effort beyond park boundaries to provide the necessary information for decision makers. A communication effort with a network of scientists and land managers at the Federal, State and local level, which has yet to be firmly established, must be forged. A new partnership will be required to examine and resolve the complex issues appearing on the horizon.

RESEARCH AREA	CLIENT					PUBLIC			ACADEMIC COMMUNITY		
	Management Plan	Training Program	Annual Rpts. of Science & CPSU Rpts.	Executive Summaries	Alternative and Action Plans	Audio Visual	Pamphlets and Brochures	Park Science	Dissertations	Masters Theses	Journal Articles
FIRE	Resource Management Plan		Prescribed Fire in Crater Lake Fire Research needs in NPS Areas of Ore. and Wash. Annual Rpts. 1977-79		Fire Restoration at Sun Creek, Mgmt. Recommendations Fire Monitoring Techniques (CRLP)	Slide Program	Fire in Pac. NW Natl. Parks	Vol. 1, No. 1 Vol. 2, No. 1	Forest & Avifaunal Structure in W. Montane Oly. Mts.	Interp. Natural Role of Fire Forest Res. at Sun Creek	Fire Effects on Pac. NW Forests First Year Ecolog. Effects of Hoh Fire Large Lightning Fires in Oly. Mts.
ELK	Resource Management Plan	Aerial Censusing Training	Elk Ecology & Mgmt. at Mt. Rainier Annual Rpts., 1977-79	Annually at Elk Mgmt Comm. Mtgs. (at Park)	Elk Monitoring Techniques - Population & Habitat	Talks before local interest groups		Vol. 1, No. 3	History, Ecology & Mgmt of Introduced Wapiti Population in Mt. Rainier		Multiple-Agency Mgmt. of a Common Resource
SOCIAL SCIENCE RESEARCH FOR INTERPRETATION	Interp. Management Plan Strategy for Social Sci. Res.	Resources Mgmt. Basic Interp.	Children's Interp. Interp. for Handicapped Annual Rpts., 1977-78	Whitman Mission Data: Interp. Activity Inventory	Design Monitoring Program Visitor Observation for Interp.		Splash! (game) Coloring Books Design for Bulletins Clams of Garrison Bay	Vol. 1, No. 1 Vol. 2, No. 1 Vol. 2, No. 2		Retirees in Parks Preparation and Career Dev. of Interp. Personnel Interpretive Activity Iventory	Cruiseship Travelers: Onboard Interp. Applying Soc. Res. to Interp. in NW Getting Connected: An Approach to Child's Interp.
SOCIAL SCIENCE RESEARCH ON BACKCOUNTRY MANAGEMENT	Backcountry Management Plan Strategy for Social Sci. Res.		Hikers on the Chilkoot Trail Annual Rpts., 1977-79	Executive Summary Rec's for McKinley	Design Monitoring Program			Vol. 1, No. 2	Study of Crowding and Social Gatherings in Alaska Natl. Parks	Visitor Use Data in the Dev. of Interp. Services	Study of Backpacker's Preferences Backcountry Use at Mt. McKinley Crowding at Katmai NP

LITERATURE CITED

Abrams, L. 1940. Illustrated flora of the Pacific States. Stanford University Press. Stanford, Calif.

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1973. Temperature effect on parr smolt transformation in steelhead trout as measured by gill sodium-potassium stimulated adenosine triphosphatase. Comp. Biochem. Physiol. 44(A):1333-1339.

Adams, L. 1939. Duck hawks in Yosemite Valley. Yosemite Nat. Notes 18:97-98.

Agee, J. K. 1980. Issues and impacts of Redwood National Park expansion. Environ. Manage. 4:407-423.

Aker, R. 1965. The Cermeno expedition at Drake's Bay, 1595. A report of the Drake's Navigators Guild. Drakes Navigators Guild, Palo Alto, Calif.

Albini, F. A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. Gen. Tech. Rep. INT-30.

Alexander, E., J. DeLapp, E. Gladish, and R. S. Skolmen. 1961. Soil-vegetation map, legend and interpretation, NW 1/4 Coyote Peak Quadrangle 11C-2. California Department of Forestry, Soil-Vegetation Survey, Sacramento, Calif.

Allison, J. 1982. Evaluation of ozone injury on the Stanislaus National Forest. Rep. no. 82-07. Forest Pest Management, U.S. Forest Service, San Francisco.

Amend, D. F., R. Antipa, and T. H. Kerstetter. 1980. Increase in ocean survival of freely migrating steelheads vaccinated against *Vibrio anguillarum*. Trans. Am. Fish. Soc. 109(3):287-289.

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. 15th ed. American Public Health Association, New York.

Anderson, D. G., and R. A. Brown. 1983. Anadromous salmonid nursery habitat in the Redwood Creek Watershed. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Anderson, H. H., and J. R. Sedell. 1979. Detritus processing by macroinvertebrates in stream ecosystems. Annu. Rev. Entomol. 24:351-377.

Anderson, J. B., and W. T. Mason, Jr. 1968. A comparison of benthic macroinvertebrates collected by dredge and basket sampler. J. Water Pollut. Control Fed. 40:252-259.

Anderson, N. H., and K. W. Cummins. 1979. The influence of diet on the life histories of aquatic insects. J. Fish Res. Board Can. 36:335-342.

Andrews, P. L. 1980. Testing the fire behavior model. Pages 70-77 *in* Robert E. Martin et al., eds. Proceedings Sixth Conference on fire and forest meteorology Society of American Foresters and the American Meteorological Society, Seattle, Washington, April 22-24. American Meteorological Society, Washington, D.C.

Appleby, E. C., and K. D. Head. 1954. A case of suspected Johne's disease in a llama *(L. glama)*. J. Comp. Pathol. 4:52-53.

Araki, D. K. 1979. VIEWIT uses on the wild and scenic upper Missouri River. Proceedings of Our national landscape: a conference on applied techniques for analysis and management of the visual resource. Incline Village, Nevada, April 23-25.

Armstrong, R. P. 1975. Wellspring: on the myth and sources of culture. University of California Press, Berkeley.

____. 1981. The powers of presence: consciousness, myth, and affecting presence. University of Pennsylvania Press, Philadelphia.

____. 1982. What's red, white, and blue and syndetic? J. Am. Folklore 95:327-346.

Arnold, J. B. 1977. Site test excavations underwater: the sequel to the magnetometer survey. Int. J. Naut. Archaeol. Underwater Explor. 6(1):21-36.

Bailey, E. H., W. P. Irwin, and C. L. Jones. 1964. Franciscian and related rocks, and their significance in the geology of western California. Calif. Div. Mines Geol. Bull. 183.

Baker, A. L. 1982. Disk and ray achene development and germination characteristics of tansy ragwort *(Senecio jacobaea* L.). Master's thesis. Washington State University, Pullman.

Beard, L. F. H., P. F. Dale, K. B. Atkinson, H. F. Law, and A. R. Elkington. 1974. A straightforward approach to stereometric photography for medical purposes. Pages 27-48 *in* Biostereometrics. Proceedings symposium of Commission V of International Society of Photogrammetry on bioengineering applications of photogrammetry, Washington, D.C., September 10-13. American Society of Photogrammetry, Falls Church, Va.

Becking, R. W. 1957. The Zurich-Montpellier school of phytosociology. Bot. Rev. 23:411-488.

____. 1982. Pocket flora of the Redwood Forest. Island Press, Covelo, Calif.

Benfield, E. F., A. C. Hendricks, and J. Cairns, Jr. 1974. Proficiencies of two artificial substrates in collecting stream macroinvertebrates. Hydrobiologia 27:353-361.

Benninghoff, W. S. 1966. The releve method for describing vegetation. Mich. Bot. 5:109-113.

Benson, N. G. 1953. The importance of groundwater to trout populations in the Pigeon River, Michigan. Trans. North Am. Wildl. Conf. 18:269-281.

Berg, M. G., and E. H. Gardner. 1978. Methods of soil analysis used in the soil testing laboratory at Oregon State University. Spec. Rep. 321. Agric. Exp. Stn. Oregon State University, Corvallis, Oreg.

Best, D., M. A. Madej, and J. Pitlick. 1983. Construction of a sediment budget for Redwood Creek watershed, Northern California. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Bigg, W. L., and I. J. Alexander. 1980. Analysis of NO^-_3 and NH^+_4 in dilute nutrient solutions using ion sensing electrodes. Laboratory practice 29. United Trade Press, London.

Binford, L. C. 1980. Heermann's gull invades Alcatraz. Point Reyes Bird Observatory no. 51.5.

Boever, W. J. and D. Peters. 1974. Paratuberculosis in two herds of exotic sheep. J. Am. Vet. Med. Assoc. 165:822-823.

Bond, R. M. 1941. Rodentless rodent erosion. Soil Conserv. 10:269.

_____. 1946. The peregrine population of western North America. Condor 48:101-116.

Botti, S. J., and T. Nichols. 1980. The Yosemite and Sequoia-Kings Canyon prescribed natural fire programs 1968-1978. Pages 46-63 *in* Proceedings of the second conference on scientific research in the National Parks, San Francisco, Calif., November 26-30, 1979. USDI National Park Service, Springfield, Va.

Box, G. E. P., W. G. Hunter, and J. S. Hunter. 1978. Statistics for experimenters. Wiley, New York.

Bradford, G. R., A. L. Page, and I. R. Straughan. 1981. Are Sierra lakes becoming more acid? Cal. Agric. 35:6-7.

Bradford, W. L., and R. T. Iwatsubo. 1978. Water chemistry of Redwood Creek and Mill Creek basins, Redwood National Park, Humboldt and Del Norte counties, California. U.S. Geol. Surv. Water Resour. Invest. 78-115.

Brett, J. 1952. Temperature tolerance of young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Board Can. 9:265-323.

Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Department of Fish and Game, Fish Bull. no. 94.

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. J. Urick. 1964. Predicting wholesale cuts of beef from linear measurements obtained by photogrammetry. J. Anim. Sci. 23:365-374.

Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA For. Serv. Gen. Tech. Rep. INT-16.

Burcham, L. T. 1957. California rangeland: an historical ecological study of the range resource of California. California Division Forestry, Sacramento, Calif.

Burgan, R. E. 1979. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. USDA Gen. Tech. Rep. INT-61.

Burns, J. 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish Game 57:44-57.

Cameron, E. 1935. A study of the natural control of ragwort. J. Ecol. 23:265-322.

Canfield, R. 1941. Application of the line interception method in sampling range vegetation. J. For. 39:388-394.

Carmean, W. H. 1975. Forest site quality evaluation in the United States. Am. Agron. 27:209-269.

Caughey, J. W. 1975. The California Gold Rush. University of California Press, Berkeley.

Chapman, D. W. 1962. Effects of logging upon fish resources of the west coast. J. For. 60:533-553.

Cheeke, P. R., ed. 1979. Symposium on pyrrolizidine (Senecio) alkaloids: toxicity, metabolism, and poisonous plant control measures. Oregon State University, Corvallis.

Christopher, R. P., J. P. Delgado, and M. T. Mayer. 1982. Cultural resource management plan, Golden Gate National Recreation Area, San Francisco. National Park Service, San Francisco.

Chutter, F. M. 1972. A re-appraisal of Needham and Usinger's data on the variability of a stream fauna when sampled with a Surber sampler. Limnol. Oceanogr. 17:139-141.

Clausen, C., and J. B. Arnold. 1976. The magnetometer and underwater archaeology: magnetic delineation of individual shipwreck sites, a new control technique. Int. J. Naut. Archaeol. Underwater Explor. 5(2):159-169.

Clifford, H. T., and W. Stephenson. 1975. An introduction to numerical taxonomy. Academic Press, New York.

Collins, T. K., and B. G. Hicks. 1971. Engineering geology in a massively unstable region (early detection of slip surface geometry). Paper presented at annual meeting Association Engineering Geology, October, 1971, Portland, Oreg.

Cook, S. E. 1976. Quest for an index of community structure sensitive to water pollution. Environ. Pollut. 11:269-288.

Cooke, W. B. In press. A list of the fungi of the Lassen Volcanic National Park. Cooperative Park Studies Unit/University of California, Davis Tech. Rep.

Cordone, A. J., and D. W. Kelly. 1961. The influence of organic sediment on the aquatic life of streams. Calif. Fish Game 47:189-228.

Cox, C. S. 1981. Environmental controls on the capacity tansy ragwort *(Senecio jacobaea* L.) to compensate for defoliation by cinnabar moth *(Tyria jacobaeae* L.). Master's thesis. Oregon State University, Corvallis.

Cox, C. S., and P. B. McEvoy. 1983. The effect of summer moisture stress on the capacity of tansy ragwort *(Senecio jacobaea)* to compensate for defoliation by cinnabar moth *(Tyria jacobaeae)*. J. Applied Ecol. 20:225-234.

Crampton, B. 1974. Grasses in California. University of California, Berkeley.

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Midl. Nat. 67:477-504.

____. 1974. Structure and function of stream ecosystems. Bioscience 24:631-641.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington and its bearing on concepts of vegetation classification. Ecol. Monogr. 22:301-330.

____. 1966. Vegetation: identification of typical communities. Science 151:291-298.

____. 1968. Plant communities: a textbook of plant synecology. Harper & Row, New York.

____. 1976. The use of vegetation in assessing the productivity of forest lands. Bot. Rev. 42:115-142.

Daubenmire, R. F., and J. Daubenmire. 1975. The community status of the coastal redwood, *Sequoia sempervirens*. Open file report. Redwood National Park, Crescent City, Calif.

Davenport, D. R. 1981. Prescribed fire plan. Oak Woodland - Schoolhouse Peak. Redwood National Park. On file at Redwood National Park, Arcata, Calif.

Davidson, D. T., and J. B. Sheeler. 1953. Cation exchange capacity of the clay fraction of loess in southwestern Iowa. Iowa Acad. Sci. Proc. 60:354-361.

Davy, J. B. 1902. Stock ranges of northwestern California: notes on the grasses and forage plants and range conditions. U.S. Dep. Agric. Bur. Plant Ind. Bull. 12:1-81.

Dawson, K. J., and C. Fryling. 1980. A case study in low desert visual resource management. *In* The Lower Gila Resource Area Management Plan. United States Bureau of Land Management, Phoenix, Ariz.

Deeming, J. E., R. E. Burgan, and J. D. Cohen. 1977. The national fire danger rating system - 1978. USDA For. Serv. Gen. Tech. Rep. INT-39.

Deinzer, M. L., P. A. Thompson, D. M. Burgett, and D. L. Isaacson. 1977. Pyrrolizidine alkaloids: their occurrence in honey from tansy ragwort (*Senecio jacobaea* L.). Science 195:497-499.

Delgado, J. P., and R. L. Bennett. 1981. Research design for the historical archaeological examination and documentation of the remains of the 1848 sidewheel steamship Tennessee at Tennessee Cove, Golden Gate National Recreation Area, Marin County, California. S.S. Tennessee Project, San Rafael, Calif.

Dempster, J. P. 1982. The ecology of the Cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera:Arctiidae) Adv. Ecol. Res. 12:1-36.

Denton, D. N. 1974. Water management for fishery enhancement on north coastal streams. California Department Water Resources, Sacramento.

Diamond, M. S. 1978. An investigation of crown and stem development of 22-year-old Douglas-fir dense unthinned stands. Master's thesis. Humboldt State University, Arcata, Calif.

Dickson, K. L., J. Cairns, Jr., and J. C. Arnold. 1971. An evaluation of the use of a basket-type artificial substrate sampling macroinvertebrate organisms. Trans. Am. Fish. Soc. 100(3):553-559.

Dixon, W. J., and M. B. Brown, eds. 1979. Biomedical computer programs. University of California Press, Berkeley.

Dixon, W. J., and F. J. Massey, Jr. 1969. Introduction to statistical analysis. 3d ed. McGraw-Hill, New York.

Downes, R. G. 1946. Tunnelling erosion in northwestern Victoria. Aust. Counc. Sci. Ind. Res. 19:283-292.

Dunne, T., and L. B. Leopold. 1978. Water in environmental planning. Freeman, San Francisco.

Dwyer, J. 1982. The discipline of crevices, poems of Yosemite. Yosemite Natural History Association, Yosemite National Park, Calif.

Dyrness, C. T., J. F. Franklin, and C. Maser. 1972. Wheeler Creek research natural area. Supplement to the Federal Research Natural Areas in Oregon and Washington: a guidebook for scientists and educators. USDA For. Serv., Pacific Northwest Forest and Range Experimental Station, Portland, Oreg.

Dyrness, C. T., J. F. Franklin, and W. H. Moir 1974. A preliminary classification of forest communities in the central portion of the western Cascades in Oregon. United States International Biological Program, Ecological Analysis Studies, Coniferous Forest Biome, Bull. 4.

Edmondson, W. T., ed. 1959. Freshwater biology. 2d ed. Wiley, New York.

Ehlke, T. A., G. A. Irwin, B. W. Linm, and K. V. Slack, eds. 1977. Methods for collection and analysis of aquatic biological and microbiological samples. U.S. Geol. Surv. Techniques Water Resour. Invest. Book 5, chap. A4.

Elford, C. R., and M. R. McDonough. 1974. The climate of Humboldt and Del Norte counties. University of California, Humboldt and Del Norte counties Agriculture Extension Service, Eureka, Calif.

Elliot, J. M. 1971. Some methods for the statistical analysis of samples of benthic invertebrates. Freshw. Biol. Assoc. Sci. Publ. 25.

Elliot, J. M., and P. A. Tullett. 1978. A bibliography of samplers for benthic invertebrates. Freshw. Biol. Assoc. Occas. Publ. 4.

Elliott, H. W., and J. D. Wehausen. 1974. Vegetation succession on coastal rangeland of Point Reyes Peninsula. Madrono 22:231-238.

Evans, C. P. 1980. Integrated control of tansy ragwort *(Senecio jacobaea* L.). Master's thesis. Oregon State University, Corvallis.

Evans, F., and E. Dahl. 1955. The vegetational structure of an abandoned field in southeastern Michigan and its relation to environmental factors. Ecology 36:685-706.

Everest, F. H. 1978. Anadromous fish habitat and forest management- economic considerations. Proc. West. Assoc. Fish Wildl. Agencies West. Div. Am. Fish. Soc. 58th Annual Conf., San Diego.

Fabre, J. H. 1949. The pine processionary. Pages 10-24 *in* E. W. Teale, ed. The insect world of J. Henri Fabre. Dodd, Mead, New York.

Ferreira, R. F. 1976. Benthic invertebrate colonization of four artificial substrates in two small streams. Master's thesis. Humboldt State University, Arcata, Calif.

Fisk, L., E. Gerstung, R. Hansen, and J. Thomas. 1966. Stream damage surveys. California Department Fish and Game, Inland Fisheries Adm. Rep. 66-10.

Fletcher, J. E., and P. H. Carroll. 1948. Some properties of soils associated with piping in Southeastern Arizona. Proc. Soil Sci. Soc. Am. 13:545-547.

Fogel, R. 1980. Mycorrhizae and nutrient cycling in natural forest ecosystems. New Phytol. 86:199-212.

Folk, R. L. 1980. Petrology of sedimentary rocks. Hemphill, Austin, Tex.

Forbes, J. C. 1977. Population flux and mortality in ragwort *(Senecio facobaea* L.) infestation. Weed Res. 17:387-391.

Foster, J. W. 1983. Schooners, steamers, and spilled cargo: a preliminary underwater survey of Fort Ross, Cove, California. Paper delivered at the annual conference of underwater archaeology, Philadelphia, Pa. (in press).

Fowells, H. A. 1965. Silvics of forest trees of North America. U.S. Dep. Agric. For. Serv. Handb. 271.

Frank, B., and J. Lee. 1966. Potential solar beam irradiation on slopes: tables for 30 to 50 degrees latitude. USFS Res. Pap. RM-18.

Franklin, J. F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. USDA For. Serv. Gen. Tech. Rep. PNW-118. Pacific Northwest Forest and Range Experimental Station, Portland, Oreg.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Tech. Rep. PNW-8. Pacific Northwest Forest and Range Experimental Station, Portland, Oreg.

Freeman, G. J. 1971. Summer fog drip in the coastal redwood forest. Master's thesis, Humboldt State University, Arcata, Calif.

Frick, K. E. 1970 *a*. *Longitarsus jacobaeae* (Coleoptera:Chrysomelidae), a flea beetle for the biological control of tansy ragwort. 1. Host plant specificity studies. Ann. Entomol. Soc. Am. 63:284-296.

____. 1970 *b*. Ragwort flea beetle established for control of tansy ragwort in northern California. Calif. Agric. 24:(4):12-13.

_____. 1973. *Longitarsus jacobaeae* (Coleoptera:Chyrsomelidae), a flea beetle for the biological control of tansy ragwort. 4. Life history and adult aestivation of an Italian biotype. Ann. Entomol. Soc. Am. 66:358-367.

Frick, K. E., and G. R. Johnson. 1972. *Longitarsus jacobaeae* (Coleoptera:Chrysomelidae), a flea beetle for the biological control of tansy ragwort. 3. Comparison of the biologies of the egg stage of Swiss and Italian biotypes. Ann. Entomol. Soc. Am. 65:406-410.

Fritz, E. 1929. Some popular fallacies concerning redwood. Madrono 1:221-224.

Fyfe, R. W., and R. R. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Can. Wildl. Serv. Occas. Pap. no. 23.

Gauch, H. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge.

Gibbs, H. S. 1945. Tunnel-gully erosion in the wither hills, Marlborough. N. Z. J. Sci. Technol. 27A:135-146.

Goodall, D. W. 1953. Objective methods for the classification of vegetation. I. The use of positive interspecific correlation. Aust. J. Bot. 1:39-63.

Gordon, B. 1980. Soils of the Bald Hills Area of Redwood National Parks. Master's thesis, Humboldt State University, Arcata, Calif.

Gould, F. W. 1945. Notes on the genus *Elymus*. Madrono 8:42-47.

Greene, L. W. 1980. Historical overview of the Redwood Creek Basin and Bald Hills regions of Redwood National Park, California. Denver Service Center, National Park Service, Denver, Colo.

Griffin, J. R. 1977. Oak woodlands. *In* M. Barbour and J. Major, eds. Terrestrial vegetation of California. Wiley-Interscience, New York.

Grim, R. E. 1942. Modern concepts of clay materials. J. Geol. 50:225-275.

Hagwood, J. J., Jr. 1982. Engineers at the Golden Gate: a history of the San Francisco District U.S. Army Corps of Engineers, 1866-1980. United States Army Corps of Engineers, San Francisco.

Hall, F. C., D. W. Hedrick, and R. F. Keniston. 1959. Grazing and Douglas-fir growth in the Oregon white oak type. J. For. 57:98-103.

Hammerstrom, F. 1963. Use of great horned owls in catching marsh hawks. Proc. 13th Int. Ornithol. Congr. 1962:866-869.

Harden, D. R., R. J. Janda, and K. M. Nolan. 1978. Mass movement and storms in the drainage basin of Redwood Creek, Humboldt County, California. A progress report, U.S. Geol. Surv. Open-File Report 78-486. Menlo Park, Calif.

Harper, J. L. 1965. Establishment, aggression, and cohabitation in weedy species. Pages 243-268 *in* H. G. Baker and G. L. Stebbins, eds. The genetics of colonizing species. Academic Press, New York.

_____. 1977. Population biology of plants. Academic Press, London.

Harper, J. L., and W. A. Wood. 1957. Biological flora of the British Isles: *Senecio jacobaea* L. J. Ecol. 45(2)617-637.

Harrel, R. C., and T. C. Dorris. 1968. Stream order, morphometry, physiochemical conditions, and community structure of benthic macroinvertebrates in a intermittent stream system. Am. Midl. Nat. 80(1):220-251.

Harrington, J. M. 1983. An evaluation of techniques for collection and analysis of benthic invertebrate communities in second order streams in Redwood National Park. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Hatzopoulos, J. N. 1983. Close-range photogrammetry in predicting animal weight. 15th International Congress, Biostereometrics.

Hawkins, C. P., and J. R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62:387-397.

Heady, H. F., T. C. Foin, M. M. Hektner, D. W. Taylor, M. G. Barbour, and W. J. Barry. 1977. Coastal prairie and northern coastal shrub. Page 733-758 *in* M. Barbour and J. Major, eds. Terrestrial vegetation of California. Wiley-Interscience, New York.

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 77 (3):653-668

Hedrick, D. W., and R. F. Keniston. 1966. Grazing and Douglas-fir growth in the Oregon white oak type. J. For. 64:735-738.

Heede, G. H. 1971. Characteristics ad processes of soil piping in gullies. Forest Service Research Paper RM-58. U.S. Department of Agriculture, Washington, D.C.

Heizer, R. F., ed. 1972. George Gibb's journal of Redick McKee's expedition throug northwestern California in 1851. Archaeological Research Facility, University of Californi. Berkeley.

Hektner, M. M., and T. C. Foin. 1977. Vegetation analysis of a northern California coast prairie: Sea Ranch, Sonoma County, California. Madrono 24:83-103.

Hektner, M., L. Reed, J. Popenoe, S. Veirs, R. Mastrogiuseppe, N. Sugihara, and D. Vezie. 198 Review of revegetation treatments used in Redwood National Park: 1977 to present. Page 70-77 *in* R. M. Coats, ed. Proceedings symposium on watershed rehabilitation in Redwoo National Park and other Pacific coastal areas. Center for Natural Resource Studies an National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981.

Hellermark, K. 1966. A disease resembling paratuberculosis (Johne's disease) in a roe dee *(Caprelus capreolus)*. Alta Vet. Scand. 7:330-363.

Hendricks, A., D. Henley, J. T. Wyatt, K. L. Dickson, and J. K. G. Silvey. 1974. Utilization of diversity indices in evaluating the effect of a paper mill effluent on bottom fauna. Hydrobiologia 44:463-474.

Herman, S. G., M. N. Kirven, and R. W. Risebrough. 1970. The peregrine falcon decline in California. I. A preliminary review. Audobon Field Notes 24:609-613.

Hickey, J. J., ed. 1969. Peregrine falcon populations, their biology and decline. University of Wisconsin Press, Madison.

Higginson, F. R., and K. A. Emery. 1972. Survey of erosion and land use within the Lake Burley Griffin catchment area. J. Soil Conserv. Serv. N. S. W. 28:22-39.

Hitchcock, C. L., and A. Cronquist. 1976. Flora of the Pacific Northwest. University of Washington Press, Seattle, Wash.

Holliday, J. S. 1981. The world rushed in: the California Gold Rush experience. Simon & Schuster, New York.

Howell, D. G. 1976. Aspects of the geologic history of the California borderland. Am. Assoc. Pet. Geol. Misc. Publ. 24.

Howell, J. A. 1981. Natural resources management plan and environmental assessment, GGNRA, San Francisco, Calif. USDI, National Park Service, San Francisco, Calif.

_____. 1982. Alcatraz Island. Bay Area Nat. 1:7.

Howell, J. A., and D. LaClergue, S. Paris, W. Boarman, A. L. Degange, and L. Binford. 1983. First nests of Heermann's gull in the United States. West. Birds 14:39-46

Howell, J. T., P. H. Raven, and P. Rutzoff. 1958. A flora of San Francisco, California. University of San Francisco, San Francisco.

Howell, R. B., and J. A. Racin. 1978. A comparison of highway slope erosion estimates by the mechanical slope erosion transect survey methods. California Department of Transportation, Interim Rep. no. CA-TL-78-20:6.

Hubbs, C. L., and O. L. Wallis. 1948. The native fish fauna of Yosemite National Park and its preservation. Yosemite Nat. Notes 27:(12):131-144.

Huffaker, C. B., and C. E. Kennett. 1959. A ten-year study of vegetational changes associated with biological control of Klamath weed. J. Range Manage. 12:69-82.

Hull, C. H., and N. H. Nie. 1981. SPSS Update 7-9. New Procedures and facilities for releases 7-9. McGraw-Hill, New York.

Hunter, J. G., and L. J. Pierson. 1980. A detailed cultural resource evaluation of exposed shipwrecks in the Los Angeles harbor deepening project landfill area south of Terminal Island, California. Report prepared for the U.S. Army Corps of Engineers, Los Angeles District.

Husch, B., C. I. Miller, and T. W. Beers. 1972. Forest mensuration. 2d ed. Ronald Press, New York.

Huxtable, R. J. 1979. Herbal teas and pyrrolizidine alkaloids. Symposium on pyrrolizidine *(Senecio)* alkaloids: toxicity, metabolism, and poisonous plant control measures. Oregon State University, Corvallis.

Isaacson, D. L. 1973 *a*. A life table for the cinnabar moth, *Tyria jacobaeae,* in Oregon. Entomophaga 18:291-303.

____. 1973 *b*. Population dynamics of the cinnabar moth, *Tyria jacobaeae* (Lepidoptera:Arctiidae). Master's thesis, Oregon State University, Corvallis.

____. 1974. Economic losses to tansy ragwort. Proc. 23d Oregon weed conference. Portland, Oreg.

Iwatsubo, R. T., and R. C. Averett. 1981. Aquatic biology of the Redwood Creek and Mill Creek drainage basins, Redwood National Park, Humboldt and Del Norte Counties, California. U.S. Geol. Surv. Open-File Rep. 81-143.

Iwatsubo, R. T., K. M. Nolan, D. R. Harden, and G. D. Glysson. 1976. Redwood National Park Studies, data release number 2, Redwood Creek, Humboldt County, and Mill Creek, Del Norte County, California, April 11, 1974-September 30, 1975. U.S. Geological Survey Open-File Rep. 76-678.

Jacobs, D. D. 1949. Aerial torpedos. Yosemite Nat. Notes 28:148-149.

Jahn, G. 1982. Application of vegetation science to forestry. Handbook of vegetation science. Vol. 12. Junk, The Hague.

Janda, R. J., K. M. Nolan, K. R. Harden, and S. M. Colman. 1975. Watershed conditions in the drainage basin of Redwood Creek, Humboldt County, California as of 1973. U.S. Geol. Surv. Open-File Rep. 75-568.

Johnson, D., and D. R. Field. 1981. Applied and basic social research: a difference in social context. Leisure Sci. 4(3):269-279.

Johnson, D. L. 1979. Geology, soils, and erosion. Pages 3.1-3.73 *in* D. M. Power, ed. Natural resources study of the Channel Islands National Monument, California. Santa Barbara Museum of Natural History, Santa Barbara, Calif.

Johnson, J. W. 1976. Closure conditions of northern California lagoons. Shore Beach 44:20-23.

Jones, J. R. 1969. Review and comparison of site evaluation methods. U.S. Dep. Agric. For. Serv. Res. Pap. RM-51. Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colo.

Jubb, K. V. F., and P. C. Kennedy. 1970. Pathology of domestic animals. Academic Press, New York.

Katic, I. 1961. Paratuberculosis (Johne's disease) with special reference to captive wild animals. Nord. Veterinaermed. 13:205-214.

Keller, E. A., and T. D. Hofstra. 1983. Summer "cold pools" in Redwood Creek near Orick, California, and their importance as habitat for anadromous salmonids. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Kemble, J. H. 1943. The Panama route, 1848-1869. University of California Press, Berkeley.

Kemnitzer, L. B. 1933. Geology of San Nicolas and Santa Barbara Islands California. Master's thesis, California Institute of Technology, Pasadena.

Kercher, J. R., and R. A. Goldstein. 1977. Analysis of an east Tennessee oak hickory forest by canonical correlation of species and environmental parameters. Vegetatio 35(3):153-163.

Kershaw, K. A. 1973. Quantitative and dynamic plant ecology. American Elsevier, New York.

Kesner, W. D. 1977. An economic evaluation of salmon and steelhead fishery resources attributable to the Klamath National Forest. Klamath National Forest, Yreka, Calif.

King, A. G., and P. McW. Bickel. 1980. Resources evaluation at nine archaeological sites, Redwood Creek Basin, Redwood National Park, California. 8480-9-0772. National Park Service, Redwood National Park, Calif.

Klecka, W. R. 1975. Discriminant analysis. Pages 434-467 *in* N. H. Nie, C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent, eds. Statistical package for the social sciences. McGraw-Hill, New York.

Klemmedson, J. O. 1979. Ecological importance of actinomycete- nodulated plants in the western United States. Bot. Gaz. 140 (suppl.):S91-S96.

Kluge, J. P., R. S. Merkal, and W. S. Monlux. 1968. Experimental paratuberculosis in sheep after oral, intratracheal, or intravenous inoculation: lesions ad demonstration of etiologic agent. Am. J. Vet. Res. 29:953-962.

Komar, P. D. 1976. Beach processes and sedimentation. Prentice-Hall, Englewood Cliffs, N.J.

Kuchler, A. W. 1973. Problems in classifying and mapping vegetation for ecological regionalization. Ecology 54:512-523.

Laffen, M. D., and E. J. B. Cutler. 1977. Landscapes, soils, and erosion of a catchment in the Wither Hills, Marlborough. 2. N. Z. J. Sci. 20:279-289.

Larson, J., J. McKeon, T. Salamunovich, and T. D. Hofstra. 1983. Water quality and productivity of the Redwood Creek Estuary. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Larson, J. P., C. L. Ricks, and T. J. Salamunovich. 1981. Alternatives for restoration of estuarine habitat at the mouth of Redwood Creek, Humboldt County, California. *In* R. M. Coats, ed. Proceedings symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas. Center for Natural Resources Studies and National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981.

Laymon, S. A., and W. D. Shuford. 1980. Middle Pacific coast region. Am. Birds 34:925-929.

Lee, K. W., G. W. Kapple, and D. R. Dawdy. 1975. Rainfall- runoff relation for Redwood Creek above Orick, California. U.S. Geol. Surv. Open-File Report.

Lenihan, D. J. 1974. Preliminary archaeological survey of the offshore lands of Gulf Islands National Seashore. Pages 34-40 *in* D. J. Lenihan, ed. Underwater archeology in the National Park Service. Division of Archeology, Southwest Region, National Park Service, Santa Fe, N. M.

____. 1983. Rethinking shipwreck archeology: a history of ideas and considerations. Pages 37-64 *in* R. Gould, ed. Shipwreck anthropology. University of New Mexico Press, Albuquerque, N. M.

Lenihan, J. M. 1983. The forest communities of the Little Lost Man Creek Research Natural Area, Redwood National Park, California. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Lennox, W. S. 1981. A computer program for classifying vegetated and unvegetated sites one to ten years following clearcut logging of coast redwood forests in the Lower Redwood Creek Basin of Redwood National Park. Unpublished. On file, National Park Service, Redwood National Park.

Lewis, O. 1949. Sea routes to the gold fields. Knopf, New York.

Leydet, F. 1969. The last redwoods, and the park lands of Redwood Creek. Sierra Club Ballatine Books, San Francisco.

Libke, K. G., and A. M. Walton. 1975. Presumptive paratuberculosis in a Virginia white-tailed deer. J. Wildl. Dis. 11.552-553.

Litton, R. B., Jr. 1968. Forest landscape description and inventories--a basis for land planning and design. USDA For. Serv. Res. Pap. PSW-49. Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

____. 1973. Landscape control points: a procedure for predicting and monitoring visual impacts. USDA For. Serv. Res. Pap. PSW-91. Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

Lotchin, R. 1974. San Francisco, 1846-1856: from hamlet to city. Oxford University Press, New York.

MacCannell, D. 1976. The tourist, a new theory of the leisure class. Schocken Books, New York.

____. 1979. Ethnosemiotics. Semiotica 27(1 & 3):149-171.

McCarthy, J. E. 1972. The distribution, substrate selection and sediment displacement of *Corophium salmonis* (Stimpson) and *Corophium spinicorne* (Stimpson) on the coast of Oregon. Ph. D. diss. Oregon State University, Corvallis.

McColl, J. G. 1981. Effects of acid rain on plants and soils in California. California Air Resources Board Contract A8-136-31.

McCrimmon, H. R. 1954. Stream studies on planted Atlantic salmon. J. Fish. Res. Board Can. 11-362-403.

McEvoy, P. B. 1982. Wind-dispersal of dimorphic achenes of tansy ragwort *(Senecio jacobaea)* in relation to habitat. Abstr. Bull. Ecol. Soc. Am. 63(2):169.

_____. 1983. Dormancy and dispersal in dimorphic achenes of tansy ragwort, *Senecio jacobaea* L. (Compositae). Oregon State Univ. Agric. Exp. Stn. Tech. Pap. no. 6500 (in press).

McGlashan, H. D., and R. C. Briggs. 1939. Floods of December, 1937 in northern California. U.S. Geol. Surv. Water Supply Pap. 843.

McLaughlin, J., and F. Harradine. 1965. Soils of western Humboldt County, California. Department of Soils and Plant Nutrition, University of California, Davis.

McLean, D. D., and E. Rett. 1926. Duck hawks at Cascades. Yosemite Nat. Notes 5:80.

Madej, M. A., H. M. Kelsey, and W. E. Weaver. 1980. An evaluation of 1978 rehabilitation sites and erosion control techniques in Redwood National Park, Watershed Rehabilitation. Tech. Rep. no. 1. National Park Service, Redwood National Park, Arcata, Calif.

Marshall, D. B. 1978. California shipwrecks: footsteps in the sea. Superior, Seattle.

Marx, D. H., and C. B. Davey. 1968. The influence of ectotrophic mycorrhizal fungi on resistance of pine roots of pathogen infections. IV. Resistance of naturally occurring mycorrhizae to inflections by *Phytophythora cinnamomi.* Phytopathology 59:559-565.

Masnik, M. T., J. R. Staufter, C. H. Hocutt, and Wilson. 1976. The effects of an oil spill on the macroinvertebrates and fish in a small southwestern Virginia creek. J. Environ. Sci. Health. 4,5:281-296.

Mason, W. T., Jr., J. B. Anderson, and G. E. Morrison. 1967. A limestone-filled, artificial substrate sampler-plot unit for collecting macroinvertebrates in large streams. Prog. Fish-Cult. 29:1-74.

Mason, W. T., Jr., C. I. Webber, P. A. Lewis, and E. C. Julian. 1973. Factors affecting the performance of basket and multiplate macroinvertebrate samplers. Freshw. Biol. 3:409-436.

Mathis, B. J. 1968. Species diversity of benthic macroinvertebrates in three mountain streams. Trans. III. Okla. State Acad. Sci. 61:171-176.

Melack, J. M., J. L. Stoddard, and D. R. Dawson. 1983. Acid precipitation and buffer capacity of lakes in the Sierra Nevada, California. Proceedings international symposium on hydrometry, Denver, Colo., June 1982. Am. Water Res. Assoc., Denver, Colo. (in press).

Melin, E. J., and E. Hakskaylo. 1958. Translocation of cations to seedlings of *Pinus virginiana* through mycorrhizal mycelium. Bot. Gaz. 119:243-246.

Melin, E., and H. Nilson. 1950. Transfer of radioactive phosphorus to pine seedlings by means of mycorrhizal hypae. Physiol. Plant. 3:88-92.

____. 1952. Transport of labeled nitrogen from ammonium source to pine seedlings through mycorrhizal mycelium. Sven. Bot. Tidskr. 46:281-285.

Merkal, R. S. 1971. Diagnostic methods for detection of *Mycobacterium paratuberculosis* (Johne's disease). Pages 620-623 *in* Proceedings 74th Annual Meeting, U.S. Animal Health Association.

Merritt, R. W., and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt, Iowa, Ind.

Meyer, H. A. 1953. Forest mensuration. State College of Pennsylvania, State College, Pa.

Meyer, L. D., and L. A. Kramer. 1969. Erosion equations predict land slope development. Agric. Engr. 50(9):522-523.

Meyers, J. H. 1980. Is the insect or the plant the driving force in the cinnabar moth-tansy ragwort system? Oecologia 47:16-21.

Milestone, J. F. 1981. Eagles Point site restoration and revegetation project. *In* R. M. Coats, ed. Proceedings symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas. Center for Natural Resource Studies and the National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981

____. 1982. Evaluation of the Eagles Point revegetation project. Ocean District Report, GGNRA. National Park Service, San Francisco.

Miller, L. 1952. Auditory recognition of predators. Condor 54:89-92.

Miller, P. R., H. M. McCutchan, and H. P. Milligan. 1972. Oxidant air pollution in the central valley, Sierra Nevada foothills, and Mineral King Valley of California. Atmos. Environ. 6:623-633.

Miller, P. R., and A. A. Millecan. 1971. Extent of oxidant air pollution damage to some pines and other conifers in California. Plant Dis. Rep. 55(6):555-559.

Miller, P. R., J. R. Parmeter, Jr., O. C. Taylor, and E. A. Cardiff. 1963. Ozone injury to the foliage of *Pinus ponderosa*. Phytopathology 53:1072-1076.

Morgan, R. P. C. 1979. Soil erosion. Longman, New York.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley.

Moyle, P. B., J. J. Smith, R. A. Daniels, and D. M. Baltz. 1982. Distribution and ecology of stream fishes of the Sacramento-San Joaquin Drainage system, California: a review. Univ. Calif. Publ. Zool. 115:225-256.

Muckelroy, K. 1978. Maritime archaeology. Cambridge University Press, Cambridge.

Mueller-Dombois, D., and H. Ellenburg. 1974. Aims and methods of vegetation ecology. Wiley, New York.

Muir, J. 1894. The mountains of California. Anchor, Garden City, N. Y.

Muldavin, E., J. Lenihan, W. Lennox, S. Veirs. 1981. Vegetation succession in the first ten years following logging of coast redwood forests. Redwood National Park, National Park Service, Tech. Rep. no. 6. Arcata, Calif.

Munz, P. A. 1974. A flora of Southern California. University of California Press, Berkeley.

Munz, P. A., and D. D. Keck. 1973. A California flora with supplement. University of California Press, Berkeley.

Murphy, L. 1980. Survey methodology: site specific survey Biscayne National Monument, 1980. Submerged Cultural Resources Unit, Southwest Region, National Park Service, Santa Fe, N. M.

____. 1983. Shipwrecks as data base for human behavioral studies. Pages 65-90 *in* R. Gould, ed. Shipwreck anthropology. University of New Mexico Press, Albuquerque, N. M.

Murphy, L., R. Kelly, D. Pugh, J. Delgado, D. Lenihan, D. Buller, D. Skiles, B. Sullivan, and J. Baker. 1983. A shipwreck survey of Point Reyes National Seashore and portions of Point Reyes-Farallon Islands National Marine Sanctuary. National Park Service, Santa Fe, N. M.

Muth, O. H. 1968. Tansy ragwort *(Senecio jacobaea)*, a potential menace to livestock. J. Am. Vet. Med. Assoc. 153(3):310-312.

National Park Service. 1978. Computer general visual analysis of alternative parking areas from Wawona Tunnel, Yosemite National Park. Western Service Center, Denver, Colo.

Needham, P. R., and R. L. Usinger. 1956. Variability in the macrofauna of a single riffle in Prosser Creek, California, as indicated by the Surber sampler. Hilgardia 24:383-409.

Newton, M., B. A. El Hassan, and J. Zavitkovski. 1968. Role of red alder in western Oregon forest succession. Pages 73-84 *in* J. M. Trappe, J. F. Franklin, R. F. Tarrant, and G. H. Hansen, eds. Biology of the alder. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent, eds. 1975. SPSS. Statistical package for social sciences. McGraw-Hill, New York.

Nisbet, D. F., N. J. L. Gilmour, and J. G. Brotherston. 1962. Quantitative studies of *Mycobacterium jonei* in tissues of sheep. III. Intestinal histopathology. J. Comp. Pathol. 72:80-91.

Nolan, K. M., and R. J. Janda. 1981. Use of short-term water and suspended sediment discharge observations to assess impacts of logging on stream sediment discharge in Redwood Creek basin, northwestern California, U.S.A. Pages 415-438 *in* Proceedings symposium erosion and sediment transport in Pacific rim steeplands, Christchurch, New Zealand, IAHS-AISH Publ. no. 132.

Panofsky, E. 1955. Meaning in the visual arts; papers in and on art history. 1st ed. Doubleday, Garden City, N.Y.

Parker, G. G. 1963. Piping, a geomorphic agent in landform development of the drylands. Int. Assoc. Sci. Hydrol. Publ. 65:103-113.

Parsons, D. J., and D. M. Graber. 1981. Study plan for long-term research on the effects of acid deposition on the ecosystems of Sequoia National Park, California. Research Office, Sequoia and Kings Canyon National Parks, Three Rivers, Calif.

Paulson, C. G. 1953. Floods of 1950 in southwestern Oregon, northwestern California. U.S. Geol. Surv. Water Supply Pap. 1137-E: 413-503.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States. 2d ed. Wiley, New York.

Pfister, R. D. 1982. Succession models to meet management needs. Proceedings symposium forest succession and stand development in the Pacific Northwest. Forest Research Laboratory, Oregon State University, Corvallis, Oreg.

Pfister, R. D., and S. T. Arno. 1980. Classifying forest habitat types based on climax vegetation. For. Sci. 26(1):52-70.

Philbrick, R. N. 1972. The plants of Santa Barbara Island, California. Madrono 21(5):329-393.

Pitlick, J. 1982. Sediment routing in tributaries of the Redwood Creek basin: northwestern California. Redwood National Park, Arcata, Calif.

Poole, A. L., and D. Cairns. 1940. Botanical aspects of ragwort (*Senecio jacobaea* L.). Bull. N. Z. Dep. Sci. Indust. Res. 82:1-61.

Popenoe, J. H. 1981. Effects of grass-seeding, fertilizer and mulches on vegetation and soils on Copper Creek watershed rehabilitation unit: the first two years. *In* R. M. Coats, ed. Proceedings symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas. Center for Natural Resource Studies and National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981.

Powers, R. F. 1980. Mineralizable soil nitrogen as an index of nitrogen availability to forest trees. Soil Sci. Soc. Am. J. 44:1314-1320.

Pritchard, D. W. 1967. What is an estuary: physical view point. Estuaries. Am. Assoc. Adv. Sci. Publ. 83:3-5.

Pronos, J., and D. R. Vogler. 1981. Assessment of ozone injury to pines in the southern Sierra Nevada, 1979 1980. USDA For. Serv. Rep. no. 81-20. Forest Pest Management, Pacific Southwest Region, San Francisco.

Pronos, J., D. R. Vogler, and R. S. Smith, Jr. 1978. An evaluation of ozone injury to pines in the southern Sierra Nevada. Report no. 78-1. Forest Insect and Disease Management, U.S. Forest Service, San Francisco.

Ramey, R. R. 1981. Yosemite National Park Peregrine Falcon nest studies—1981. Located at: Resource management files, Yosemite National Park.

Rasmussen, L. J. 1970. San Francisco ship passenger lists. San Francisco Historic Records, Colma, Calif.

Raunkiaer, C. 1937. Plant life forms. Clarendon, Oxford.

Reed, L., and M. Hektner. 1981. Evaluation of 1978 rehabilitation techniques, Redwood National Park. National Park Service, Redwood National Park, Arcata, Calif. Tech. Rep. no. 5.

____. 1983. Effects of seed, fertilizer and mulch application on vegetation re-establishment on Redwood National Park rehabilitation sites. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Reid, G. K. 1961. Geology of inland waters and estuaries. Van Nostrand Reinhold, New York.

Reimers, P. E. 1973. The length of residence of juvenile fall Chinook Salmon in Sixes River, Oregon. Research Report Fish Commission 4(2). Portland, Oreg.

Reiser, D. W., and T. C. Bjornn. 1979. Habitat requirements of anadromous salmonids. USDA Forest Serv. Gen. Tech. Rep. PNW-96.

Resh, V. H. 1979. Sampling variability and life history features: basic considerations in the design of aquatic insect studies. J. Fish. Res. Board Can. 36:290-310.

Ricks, C. L. 1983. Redwood Creek estuary flood history, sedimentation and implications for aquatic habitat. *In* C. van Riper, III, L. C. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10.

Riemann, H. M. R. Zaman, and R. Ruppaner. 1979. Paratuberculosis in cattle and freeliving exotic deer. J. Am. Vet Med. Assoc. 174:841-843.

Roby, K. B., J. D. Newbold, and D. C. Erman. 1978. Effectiveness of an artificial substrate for sampling macroinvertebrates in small streams. Freshw. Biol. 8:1-8.

Ross, R. W., Jr. 1979. The Bureau of Land Management and visual resource management—an overview. Proceedings of Our national landscape: a conference on applied techniques for analysis and management of the visual resource. Incline Village, Nevada, April 23-25.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Res. Pap. INT-115.

____. 1983. How to predict the spread and intensity of forest and range fires. USDA For. Serv. Gen. Tech. Rep. INT-143.

Rothermel, R. C., and J. E. Deeming. 1980. Measuring and interpreting fire behavior for correlation with fire effects. USDA For. Serv. Gen. Tech. Rep. INT-93.

Rowe, J. S. 1961. The level-of-integration concept and ecology. Ecology 42:420-427.

____. 1971. Why classify forest land? For. Chron. 47:144-148.

Saunders, R. I., and E. B. Henderson. 1973. Influence of photoperiod on smolt development and growth of Atlantic salmon *(Salmo salar)*. J. Fish. Res. Board Can. 27:1295-1311.

Savage, W. 1974. Plant life of the Golden Gate National Recreation Area with recommendations for management and research. Natural Resources Inventory, GGNRA. San Francisco, Calif.

Sawyer, J. O., D. A. Thornberg, and J. R. Griffin. 1977. Mixed evergreen forests. Pages 359-381 *in* M. Barbour and J. Major, eds. Terrestrial vegetation of California. Wiley-Interscience, New York.

Scott, D. C. 1958. Biological balance in streams. Sewage Ind. Wastes 30:1169-1173.

Seber, G. A. F., and E. D. LeCren. 1967. Estimating population parameters from catches large relative to the population. J. Anim. Ecol. 36:631-643.

Sebok, T. A., ed. 1978. Sight, sound, and sense. Indiana University Press, Bloomington.

Seidel, K. N. 1973. Mixed pine-fire of eastern Oregon and Washington. *In* Silvicultural system for the major forest types of the United States. U.S. Dep. Agric. Agric. Handb. 445.

Severinghaus, C. W. 1981. Overwinter weight loss in white-tailed deer in New York. N. Y. Fish and Game J. 821:61-67.

Seymour, R. J., J. O. Thomas, D. Castel, A. E. Woods, and M. H. Sessions. 1980. California coastal data collection program. Fifth Annual Report, January 1980 through December 1980. U. S. Army Corps of Engineers and the California Department of Boating and Waterways, La Jolla, Calif.

____. 1982. California coastal data collection program. Monthly Reports, March 1980 through January 1982. U.S. Army Corps of Engineers and the California Department of Boating and Waterways. La Jolla, Calif.

Shanks, R., and J. Shanks. 1976. Lighthouses of San Francisco Bay. Costano Books, San Anselmo, Calif.

Shapovalov, L., and A. Taft. 1954. The life histories of the steelhead rainbow trout *(Salmo gairdneri gairdneri)* and silver salmon *(Oncorhynchus kisutch)* with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game Fish. Bull. no. 98.

Sharrow, S. H., and W. D. Mosher. 1982. Sheep as a biological control agent for the tansy ragwort. J. Range Manage. 35(4):480-482.

Sheridan R. E. 1978. Site charting and environmental studies of the *Monitor* wreck. Pages 33-41 *In* The *Monitor:* its meaning and future: papers from a national conference. Preservation, Washington, D.C.

Smith, J. 1982. Summary of economic benefits possible from HR 6536 91982 prices. Trinity County Board of Supervisors, Weaverville, Trinity County, Calif.

Snyder, L. A. 1950. Morphological variability and hybrid development in *Elymus glaucus.* Am. J. Bot. 37:628-636

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. Freeman, San Francisco.

Soltys, M. A., C. E. Andress, and A. L. Fletch. 1967. Johne's disease in a moose *(Alces alces).* Bull. Wildl. Dis. Assoc. 3:183-184.

Sowers, G. F., and F. L. Royster. 1978. Field investigation. *in* R. L. Schuster and R. J. Krizek, eds. Landslides, analysis and control. Trans. Res. Board Spec. Rep. 176. 2d ed. National Academy of Sciences, Washington, D.C.

Sowls, A. L., A. R. DeGange, J. W. Nelson, and G. S. Lester. 1980. Catalog of California seabird colonies. U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program, FWS/OBS 37/80.

Stebbins, G. L. 1956. The hybrid origin of microspecies in the *Elymus glaucus* complex. Pages 336-340 *in* Proceedings international genetics symposia. Organizing Committee International Genetics Symposia, Scientific Conference Japan, Ueno Park, Tokyo.

_____. 1959. The role of hybridization in evolution. Proc. Am. Philos. Soc. 103:231-251.

Stebbins, G. L., Jr., and M. S. Walters. 1949. Artificial and natural hybrids in the Gramineae, tribe Hordeae. III. Hybrids involving *Elymus condensatus* and *E. triticoides*. Am. J. Bot. 36:291-301.

Stimac, J. L. 1977. A model of a plant-herbivore system. Ph. D. diss. Oregon State University, Corvallis.

Strand, R. G. 1963. Compiler: explanatory data, weed sheet, geologic map of California. Olaf P. Jenkins, ed. California Division of Mines and Geology, Sacramento, Calif.

Sugihara, H. G., and K. Cromack, Jr. 1981. The role of symbiotic microorganisms in revegetation of disturbed areas—Redwood National Park. *In* R. M. Coats, ed. Proceedings of symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas. Center for Natural Resource studies and National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981.

Sugihara, N. 1983. The role of symbiotic micro-organisms in post-disturbance ecosystems—Redwood National Park. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Sumner, L. 1959. The battle for Santa Barbara. Outdoor Calif. 20(2):4-7.

Surber, E. W. 1936. Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish Soc. 66:193-202.

Tarrant, R. F., and R. E. Miller. 1963. Accumulation of organic matter and soil nitrogen beneath a plantation of red alder and Douglas-fir. Soil Sci. Soc. Am. Proc. 27:231-234.

Tatsuoka, M. M. 1970. Discriminant analysis. Selected topics in advanced statistics. no. 6. Institute for Personality and Ability Testing, Champaign, Ill.

Tesch, F. W. 1971. Age and growth. Pages 98-130 *in* W. E. Ricker, ed. Methods for assessment of fish production in fresh waters. IBP Handb. no. 3, 2d ed.

Thelander, C. G. 1976. Distribution and reproductive success of peregrine falcons *(Falco peregrinus anatum)* in California during 1975 and 1976. Calif. Dep. Fish Game, Wildl. Manage. Branch, Adm. Rep. no 76-3.

Thilenius, J. F. 1968. The *Quercus garryana* forests of the Willamete Valley, Oregon. Ecology 49:1124-1133.

Thoen, C. O., W. D. Richards, and J. L. Jarnagin. 1977. Mycobacteria isolated from exotic animals. J. Am. Vet. Med. Assoc. 170:987-990.

Thornes, J. B. 1980. Pages 179-182 *in* M. J. Kirby and R. P. C. Morgan, eds. Soil erosion. Wiley, New York.

Tinbergen, N. 1958. Curious naturalists. Doubleday, Garden City, N.Y.

_____. 1961. The herring gull's world: a study of the social behavior of birds. Basic Books, New York.

Tlusty, W. 1979. The use of VIEWIT and PERSPECTIVE PLOT to assist in determining the landscape's visual absorption capability. Proceedings of Our national landscape: a conference on applied techniques for analysis and management of the visual resource. Incline Village, Nevada, April 23-25.

Travis, M. R., G. H. Elsner, W. D. Iverson, and C. G. Johnson. 1975. VIEWIT: a compilation of seen areas, slope, and aspect for land-use planning. USDA For. Serv. Gen. Tech. Rep. PSW-11. Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

Trijonis, J. 1980. Visibility in California: final report to the California Air Resources Board. Technology Service Corp., Santa Monica, Calif.

Unger, D. D. 1978. The transport of photochemical smog in the central valley and the Sierra Nevada mountains of California. Proceedings conference on Sierra Nevada meteorology. American Meteorological Society, Boston, Mass.

U.S. Army Corps of Engineers. 1961. Survey report of flood control and allied purposes, Redwood Creek, Humboldt County, California. U.S. Army Engineer District, San Francisco, Calif.

U. S. Department of Agriculture. 1937. Range Plant Handbook. Government Printing Office, Washington, D. C.

U.S. Department of Agriculture, Soil Conservation Service. 1963. National Cooperative Soil Survey. Soil series in northwestern California. Berkeley, Calif.

U.S. Department of Commerce, Environmental Science Services Administration. 1970-1980. Climatological data—California. Government Printing Office, Washington.

U.S. Department of the Interior. 1960. Natural resources of northwestern California; a preliminary survey of fish and wildlife resources. Report Appendix. U.S. Fish and Wildlife Service, Pacific Southwest Field Committee.

U.S. Department of the Interior, National Park Service. 1978. Management policies. Government Printing Office, Washington, D.C.

U.S. Department of the Interior, National Park Service, Yosemite National Park. 1979. Peregrine falcon management plan. Available from: Resources Management files, Yosemite National Park.

U.S. Department of the Interior, National Park Service. 1981 Draft Environmental Impact Statement, U.S. 101 Bypass. Denver Service Center, Denver, Colo.

U.S. Department of the Interior, National Park Service. 1981. Watershed Rehabilitation Plan, Redwood National Park. Denver Service Center, Denver, Colo.

U.S. Department of the Interior. 1982. Resources management plan, Redwood National Park, Arcata, Calif. Government Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. Division of Ecological Services. 1975. Environmental summary of existing information relating to past and present fishery resources at Redwood Creek, California. Memorandum on file at California Fish and Game Office, Eureka, Calif.

Vance, M. N. 1961. Johne's disease in a European red deer. Can. Vet. J. 2:305-307.

van der Meijden, E., and R. E. van der Waals-kooi. 1979. The population ecology of *Senecio jacobaea* in a sand dune system. J. Ecol. 67:131-153.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37:131-137.

van Wagtendonk, J. W. 1974. Refined burning prescriptions for Yosemite National Park. USDI Natl. Park Serv. Occas. Pap. 2.

____. 1977. Fire management in the Yosemite mixed conifer ecosystem. Proceedings Symposium on the Environmental. Consequences of fire and fuel management in Mediterranean Ecosystems. Stanford University, August 1-5. USDA For. Serv. Gen. Tech. Rep. WO-3:459-463.

Varnes, D. J. 1978. Slope movement types and processes. *In* R. L. Schuster and R. J. Krizek, eds. Landslides, analysis and control. Trans. Res. Board Spec. Rep. 176, 2d ed. National Academy of Sciences, Washington, D.C.

Veirs, S. D., Jr. 1982. Coast redwood forests: stand dynamics, successional status, and the role of fire. Pages 119-141 *in* Proceedings of forest succession and stand development research in the northwest, symposium. School of Forestry, Oregon State University, Corvallis, March 26, 1981.

Veirs, S. D., Jr., and W. S. Lennox. 1981. Rehabilitation and long-term park management of cutover redwood forests: problems of natural succession. Pages 50-55 *in* R. M. Coats, ed. Proceed ings of symposium on watershed rehabilitation in Redwood National Park and other Pacific coastal areas. Center for Natural Resource Studies and National Park Service, John Muir Institute, Sacramento, Calif. August 25-28, 1981.

Viereck, L. A., and C. T. Dyrness. 1980. A preliminary classification system for vegetation of Alaska. USDA For. Serv. Gen. Tech. Rep. PNW-106. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Vogler, D. R. 1979. Ozone and conifer injury in Sequoia and Kings Canyon National Parks. Paper presented at Second Conference on Scientific Research in the National Parks. San Francisco, November 26-30.

Wagner, H. H. 1974. Seawater adaptation independent of photoperiod in steelhead trout *(Salmo gairdneri)*. Can. J. Zool. 52:805-812.

Wahrhaftig, C. 1974. Geology of Golden Gate N.R.A. Report to Golden Gate National Recreation Area, San Francisco, Calif.

Wallner, D. 1981. Analysis of ozone injury to ponderosa and Jeffrey pines in Sequoia and Kings Canyon National Parks, interim reports. Resources Management Office, Sequoia and Kings Canyon National Parks, Three Rivers.

Walton, J. S. 1977. Cinematographic techniques for quantifying human athletic performances. Pages 83-90 *in* T. Hirshfeld and R. E. Herron, eds. Applications of optics in medicine and biology. Proceedings Society Photo-optical Instrumentation Engineers, San Diego, Calif., August 26-27. Society of Photo-optical Instrumentation Engineers, Palos Verdes Estates, Calif.

Waring, R. H., and J. Major. 1964. Some vegetation of the California coastal redwood region in relation to gradients of moisture, nutrients, light and temperature. Ecol. Monogr. 34:167-215.

Warner, T. E., D. Wallner, and D. R. Vogler. 1982. Ozone injury to ponderosa and Jeffrey pines in Sequoia-Kings Canyon National Parks. *In* C. van Riper, III, L. D. Whittig, and M. L. Murphy, eds. Proceedings first biennial conference of research in California's National Parks. Cooperative Parks Studies Unit, University of California, Davis, September 9-10, 1982.

Warren, C. E. 1971. Biology and water pollution control. Saunders, Philadelphia.

Webster, D. A., and G. Eiriksdottir. 1976. Upwelling water as a factor influencing choice of spawning sites by brook trout. Trans. Am. Fish. Soc. 105:416-421.

West, J. R. 1979. The detection of change in benthic invertebrate communities with surber and modified multiple plate sampler. Master's thesis. Humboldt State University, Arcata, Calif.

West, N. E., and W. W. Chilcote. 1968. *Senecio sylvaticus* in relation to Douglas-fir clear-cut succession in the Oregon Coast Range. Ecology 49(6):1101-1107.

Wester, L. 1982. Composition of native grasslands in the San Joaquin Valley, California. Madrono 28:231-241.

Westhoff, V., and E. van der Maarel. 1978. The Braun-Blanquet approach. Pages 287-300 *in* R. H. Whittaker, ed. Ordination of plant communities. Junk, The Hague.

Wilhm, J. W., and T. C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18(b)477-481.

Williams, E. S., T. R. Spraker, and G. S. Schoonveld. 1979. Paratuberculosis (Johne's disease) in bighorn sheep and a Rocky Mountain goat in Colorado. J. Wildl. Dis. 15:221-227.

Williams, W. T. 1978. Acid rain: the California context. Environ. Rev. May:6-10.

_____. 1980. Air pollution disease in the California forest - a baseline for smog disease on ponderosa pine and Jeffrey pine in the Sequoia and Los Padres National Forests, California. Am. Chem. Soc. 14(2):179-182.

Williams, W. T., M. Brady, and S. C. Willison. 1977. Air pollution damage to the forests of the Sierra Nevada Mountains of California. J. Air Pollut. Control Assoc. 27(3):230-234.

Wilson, D. S. 1977. Nature as education in America. Pages 149-172 *in* V. Crockenberg and R. LaBreque, eds, Culture as education. Kendall/Hunt, Dubuque, Ia.

_____. 1978. In the presence of nature. University of Massachusetts Press, Amherst.

Wiltsee, E. 1938. Gold Rush steamers of the Pacific. Grabhorn, San Francisco.

Winget, R. N., and F. A. Mangum. 1979. Biotic condition index: integrated biological, physical and chemical stream parameters for management. U.S. Department of Agriculture, Uinta Forest, Utah.

Wittreich, C. D., and E. O. Garton. 1979. A preliminary study of peregrine falcons in Yosemite National Park. Available from: College of Forestry, Wildlife and Range Science, University of Idaho, Moscow.

Wright, A. M., H. U. Lichtenberg, and R. Moore. 1974. Photogrammetry—a planning tool in facial reconstruction. Pages 154-160 *in* Biostereometrics. Proceedings symposium of Commission V of International Society of Photogrammetry on biomedical and bioengineering applications of photogrammetry, Washington, D.C., September 10-13. American Society of Photogrammetry, Falls Church, Va.

Youngberg, C. T., and A. G. Wollum, II. 1976. Nitrogen accretion in developing *Ceanothus velutinus* stands. Soil Sci. Soc. Am. Proc. 40:109-112.

Zinke, P. J. 1977. Redwood forest and associated north coast forests. Pages 679-698 *in* M. Barbour and J. Major, eds. Terrestrial vegetation of California. Wiley-Interscience, New York.