PARK SCIENCE
Integrating Research and Resource Management

Volume 15 – Number 3 National Park Service • U.S. Department of the Interior Summer 1995

Beetlemania Sweeps the Hook

Federally threatened northeastern beach tiger beetle on comeback at Sandy Hook Unit of Gateway National Recreation Area

By Bruce Lane

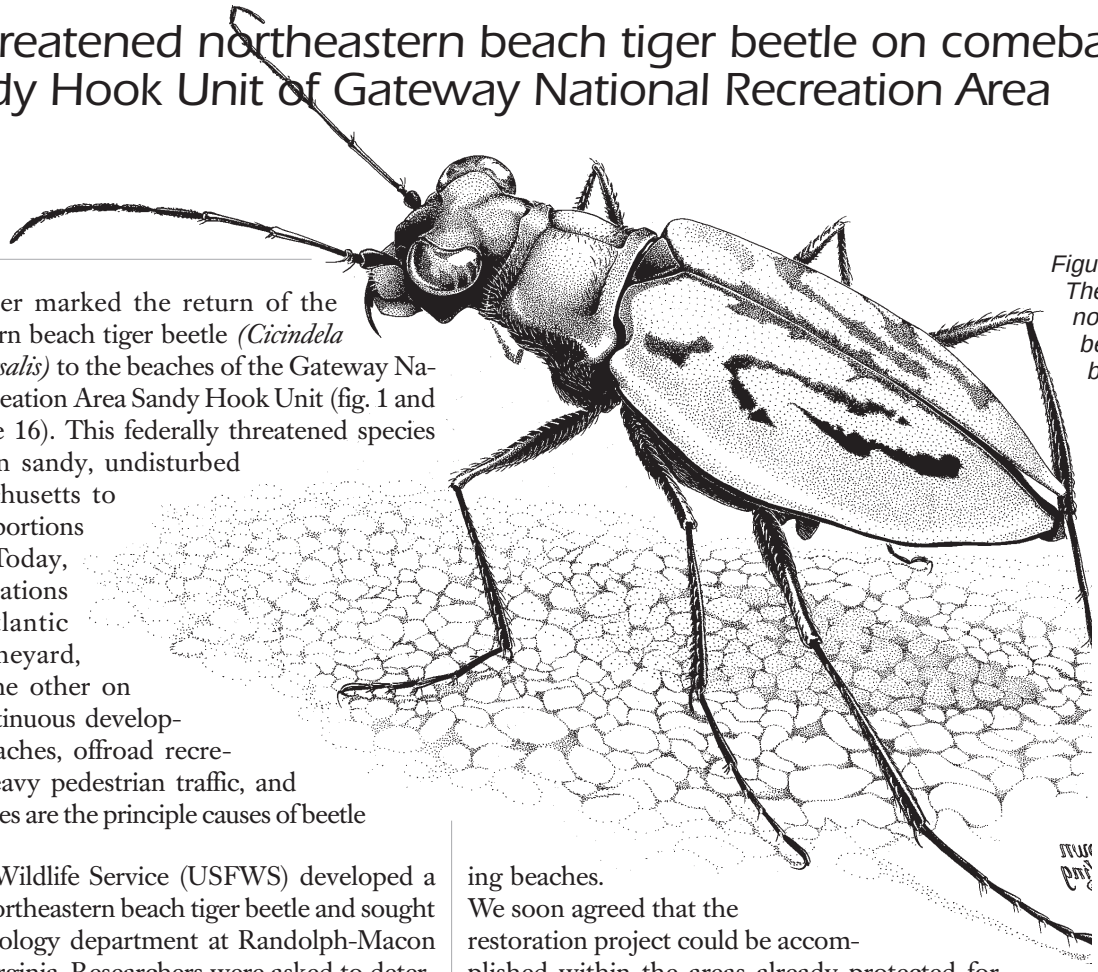


Figure 1. The adult northeastern beach tiger beetle.

Last October marked the return of the northeastern beach tiger beetle *(Cicindela dorsalis dorsalis)* to the beaches of the Gateway National Recreation Area Sandy Hook Unit (fig. 1 and fig. 2, page 16). This federally threatened species was once common on sandy, undisturbed beaches from Massachusetts to New Jersey and along portions of Chesapeake Bay. Today, only two small populations exist, one on the Atlantic coast of Martha's Vineyard, Massachusetts, and the other on Chesapeake Bay. Continuous development along ocean beaches, offroad recreational vehicle use, heavy pedestrian traffic, and the effects of storm surges are the principle causes of beetle decline.

The U.S. Fish and Wildlife Service (USFWS) developed a recovery plan for the northeastern beach tiger beetle and sought the expertise of the biology department at Randolph-Macon College in Ashland, Virginia. Researchers were asked to determine the current population status in New Jersey, conduct site evaluations, and develop procedures for beetle restoration. The researchers found that the conditions on Sandy Hook offered the best chance of survival for restoring a population.

During the summer of 1993, USFWS personnel and the Randolph-Macon biologists met at Sandy Hook with park staff to further evaluate the site and discuss the proposal of an experimental restoration. The park expressed some concern regarding potential conflicts between managing a federally threatened species and providing active recreation on the bathing beaches. We soon agreed that the restoration project could be accomplished within the areas already protected for nesting shorebirds, including the federally threatened piping plover. Despite the current use level, Sandy Hook remained the best possible site for reestablishing a beetle population.

Over the next year we initiated the formal consultation process as required by section 7 of the Endangered Species Act with the U.S. Fish and Wildlife Service. The agency authorized the removal of up to 1,000 tiger beetle larvae from the Chesapeake Bay population to be released at Sandy Hook. A USFWS

Continued on Page 16

PARK SCIENCE
Integrating Research and Resource Management
Volume 15—No. 3 • Summer 1995

PUBLISHED BY
The National Park Service
U.S. Department of the Interior
DIRECTOR
Roger G. Kennedy
ASSOCIATE DIRECTOR, NATURAL RESOURCES
Michael Soukup
EDITOR
Jeff Selleck

EDITORIAL BOARD
CHAIR
Ron Hiebert
Assistant Director for Natural Resources
Central Field Directorate
MEMBERS
Gary E. Davis
NBS Marine Research Scientist
Channel Islands National Park
John Dennis
Acting Deputy Associate Director,
Natural Resources
Jon Jarvis
Superintendent
Wrangell-Saint Elias National Park and Preserve
Elizabeth Johnson
Chief, Research and Resource Planning
Delaware Water Gap National Recreation Area

Park Science (ISSN-0735-9462) is a quarterly science and resource management bulletin that reports recent and ongoing natural and social science research, its implications for park planning and management, and its application in resource management. The bulletin is published in January, April, July, and October for distribution to interested parties.

The editor welcomes submissions of case studies, feature articles, and highlights. See *Park Science* **14(4)**:13 for submission criteria or contact the editor at:

National Park Service
Natural Resources Publication Office
P.O. Box 25287 (WASO-NRPO)
Denver, CO 80225-0287
Phone (303) 969-2147
E-mail: "jeff_selleck@nps.gov" & NPS cc:Mail

Printed on recycled paper

CONTENTS

DEPARTMENTS

- Editorial 3
- News & Views 3
- MAB Notes 6
- Information Crossfile 7
- Highlights 8
- Book Review 27
- Meetings of Interest 32

FEATURES

- Federally Threatened Northeastern Beach Tiger Beetle on Comeback at Gateway National Recreation Area 1
- Spruce Grouse on Mt. Desert Island, Maine 10
- Profile of the NBS Midcontinent Ecological Science Center, Fort Collins, Colorado 12
- Buffalo River Watershed Students Get *W*E*T* 15
- Landscape-Scale Fire History Studies Support Fire Management Action at Bandelier 18
- Prescribed Natural Fire Management: Lessons Learned in the Glacier National Park Classroom 20
- Announcing the New Grand Canyon Science Center 23
- Vegetation Mapping in Northwestern Parks 24
- Caldera Unrest, Lake Levels, and Archeology: The View from Yellowstone Lake 28

IN THE NEXT ISSUE. . .

Native plant and animal species restoration and the connections between archeology and the natural sciences remain themes next time with articles from Indiana Dunes National Recreation Area (grasses and other vegetation), Big South Fork National River and Recreation Area (black bears), and Amistad National Recreation Area (pictographs and their natural accretions), respectively. Also, look for a skunk behavior study at Great Smoky Mountains National Park and a reader survey on natural resource publications, including Park Science.

Business as Usual?

The recent restructuring exercise has many of us making adjustments. Some readers are moving to parks from central offices; others are shifting from regional offices to system support offices and are presently sorting out their relationships with park clusters; while parks no longer report to regional offices, they are preparing for the potential of increased workloads associated with certain resource management tasks that were once performed by regions, but now must be done by parks.

Park Science, too, makes a minor adjustment this issue that reflects our very new way of conducting business organizationally. In adopting our new model of field areas, system support offices, and clusters last May, we consequently made the Regional Highlights department of this publication obsolete (in name only). This most popular collection of brief park research and resource management stories will continue, to be sure, but will now be organized by clusters and will simply be known as Highlights.

Completely unconcerned with NPS restructuring is the northeastern beach tiger beetle, an insect recently restored at Gateway National Recreation Area. Our cover story reports on the restoration activities on Sandy Hook, New Jersey, and illustrates an important point: *less charismatic microfauna* deserve our efforts, and urban parks (perhaps more than large natural area parks) can make a big difference in recovering threatened and endangered species.

Also making a possible comeback is the spruce grouse of Acadia National Park and Mount Desert Island, Maine. Wildlife Biologist Allan O'Connell assesses their numbers and anticipates possible difficulties with their ongoing natural recovery due to local habitat fragmentation. Habitat fragmentation on a landscape scale is just one characteristic that the regional GIS vegetation mapping effort (described on page 24) will show in the Pacific Northwest. A multiyear project in the making, this GIS database will be a valuable tool for land managers interested in forming ecosystem management partnerships.

As fire season approaches, one article recounts the dramatic regularity (and later absence) of fire in the Jemez Mountains of New Mexico until around the turn of the century. A second piece on fire reports on the importance of updated fire management plans, sophisticated predictive models, and other techniques we can (and must) employ these days to accomodate this natural force in our parks.

While restructuring represents a dramatic change in our organization and how we conduct some research and resource management business, it does not change the nature of that business. As the articles here remind us, our efforts remain focused on finding answers to resource management questions and applying them in the field for the protection and celebration of park resources as usual.

Jeff

News & Views

Errata

In the satellite radiotelemetry article on page 24 last issue James Fraser of Virginia Polytechnic and State University was incorrectly credited with assisting with the Denali golden eagle study; he participated in the Glacier Bay bald eagle study.

Also in that issue, Wildlife Veterinarian Mark Johnson was credited with writing the news brief on page 3 that dealt with computerizing the Yellowstone rare animal report system. The correct authors are Kerry Gunther and John Mack, both of the Yellowstone Center for Resources.

George Wright Conference Sustains Interest

Exploring the theme of sustainability in society and protected areas, the George Wright Society Eighth Conference on Research and Resource Management In Parks and on Public Lands provided valuable discussions on this all-important ideal at a time when environmental protection is being deemphasized and associated laws may be potentially scaled back. With more than 425 people in attendance, the April meeting brought together public and private lands scientists, resource managers, administrators, and other natural and cultural resource leaders for the presentation or attendance of numerous poster sessions and nearly 100 presentations. Five concurrent tracks organized the presentations according to their relevance to the following different aspects of sustainability: sustainable protected area management, planning for use and management, integrating cultural and natural resource management, applying science and technology, or ecosystem management. Three plenary sessions, a day of field trips, an awards banquet, and unlimited opportunities to visit amongst the participants rounded out the valuable and enjoyable four days.

Opening the conference with a presentation that was to become its centerpiece was Oregon State University Professor George Stankey. Speaking on the social foundations of sustainability, Stankey assessed our present standing and what we must do to move beyond the current stagnant, even regressive, times. He described sustainability as a philosophical construct that helps society set standards to live by; he also noted that our ideals must be translated into a public discourse that transcends our ideological ignorance and prompts action to reverse our resource- (and self-) destructive ways. Other highlights included a passionate and logical appeal to environmentally responsible land management practices by the Chairman of the Confederated Tribes of the Umatilla (Oregon) Indian Reservation, National Biological Service Director Pulliam's honesty about and hopes for his agency, and Deputy Director Reynolds' call for exemplary NPS actions and operations.

Continued on page 4

Continued

In contrast to these, the majority of presentations simply reflected research and resource management work at hand on our public lands. Scientists, resource managers, and land administrators seem to know the importance and practicality of staying focused on projects that create results at home. In this regard, sessions touched on fire management practices, exotic species control and vegetation restoration projects, visitor experience assessment methods and use planning, managing visitor impacts, tourism, international cooperation, the implications of historic Native American impacts on resource management activities, and recent examples of ecosystem management efforts, among many, many others. Making a difference in one's own sphere of influence on furthering the principles of sustainability was perhaps the biggest take home message from the conference.

As usual, the conference covered National Park Service concerns and system areas well and boosted science and resource management communications. Forty-one papers are published in a volume available from the George Wright Society (call Bob Linn or Dave Harmon at ((906) 487-9722). The ninth such conference is planned for Albuquerque, New Mexico, in March 1997.

A longer review of the conference by William E. Brown can be found in the summer George Wright Forum (volume 12, no. 2), which should be circulated in early July.

Matthews Honored

The George Wright Society honored former *Park Science* editor and founder Jean Matthews with its George Melendez Wright Award for Excellence at its April gathering in Portland, Oregon. The award is given to research, management, and interpretation professionals in recognition of their lifetime contributions to natural area understanding. Jean was recognized specifically for her lifework in communication bringing the achievements of research to bear on resource management and interpretive programs in national parks and equivalent reserves.

A journalist by training, Matthews worked as a reporter for several newspapers before beginning a government writing career in 1962. Initially a speech writer for Secretary of the Interior Stuart Udall and Ladybird Johnson, Matthews also produced several highly regarded yearbooks on the work and staff of the Department of the Interior. In the early 1970s, Jean began writing speeches for NPS Director George Hartzog and served on an environmental education task force that sought to integrate natural systems concepts into NPS interpretive media. Jean's idea to publicize the marriage of science and resource management came about in 1980 when she launched *Park Science,* a project she oversaw until her retirement in 1994.

NPS PHOTO BY JEFF SELLECK

Jean Matthews—a recipient of the George Melendez Wright Award for Excellence

Also receiving this award were Everglades biologist Bill Robertson and historian Robert Utley. Robertson started his career as a park fire control aid and later became the first research biologist for Everglades National Park and the former Fort Jefferson National Monument in 1957. In this role, he maintained a strong interest in breeding bird populations of tropical Florida in relation to vegetation. For more than 40 years, Robertson's insights into the intricacies of the Everglades ecosystem and his ability to articulate them have proven invaluable.

Robert Utley first worked for the National Park Service in 1947 as a historical aid in the former Custer Battlefield National Monument. He later held numerous historian positions in government including NPS Southwest Regional Historian, NPS Chief Historian, and Director of the Office of Archeology and Historic Preservation. He rose to NPS Assistant Director for Park Historic Preservation and served as the Deputy Executive Director of the President's Advisory Council on Historic Preservation. Also an author, Utley most recently wrote an award winning biography of Sitting Bull.

Bob Krumenaker, Leader of the Shenandoah National Park Center for Resources, won the 1995 George Wright Society Natural Resource Management (Francis Jacot) Award for his leadership in the role of Southwest Region Chief of Resource Management from 1991-1995.

Biologist George Wright was a rising NPS scientist in the 1920s and 1930s when a car accident took his life at the age of 31 in 1936. During his distinguished but short career, Wright championed the importance of science in park management early on. He also coauthored the classic wildlife treatises Fauna 1 and 2, wherein he recognized that parks alone were not adequately large or ecologically complete for the preservation of large mammals. The awards, given in his memory, are the highest honors given by the George Wright Society.

Earthwatch Supports Research

The Center for Field Research invites proposals for 1996 field grants awarded by its affiliate Earthwatch. Earthwatch is an international nonprofit organization dedicated to research and public education in the sciences and humanities. In 1995, Earthwatch is supporting seven park research and resource inventory projects with approximately $83,000 and 185 volunteers. All funds awarded by Earthwatch are derived from the contributions of Earthwatch members who pay for the opportunity to join scientists in the field and assist with data collection and other research tasks. Inventory and monitoring projects sponsored by Earthwatch are eligible for additional funding through the NPS Expedition Into America program.

Preliminary proposals for Earthwatch field grants should be submitted at least 13 months in advance of anticipated field dates. Full proposals are invited upon review of preliminary proposals. For more information about the field grants contact Dee Robbins, Life Sciences Program Director, The Center for Field Research, 680 Mt. Auburn Street, Watertown, MA 02172. Phone: (617) 926-8200 or fax: (617) 926-8532 or e-mail: "drobbins@earthwatch.org". For more information about Expedition Into America grants contact Lissa Fox, National Park Service, P.O. Box 37127, Mailstop 490, Washington DC 20013-7127. Phone (202) 343-3022.

Bat Conservation Agreement Signed

The National Park Service recently entered into a memorandum of understanding with Bat Conservation International, a private, nonprofit organization dedicated to sustaining remaining bat populations around the world. The agreement will help both organizations to become more effective in protecting bats and their habitat and educating the public about the environmental contribution made by these often misunderstood mammals.

Both organizations plan to develop joint projects, such as conducting inventories and habitat assessments, and producing educational publications and programs. Presently, Bat Conservation International heads a program to assist land managers in developing bat population assessment and habitat management techniques for caves and abandoned mines. Both organizations are working together to protect these habitats, which are often critical to bats. National Park Service staff will also be able to participate in nationally recognized bat conservation and habitat management workshops put on by the conservation organization in an effort to raise awareness about these animals.

Software Improved for Annual Resource Management Updates

Parks prepared over 14,000 project statements in the 1995 annual resource management plan (RMP) update. The new RMP software (version 2.12) allows park staff to track project funding beyond the previous limitation of 4 years, automatically generate annual accomplishment reports for funded projects, and archive completed project information including the problem statement and description of actions. The archive function should substantially increase the ability of the RMP system to serve as a parkbased data repository of resource management goals, priorities, and accomplishments.

The RMP software also enables park staff to prepare and track project statement information in a consistent format. Administrative offices and program managers use the information provided in the annual updates to ascertain and justify resource management budget requests and allocations. Without the automated RMP annual updates, parks would receive frequent requests for data surveys, project justifications, and status reports.

Another benefit of the RMP update process is the ease with which the project database can be searched. For example, we recently searched the 1995 servicewide RMP data to identify and fund high priority projects meeting the specific criteria of a corporate sponsor providing a $450,000 donation. The rapid identification of specific resource management project types and ability to justify funding requirements with problem statements and action descriptions is only possible through the data and software capabilities provided in the RMP system.

In March, parks gathered information for 2,155 research projects for the 1994 Investigators Annual Report (IAR) update. The IAR system was originally designed to provide park staff with an automated tool for organizing, storing, and tracking annual activities and accomplishments performed by non-NPS researchers. This information includes project objectives, findings, and bibliographic references, which can supplement the long-term history of science within parks.

Computer Specialist Tim Goddard of the NPS Natural Resource Service Center in Fort Collins, Colorado, is redesigning the IAR software so that park staff can more effectively store multiple year report data. This will enhance the functionality of the IAR system to better serve park needs as a repository of research project reports collected over many years. Additional modifications should also enable parks to automate the process of generating and tracking research permits.

Both the resource management plan and investigators annual report systems are useful tools for parks and administrators to track progress toward research and resource management goals. Goddard

Continued on page 13, column 3

Editor's Note: The following contribution from Great Smoky Mountains National Park breaks our pattern of reporting just the national MAB news in this column. Our long-term strategy with MAB Notes is to balance reporting the activities of the national MAB committee with park experiences, like this one, related to the MAB program. Accordingly, parks are invited to contribute to this department.

The Southern Appalachian Mountains, in the souteastern United States, is one of the many biosphere reserves designated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). As of January 1994, UNESCO had designated 324 biosphere reserves in 82 countries, with 47 occurring in the United States; the majority (30) of United States Man and the Biosphere Program (USMAB) areas are also national park system areas. Although the Southern Appalachian Biosphere Reserve (SAMAB) includes Great Smoky Mountains National Park, it differs from most USMAB areas, as it comprises protected units scattered over 50,000 square miles in Tennessee, Virginia, North and South Carolina, Alabama, and Georgia.

Created "… to foster harmonious relationships between humans and their environment through programs and projects that integrate the social, physical, and biological sciences to address … problems," SAMAB presents a complex management situation due to its size. To manage the biosphere reserve cooperatively, six federal agencies with southeastern United States land management responsibilities signed interagency and cooperative agreements in 1988 to form the Southern Appalachian Man and the Biosphere Cooperative. The charter members were the U.S. Forest Service, National Park Service, Tennessee Valley Authority (TVA), U.S. Fish and Wildlife Service, Oak Ridge National Laboratory (Department of Energy), and the Economic Development Administration (EDA).

The original partnership has grown steadily and now includes the Environmental Protection Agency, U.S. Geological Survey, U.S. Army Corps of Engineers, National Biological Service, Appalachian Regional Commission, and the states of North Carolina, Georgia, and Tennessee. Other federal agencies and states are expected to join in future years. Private sector involvement and support is achieved through the SAMAB Foundation. First chartered in 1990, the foundation was subsequently granted nonprofit status. In 1990, USMAB and UNESCO recognized SAMAB as the first regional demonstration model for other biosphere reserves across the country.

The management cooperative is governed by an executive committee, comprised of one representative from each federal and state member agency and the chairman of the SAMAB Foundation board of directors. Six committees made up of area specialists from the member agencies do most of the work, enlisting the aid of other specialists from member agencies. These committees are: environmental research and monitoring, sustainable development, environmental education, natural resource management, public affairs, and cultural and historic resources.

Funding for SAMAB comes from the member agencies who, by pooling funds and other resources, sustain the cooperative. The Tennessee Valley Authority and Great Smoky Mountains National Park have been especially supportive. The executive director is a TVA employee assigned fulltime to this function, and the agency has also provided administrative, legal, and financial assistance to the cooperative. The park provides office space and related services to the executive director.

Management Units

At the heart of the regional programs are biosphere reserve management units, which are typically geographic areas that are shielded from unbridled development. These units seek cooperative regional programs and share any lessons learned with other management units. Although it started with just two such management units, SAMAB now has five, and expects to add three more in the near future. The current units are the Great Smoky Mountains National Park; the Department of Energy Oak Ridge National Environmental Research Park; the Coweeta Hydrologic Laboratory of the U.S. Forest Service; Mt. Mitchell State Park, which is operated by the State of North Carolina; and Grandfather Mountain, a privately operated environmental park also in North Carolina. Each is recognized by UNESCO as a unit of the larger SAMAB that is part of the international biosphere reserve network.

While the SAMAB research, education, and demonstration ecosystem management programs center on the management units, they extend outward in a zone of cooperation that embraces the entire biosphere reserve. The zone of cooperation was not chosen arbitrarily; rather, it was identified because it shares common geological, biological, and cultural resources. It also lies within the administrative boundaries of the southeastern offices of the various federal agencies in the SAMAB cooperative.

Issues

The SAMAB cooperative has proven its usefulness in exploring solutions to many environmental issues and, although several have related directly to Great Smoky Mountains National Park, three are especially noteworthy:

(1) When the U.S. Fish and Wildlife Service launched its program to restore the red wolf in the Great Smoky Mountains National Park, they expected public opposition. Through its public affairs and environmental education committees and in cooperation with the NBC Knoxville, Tennessee, affiliate, WBIR, SAMAB developed a campaign that clarified the true nature of the red wolf project and contributed significantly to diffusing the sensitive issue. Posters, teachers guides, classroom packages, brochures, and a TV documentary were all developed and distributed in this initiative.

(2) Concerned about runaway tourist development in park gateway communities, the relatively small, undeveloped, park-abutting town of Pittman Center asked SAMAB to help it plan for future growth. Together with the University of Tennessee and the Economic Development Administration, SAMAB helped Pittman Center develop a strategic plan. This led to additional zoning ordinances in the town, which were implemented after extensive public involvement. A community development plan based upon the Pittman Center model has been prepared and widely distributed. Another Smokies gateway community, Townsend, is using this plan as are communities in Canada and Asia.

(3) Very serious air quality problems led SAMAB to convene a forum in March 1992 to give concerned regional parties an opportunity to discuss conflicting viewpoints on the controversial issue. For the first time, about 125 people from federal and state agencies, industry, universities, and citizen groups participated in the sometimes emotional discussions. A direct result of the conference was the formation of the Southern Appalachian Mountain Initiative, a regional partnership of the state air quality regulatory agencies for addressing southern Appalachian air quality issues. The Environmental Protection Agency has provided more than $600,000 in support of the program, whose mission is to "… remedy … effects from … air pollution on the air quality related values … of the southern Appalachians…." Many of the SAMAB member agencies also participate in this new air quality partnership, which will adopt requirements in addition to those of the Clean Air Act in May 1997.

Currently SAMAB is involved in conducting an assessment of environmental conditions in the southern Appalachian region. The assessment is a joint effort of the various federal and state SAMAB cooperative members. The assessment is scheduled for completion at the end of calendar year 1995 and the results are intended for use in making environmental management decisions.

In view of current federal downsizing and even agency deauthorization discussions, SAMAB cooperative members are concerned about the future willingness of agency managers to continue committing funds and staff to SAMAB. Will managers want to "circle the wagons" and focus exclusively on "their own" missions? As a member agency, we hope not. Member agency personnel constitute a valuable pool of knowledge and experience; SAMAB uses these resources as a conduit for sharing, not only with other cooperative members, but also with public and private land managers throughout the region. Let us hope future managers will see the logic in working toward more cooperation, not less.

Readers can contact Joe Abrell, Chief of Resource Management, and Bob Miller, Management Assistant, at Great Smoky Mountains National Park for further information on SAMAB. (615) 436-1207.

The relative abundance of coyotes and gray wolves has changed in disturbed habitats of North America. Hybridization has occurred between these species, where coyote populations have increased in abundance and where gray wolf populations have declined. Genetic divergence among coyotes and gray and red wolf populations in North America was the subject of a recent publication by Michael S. Roy et al. (Molecular Biological Evolution **11(4)**: 553-570, 1994). Researchers selected microsatellite loci to quantify genetic differentiation and hybridization within and between species. These loci exhibit a much higher rate of mutation than that of nuclear loci and consequently are more sensitive to detecting recent genetic divergence. Coyotes show no evidence of genetic subdivision, which is a result of high rates of genetic exchange throughout their recent range expansion. Hybridization between coyotes and gray wolf populations of Minnesota and southern Quebec has significantly affected allele frequencies (alternative gene forms at given locus) of these wolf populations. The analyses also support the hypothesis that the intermediate phenotype of the red wolf is derived from historic hybridization between coyotes and gray wolves. More recently, extensive hybridization occurring between red wolves and coyotes has caused red wolves to become even more genetically similar to coyotes. The authors concluded that continued habitat changes favoring range expansion of coyotes will threaten the genetic integrity of gray wolf populations.

• • •

Biodiversity is most often defined in terms of species richness. A recent publication by R. Gresswell, W. Liss, and G. Larson (Canadian Journal of Fisheries and Aquatic Sciences, 1994, number 51, Supplement 1:298-309) focuses on the importance of recognizing intraspecific variability for maintaining biodiversity at the species level. The authors examined life history organization of Yellowstone cutthroat trout. They also examined in detail subspecies and metapopulation hierarchial levels of differentiation. Variation in life history and morphometric characteristics of Yellowstone cutthroat trout were documented between populations in different lakes and within subpopulations in the same lake. Differences found in life history organizations included reproductive isolation and homing, pattern of spawning migration, initiation and duration of spawning, juvenile emigration and residence, abundance of spawners, age and size of spawners, and male:female ratio and fecundity. The authors concluded that loss of diversity at any hierarchial level jeopardizes the ability of the species to adapt to changing environments and increases the risk of extinction.

Editor's Note: *With the recent NPS reorganization and adoption of field areas, system support offices, and clusters in lieu of the traditional regional paradigm, we reorganize regional highlights under the name of simply "Highlights." Newsworthy science and resource management tidbits are presented here under the names of park clusters and their system support offices (16 in all).*

ROCKY MOUNTAIN

In July 1994, anglers caught nonnative lake trout (*Salvelinus namaycush*) in Yellowstone Lake, which represents 80% of the remaining lacustrine range for the world population of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*). Mitigating the effects of the much larger and predatory lake trout on the native cutthroat trout population is the third priority natural resource management issue in the park resource management plan (March 1995). In response to this potential ecological crisis, Yellowstone National Park held a workshop February 15-17, 1995, with fisheries biologists and managers familiar with salmonids. The majority of participants concluded that "chances are high that [lake trout] cannot be eliminated and will seriously reduce the cutthroat population. . ." The group also concluded that lake trout abundance can be limited through an aggressive control program, which would require a long-term commitment of expert staff and dedication of supplies and equipment.

The park has outlined a program with the objective to maintain a robust native cutthroat trout population in the Yellowstone Lake-Yellowstone River ecosystem by minimizing the effects of introduced lake trout. A high degree of uncertainty remains as to the extent and status of the lake trout population in Yellowstone Lake. The most immediate needs are (1) to increase the information base about both lake trout and cutthroat trout populations, and (2) to begin suppressing the lake trout population. The experts recommend that a well-designed mechanical removal program that minimizes unintended cutthroat trout loss is most likely to provide both information on and control of lake trout. The park hopes to begin an experimental effort to gillnet lake trout this summer. This effort will allow us to test methods temporarily and geographically prior to developing a long-range action plan to control nonnative lake trout in Yellowstone Lake.

• • •

Visitors are finding something new underfoot in the Old Faithful area of Yellowstone National Park. Last year, the park replaced 30 feet of traditional boardwalk with lumber made from recycled plastic with more to come. In all, 1,000 linear feet of boardwalk in the Upper Geyser Basin will be replaced with the recycled plastic lumber.

Eaglebrook Products, Inc., manufactures the *lumber,* call-ed Durawood. Made of recycled plastic from thick, plastic bottles like milk containers, the lumber is 90% recycled post–consumer plastic.

The lumber used in Yellowstone boardwalks is the color of weathered wood, although many different colors are available. In testing, the color changes very little over time. Durawood will not rot, warp, splinter, or crack from exposure and requires very little maintenance. It can be cut and drilled like wood, and it can be fastened with ordinary screws or nails. However, it is not as rigid as wood and cannot be used in the structural supports of boardwalks. Beneath the uniformly colored walkway is the same wooden structure that holds up the rest of the park boardwalks.

Nancy Ward, Supervisory Environmental Engineer, says there has been no trouble with the new boardwalk, although she points out that using Durawood in a geyser basin boardwalk is experimental. The company is confident of their product, but they acknowledge that it has never been used this way; they have never tested it for buffalo walking on it, for example. She says it costs more than wood, but may be cost effective if it lasts longer than wood.

Lever Brothers Company donated the Durawood to the National Park Foundation to promote creative uses for recycled materials. Nine other national parks will also receive recycled materials, including the Washington, D.C., mall, Martin Luther King, Jr., National Historic Site, Georgia, and Mount Rainier National Park, Washington. Yellowstone is the first to install the donated recycled materials.

PACIFIC-GREAT BASINS

Death Valley National Park hosted the first western area wilderness stewardship session for line officers last May. Planned and instructed by National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service staff, this session focused attention on wilderness philosophy, operations constraints inherent in the 1964 Wilderness Act, and resource and visitor management issues in light of the passage of the California Desert Protection Act. A second session will be held in Arizona during October.

• • •

Great Basin National Park installed a remote weather station on the summit of Bald Mountain last September making it the highest in Nevada and one of the highest in North America. At 11,562 feet above sea level, the new weather station provides data for resource management and research activities and also enhances the safety of park visitors.

The weather station transmits data by radio to a base station at park headquarters. Visitor center staff can query the station at any time in order to inform hikers and climbers of current high elevation weather conditions. This information is especially useful to those who plan to climb 13,063 foot Wheeler Peak, which is located just south of Bald Mountain and is the highest peak in Great Basin National Park.

Currently, the station is programmed to record the hourly average wind speed and direction, air temperature, relative humidity, solar radiation, and maximum wind gust and its direction. To make these measurements, the station uses an anemometer, wind vane, air temperature and relative humidity sensor, and a solar absorption pyranometer. A datalogger controls the sensors and is housed in a small structure that also shelters a

Humboldt National Forest radio repeater. Solar panels on the roof of the shelter recharge the batteries that power the station. The meteorological sensors are mounted on a 5-meter-tall mast, attached to the shelter.

This project was three years in the planning and took several months of effort during 1994 to complete. All park divisions and other agencies, including the U.S. Forest Service, the Office of the State Climatologist, and the Nevada Air National Guard, helped to establish the high elevation weather station.

Less than two weeks after being installed, the new weather station recorded a 146 mph southerly wind gust that occurred during prefrontal conditions. This set a state record for October, and is one of the highest gusts recorded for any month. That same day, the station indicated an average wind speed for one hour to be 86 mph!

CHESAPEAKE

Morristown National Historical Park recently received a $10,000 grant from the National Park Foundation through the NPS Expedition Into America Program. The park will use the money to conduct the first herbaceous plant survey within Morristown, as it has neither the staff nor funding to conduct this inventory by its own means. Plant population ecology professor Steven Handel of Rutgers University is conducting the survey based on a sampling design of his own. Dr. Handel's sampling method ensures that all different habitats and forest types are surveyed when flowers are in bloom, facilitating plant identification.

With volunteer help from the Garden Club of America, Dr. Handel and his staff conducted the first survey in late April. While Dr. Handel's team ensured data quality, the volunteers enthusiastically assisted in identifying many spring ephemerals and participated in other hands-on fieldwork.

The information acquired from the inventory will assist the park in determining whether the number and variety of herbaceous plants has declined as a result of white-tailed deer browsing and exotic species spread. Also, volunteers will gain a greater understanding of park natural resource management issues through their close involvement with the program.

The interest, enthusiasm, and knowledge demonstrated by Garden Club of America members proves that small parks located in densely populated areas can attract nearby volunteers to conduct biological inventories. We are hoping that this project will develop a committed pool of long-term volunteers, who will continue to survey and monitor plants in the park.

COLUMBIA CASCADES

Richard Aroksaar, Automation Librarian for the Columbia-Cascades System Support Office Library, is working with a NPS Inventory and Monitoring Program and U.S. Geological Survey (USGS) team to determine the existence, location, scope, and quality of park-related geological maps. The team search-es GEO-REF, a commercial database, and Geoindex, a USGS database, for records concerning parks and downloads them. Aroksaar has developed a program to convert these downloaded records into Pro-Cite, the NPS bibliographic software standard, for use by parks. For more information, contact Aroksaar at (206) 220-4252.

• • •

The system support office recently obtained a copy of Slicer, a 3D viewing software package. This software allows the user to display three dimensional data with shaded renderings, vary the opacity of different areas, rotate volumes, and create cutaway views at any angle. The software might be useful for modeling caves and subsurface hydrology or geology, and may have specific applications at Oregon Caves, Hagerman Fossil Beds, Crater Lake, and Mount Rainier, among others.

• • •

The National Park Service proposed revising the current regulation concerning admission to Oregon Caves National Monument found in 36 *Code of Federal Regulations* 7.49 that prohibits access to children under the age of six years from entering. The proposal would allow children to enter the caves regardless of age. The current age restriction is inequitable and is not necessary to provide safe, high-quality interpretive tours in the caves.

• • •

Wasp and yellowjacket season is upon us in many of our parks. Often a nuisance, bees and wasps commonly congregate in visitor use areas as a result of food residue in trash receptacles. Chemical-free mitigation of hymenopterids can be achieved by regular steam cleaning of trash cans to remove dried syrups and food debris, which provide a reliable food source for the animals. Pesticide application is counterproductive and not justifiable in this circumstance, because it does not remove any food residue.

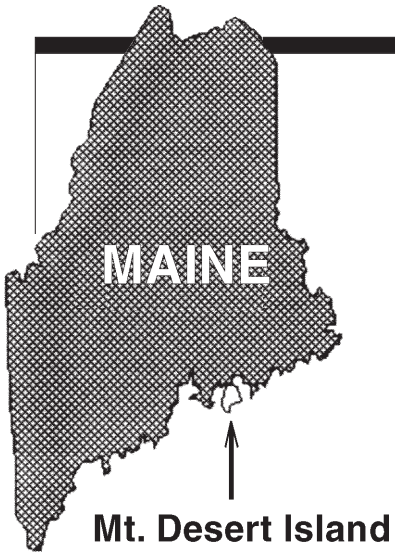
While hymenopterids are protected in parks, as are all native animals, pesticides are justified in some situations. For example, when wasps inhabit an inaccessible wall void or nest under a restroom eaves they create a public health risk that may warrant use of a pesticide. If this is the case, look for a product with pyrethrin or allethrin as the main ingredient. This provides the least toxic and most specific quick knockdown results. Remember to obtain approval prior to purchasing any pesticide and do not overstock on products; the Environmental Protection Agency may change pesticide use status, leaving parks to dispose of hazardous waste.

COLORADO PLATEAU

Last November, the National Park Service reached a milestone in studying carrying capacity limits on park visitors through a process applied at Arches National Park, Utah. Known as visitor experience and resource protection (VERP), the study process determines natural resource and social indicators and standards for the protection of park resources and maintenance of high quality visitor experiences.

Concern over resource and visitor experience degradation associated with the growing popularity of hikes to Delicate Arch, Double O Arch, and automobile travel on 4-wheel

Continued on page 13, column 3



Spruce Grouse on Mt. Desert Island

Fragmented habitat complicates species management

By Allan F. O'Connell, Jr., Frederick A. Servello, and Scott D. Whitcomb

National Park Service managers need reliable scientific data to protect park resources. Yet information needs often extend beyond NPS boundaries and include other public and private lands. Increasingly fragmented landscapes and a scarcity of current inventory and monitoring data increase the difficulty of protecting and managing park natural resources. These circumstances are particularly true in the northeastern United States where park areas are typically small and often within an urban or suburban setting and landscapes are characterized by diverse landownership. Even Acadia National Park (the only national park in the northeastern United States) has a highly fragmented boundary. Located mostly on Mount Desert Island (see locator map), the park can be affected by adjacent land use practices, because 56% of Mount Desert Island does not lie within the park boundaries.

Spruce grouse *(Dendrapagus canadensis),* a common gallinaceous bird of the North American boreal forest, reach their southeastern range limit on Mount Desert Island (fig. 1). Once believed common on the island, this species was thought to have been extirpated in the late 1800s due to land use changes and human impacts. Throughout the 1980s, however, park visitors filed approximately a dozen unverified reports of the bird.

In that Acadia National Park comprises less than half of Mount Desert Island's area, potential spruce grouse habitat reaches beyond park boundaries. As a result, park spruce grouse demographics are likely influenced by the grouse population outside the park. Uncertainty over the status of the population resulted in a park request for funds to document the bird and gather current local ecological information. In this study, we attempted first to document the existence of spruce grouse on Mount Desert Island; later we estimated population size, distribution, and productivity, and evaluated habitat occupancy and dispersal.

Methods

Spruce grouse are conifer specialists and inhabit different conifer types depending on locality and latitude. Researchers in the Adirondacks of northern New York (also along the southeastern edge of spruce grouse range) found that this grouse is restricted to patches of lowland conifer habitat (black spruce and tamarack *[Picea mariana* and *Larix laricina,* respectively]) (Fritz 1979). We delineated all black spruce-tamarack habitat on Mount Desert Island using aerial photographs and vegetation maps. Although mature spruce-fir upland is considered marginal habitat for spruce grouse, we also selected 22 spruce-fir sites in order to fully evaluate local occupancy of all conifer habitat.

We conducted *call-back surveys* (listened for vocal responses to broadcast tape recorded grouse calls) along transects to locate grouse and estimate population size. We captured individuals with telescoping noose poles, marked each with colored, numbered leg bands, and outfitted females and juveniles with radio transmitters (fig. 2). We grouped potential habitat patches into three categories: large (> 26 ha or 64.2 acres), medium (10-26 ha or 24.7-64.2 acres), and small (4-10 ha or 9.9-24.7 acres). We used a minimum of 4 ha (9.9 acres) to evaluate patch occupancy based on known spruce grouse home range requirements. Finally, we determined spatial characteristics of patch occupancy by using digital data produced from vegetation maps and a personal computer version of Arc-Info software.

Results and discussion

Minimum breeding population estimates for spruce grouse on the island were 72 in 1992 and 56 in 1993. During our

Figure 1. Believed extirpated on the island since the late 1800s, the spruce grouse has been reported occasionally within Acadia National Park since 1980. The study estimated a minimum 1993 breeding population of 56 of the forest dwelling individuals living both within the national park and on nearby private lands.

Figure 2. The wildlife study called for marking birds with colored, numbered leg bands and necklace-mounted radio transmitters for subsequent identification. Study grouse preferred larger habitat patches and tended to cluster in those patches that were closest to one another. The study also showed that compared to other eastern U.S. spruce grouse populations reproductive success is low in the Mount Desert Island population.

study, predators killed seven of 18 radio-tagged female grouse (39%), three during egg-laying, two during incubation, and two with broods. As of August 28, the beginning of the late brood rearing period, only five females (26%) had successfully raised broods. Initial brood size (1-3 days after the hatch) ranged from one to six birds (x=3.4). Most chick mortality (41%) occurred within the first 9 days posthatch, including four entire broods, and only 11 of 37 (30%) chicks survived until August 28. Grouse productivity (number of chicks produced divided by the number of females) during the first 2 years of this study was low compared to other populations in eastern North America.

The proportion of patches occupied by spruce grouse was related to patch size and distance between patches. Occupied patch size varied greatly (7.7-269 ha or 19.0-664.4 acres). During this study, grouse occupied both large patches, five of six medium-sized patches, and one of 10 small patches, with a significant difference between small- and medium-sized patch occupancy. Unoccupied patches were farther from the nearest occupied patch (x=2.5 km or 1.6 mi) than were other occupied patches (x=1.2 km 0.7 mi), suggesting that patch size and interpatch distance are important in determining patch occupancy. We only observed two spruce grouse on the 22 spruce-fir sites surveyed, and they were at a distance of <500 m away from suitable lowland sites.

Home ranges for broods ranged from 12.8-26.5 ha (31.6-65.5 acres). Nearly all juveniles dispersed from natal habitat patches and exhibited longer dispersal distances on Mount Desert Island than they did in more contiguous habitats. This may be due to the extensive amount of marginal or unsuitable habitat surrounding patches of suitable lowland-conifer. Six of nine juveniles traveled 8 km (5 mi), and only two of nine located other suitable lowland conifer patches. The remaining seven will probably have to move again in the spring to locate breeding habitat. Juveniles moved through deciduous or mixed deciduous-conifer habitats indicating that these cover types were not the barriers to dispersal that some had thought.

Mount Desert Island spruce grouse resemble a metapopulation, because of their association with patches of black spruce-tamarack scattered across the island. Although we found birds in eight different patches, they were grouped in two clusters, which suggests the importance of interpatch movement. Spruce grouse are listed as a threatened species in New York where small populations are confined to fragmented patches of habitat. Decline of softwoods (by logging or development) and an unknown number killed by hunters each year (because spruce grouse are exceptionally approachable by humans and resemble ruffed grouse) may reduce populations especially in fragmented habitats (Bouta and Chambers 1990). In view of this, and because several Mount Desert Island black spruce-tamarack patches are privately owned, it may be appropriate to incorporate protection of suitable spruce grouse habitat into the Acadia National Park Land Protection Plan. Long-term protection of critical spruce grouse habitat through the purchase or donation of conservation easements also appears appropriate. National Park Service land protection plans should consider future implications for wildlife species like spruce grouse, and parks should note the connection between park resources and adjacent private lands.

References

Bouta, R.P., and R.E. Chambers. 1990. Status of threatened spruce grouse populations in New York: A historical perspective. Pages 82-91 *in* R.S. Mitchell, C.J. Sheviak, and D.J. Leopold, editors. Ecosystem Management: Rare species and significant habitats. Proceedings of the 15th Annual Natural Areas Conference, Bulletin 471. New York State Museum. Albany, New York.

Fritz, R.S. 1979. Consequences of insular population structure: Distribution and extinction of spruce grouse populations. Oecologia **42**:57-65.

Robinson, W.L. 1980. Fool hen: The spruce grouse on the Yellow Dog Plains. University of Wisconsin Press. Madison. 221 pp.

O'Connell is a research Wildlife Biologist with the National Biological Service and serves as the Leader of the CPSU at the University of Maine; (207) 581-2873. Servello is an Associate Professor in the Department of Wildlife Ecology at the University of Maine; (207) 581-2872. Whitcomb is presently a Wildlife Biologist with the Virginia Department of Game and Inland Fisheries. He conducted this spruce grouse study for his M.S. degree at the University of Maine.

Profile of the NBS Midcontinent Ecological Science Center, Fort Collins, Colorado

By the editor

Editor's note: *This is the first of several science center profiles to be published in* Park Science *during the next couple of years. In preparation for the article, the editor visited the center during its second annual meeting with client agencies in February. Also fundamental was the center's prospectus of expertise and services.*

The Midcontinent Ecological Science Center (MESC), located in Fort Collins, Colorado, conducts ecological research and develops technologies to improve the understanding and management of biological systems (species, populations, communities, landscapes, and ecosystems) of the western interior United States. The center also develops and implements inventory and monitoring programs for the accurate assessment of biological status and trends, and provides information, technical services, and training related to the management of biological resources. Like most science centers, MESC generally concentrates on regional ecological research, although there is no requirement to work exclusively within the Midcontinent Region.

One of 15 NBS science centers, MESC is the second largest with 240 employees (42 from NPS) working in 16 locations. At $15 million, the MESC budget is the largest among the science centers. To achieve its mission, the center is divided into 11 sections that are either organized by discipline or geography. The center also maintains 15 field stations that can conduct park research. These stations came to the NBS from various agencies, and several in the NBS Midcontinent Region are located within parks. Additionally, 13 regional cooperative research units (former CPSUs), although administered separately from science centers, are associated with universities throughout the region and conduct research that is often very applicable to parks.

Dr. Rey Stendell, a zoologist and research administrator, heads the science center with assistance from Dr. Tom O'Shea, a mammalogist and conservation biologist. Dr. Cliff Martinka has recently transferred from Glacier National Park to become the Mountain Ecosystems Section Leader. Along with O'Shea (acting in the role of Southwestern Ecosystems Sections Leader), they facilitate research and technical assistance needs among southwestern and northern Rocky Mountain national parks and find funding to accomplish the work.

Generally speaking, long-term (strategic) research priorities are set through an evolving process at the national level that places high value on the natural resource planning that we already do quite well. These projects trickle down to the appropriate regions, science centers, cooperative units, and field stations for implementation. A major area of unrest presently among client agencies is how the NBS addresses more immediate, unplanned requests for tactical research and technical assistance. The recently appointed NBS regional directors, including Midcontinent's Dave Garrett, acknowledge that their agency is not meeting client needs in this area and plan to address this issue as a high priority in the near future.

Figure 1. NBS researcher Susan Skagen of the MESC Vertebrate Ecology Section prepares to band a shorebird in her study on migration ecology. She hopes to determine species reliance on river corridors and desert oases as neotropical migrant stopover locations.

The work of the center is carried out under three major NBS programmatic areas: research, inventory and monitoring, and information and technology services. The *research* area of MESC (see figure 1) strives to improve the understanding and management of ecosystems, landscapes, communities, populations, and species. Ecosystem research is aimed at understanding the structure and function of montane, prairie, and arid lands and associated aquatic habitats while taking into consideration human impacts and global change on these systems. Current research projects that might have utility in parks include impacts of fire and revegetation in selected NPS areas, evaluating, restoring, and enhancing river corridor ecosystems, and restoring and creating wetland and riparian ecosystems.

Within this broad research function, the center also emphasizes *population ecology*. This area focuses on demography, population genetics, and the management and biology of small populations and metapopulations in relation to habitat change and land use patterns. A sample of ongoing investigations of likely interest to parks includes population genetics of the black-footed ferret, estimating and maintaining population sizes of endangered fish and amphibians, and developing census techniques and population models for other species of concern.

Species biology research determines the life history, systematics, and habitat requirements of selected species. The National Biological Service emphasizes endangered, declining, and nongame species and those species that may become candidates for listing. Ongoing investigations involve the grizzly bear, desert tortoise, bats, mountain plover, and other species of concern in NPS areas.

The *inventory and monitoring* activities of MESC track the status and trends of biological resources. The center carries out these activities at the national level as needed by providing expertise, developing technologies with wide applications, and developing spatial and tabular databases to support inventory and monitoring activities. The National Biological Service is conducting the following activities that may be of help to parks: determining the vertebrate faunas and faunal histories of federal lands including national park areas and managing herbaria and vertebrate repository collections at strategic locations within the region.

A fundamental intent of the National Biological Service is to make available information on biological resources to Department of the Interior managers (and the public, states, etc.), and MESC supports this objective through its *information and technology services*. The center provides information, technical services, and training related to the management of biological resources. They also provide expertise on a national scale for the development of new technologies and models critical to the management of these resources, and training in the use of these tools. Their strengths include the ability to develop habitat models and provide technical assistance with social, economic, and institutional analyses. In this area the National Biological Service can develop species- and community-level habitat suitability models for habitat management planning, develop GIS to aid analysis of endangered species critical habitat, evaluate social perceptions of natural resource management alternatives, analyze economic impacts of endangered species critical habitat decisions, and develop computer technologies and expert systems for application to biological resource management.

Expertise and recent MESC projects

The formation of the National Biological Service and subsequent restructuring of all land management client agencies has led to a firm beginning in human resources consolidation and ecosystem management. As agencies shrink and are forced to rely more on each other for cooperation and the NBS for biological research and technical assistance, it makes sense economically and organizationally to begin to approach resource management from a more holistic point of view. A few of the projects and services that the scientists at MESC have been working on recently, in addition to those already mentioned, are also beginning to show this orientation toward ecosystem management, perhaps especially at this science center. Table 1 (on page 14) shares a list of MESC sections, leaders, expertise, and selected research activities that are relevant to NPS needs (but by no means complete).

Other common services or products of MESC include scientific design assistance, statistical analysis, GIS, publications, bibliographies, species status and trends reports, global positioning system equipment, training (environmental negotiations, etc.), symposia, book chapters, ecological computer modelling tools, and technical assistance.

Continued on page 14

News & Views continued

will continue refining software periodically to ensure that these systems evolve in order to meet the demands and expectations of NPS information users for planning and documentation. For further information, contact Goddard at (970) 225-3543.

Highlights continued

drive roads led the park and VERP developers to test the process at Arches last fall. The VERP process starts with designation of different management zones based upon different types and amounts of visitor use (e.g., permit-controlled backcountry hiking, unrestricted frontcountry hiking, etc.). Standards for social indicators vary according to the resource and visitor experience objectives of the different management zones.

At the core of the VERP program are the indicators and standards that seek to mitigate resource and visitor experience degradation. When exceeded, the indicators and standards trigger management actions that social conditions back within acceptable limits.

Specifically, the social standard for Delicate Arch requires management action if more than 30 hikers at one time are observed in 10% or more of the samples collected during the peak hours of the peak months of the visitor season. Likewise, visitors will encounter no more than three verhicles per hour or 10 widenings per mile (areas where vegetation and soils are disturbed by vehicles leaving the road) while travelling park 4-wheel drive roads. If these conditions are violated more than 10% of the sampling period, management must take action to bring conditions back within the acceptable limit.

Monitoring will be completed in 1996 and may indicate certain restrictions on some visitor activities in 1997. The VERP process also suggests that a parkwide carrying capacity may be necessary if visitation continues to grow.

Denver Service Center and park staff are currently writing the VERP implementation plan that will explain in detail the management zones, indicators and standards, and management actions that the park will take initially.

Table 1. Profile of MESC sections, leaders, and expertise.

Leader	Expertise	Recent or Ongoing NPS-relevant Study or Product
Social, Economic, and Institutional Analysis Section		
Lee Lamb; (970) 226-9256	Economics, environmental law, institutional analysis, land use policy, legislative process, policy analysis, political science, sociology, water law, and wildlife and habitat values.	Visitor values of Rocky Mountain National Park natural resources (published in Park Science 15(1):10 by Jonathan Taylor).
Southwestern Ecosystems Section		
Tom O'Shea (acting); (970) 226-9398; Field Stations at Los Alamos and Albuquerque, NM, Moab, UT, and Flagstaff, AZ	Arid & montane habitats; biodiversity; disturbance; endangered and declining species; fire ecology; habitat restoration; inventory and monitoring; landscape, plant, & soil ecology; taxonomy & systematics, & vertebrates.	Soil compaction impacts to desert lands (grazing, visitor trampling) and effects on biodiversity and plant recovery (Jane Belnap).
Mountain Ecosystems Section		
Cliff Martinka; (970) 226-9342; Field stations at West Glacier, MT, Yellowstone, WY, and Fort Collins, CO.	Animal behavior, aquatic systems, global change, landscape ecology, natural areas, plant ecology, threatened species, trend and analysis, and vertebrates of Glacier, Yellowstone, and Rocky Mountain National Parks.	Landscape scale gap analysis program to consolidate data for parks and forests in evaluating patterns of biodiversity (Leo Marnell).
Atmospheric and Watershed Ecosystems Programs Section		
Raymond Hermann; (970) 226-9342	Air pollution dispersion modeling, air quality, biodiversity, GIS, global change, inventory and monitoring, remote sensing, smoke management, water quality monitoring, and watershed science.	Atmospheric inputs and watershed outputs monitoring at Sequoia, Rocky Mountain, Olympic, and Isle Royale National Parks as a way to assess and model ecosystem dynamics (Robert Stottlemeyer).
Vertebrate Ecology Section		
Fritz Knopf; (970) 226-9325	Amphibians, biodiversity, birds, field biology, landscape ecology, mammals, and reptiles.	Restoration ecology of western rangelands using reintroduction of keystone species, such as beaver and prairie dogs (Bruce Baker).
Endangered Species Section		
John Oldemeyer; (970) 226-9491; Field stations at Bozeman, MT, Riverside and Palm Springs, CA, Las Vegas, NV, and Saint George, UT.	Animal behavior, arid habitats, botany, disturbance, endangered species, fire ecology, mammals, plant ecology, predator-prey relations, radiotelemetry, reptiles, threatened species, Great Plains, Mojave Desert, Rocky Mountains, Yellowstone National Park.	Fire effects on Yellowstone grizzly bears (Richard Knight).
Stream and Riparian Ecology Section		
Lee Ischinger; (970) 226-9331	Stream vegetation responses to changes in stream flow.	Contaminant impacts on western stream gravel bed aquatic habitats (Del Nimmo) and relationships between biotic indicators of ecosystem health and environmental variables (Terry Boyle).
River Systems Management Section		
Clair Stalnaker; (970) 226-9332	Ecotoxicological monitoring, geomorphology, habitat restoration, hydraulic and civil engineering, hydrology, impact assessment, invertebrate ecology, plant ecology, riparian and wetland ecology, sediment dynamics, stream ecology, systems modeling, and water quality.	Model development of in stream flow needs for multiple species in southeastern U.S. rivers (Ken Bovee) and multiagency Colorado River management model development using multiple criteria approach (Marshall Flug).
Landscape and Habitat Analysis Section		
Vacant; (970) 226-9305	Agricultural policy, bioenergenetics, birds, forest management, GIS, global change, habitat analysis and modeling, impact assessment, landscape ecology, remote sensing, riparian ecology, statistics, stream ecology, systems modeling, and wetland ecology.	Techniques development for predicting responses of fish and wildlife to changes in habitat and Unix-Internet database of contaminants on federal lands.

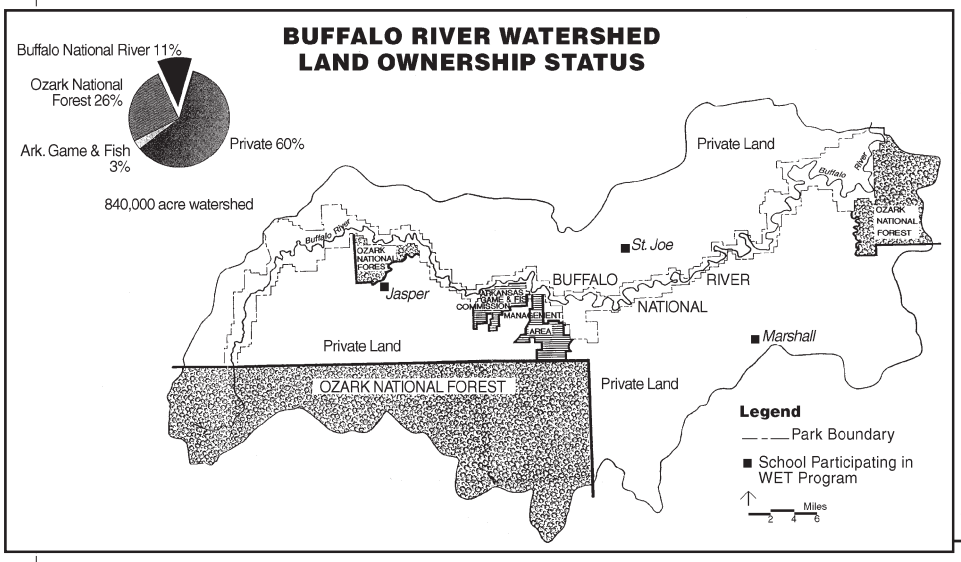


*Figure 1 (left). Buffalo River water quality depends greatly on land use practices outside park, forest, and game and fish management area boundaries, all areas within the Buffalo River watershed. The watershed figure shows land ownership and location of schools participating in the water education team (W*E*T) program.*

*Figure 2 (below). Standing ankle deep in Buffalo River tributary Calf Creek, W*E*T students get an introduction to physical monitoring techniques from U.S. Forest Service Hydrologist Jay Swafford. The two day training combined classroom and field activities to teach students what they need to know to participate in the water quality study program.*

Buffalo River Watershed Students Get *W*E*T*

By David N. Mott and Michael Naranjo

If ten glasses are filled with water from the Buffalo River, the contents of just one glass originates from inside the park! In other words, Buffalo National River manages only 11% of the total watershed, sharing ownership with Ozark National Forest (26%), Arkansas Game and Fish Commission (3%), and many private land owners (60% [fig. 1]).

Land use activities, such as logging, gravel mining, and agricultural operations, occur within the watershed. Although the quality of the water flowing into and in the Buffalo River is generally considered excellent, these practices adversely affect the river in some areas. With 60% of the watershed being managed privately, the future of the river may well be in the hands of our upstream neighbors.

One strategy for preserving the ecological health of the river and its tributaries is education. The National Park Service, U.S. Forest Service, National Park Foundation, Arkansas Department of Pollution Control and Ecology (ADPCE), and Arkansas Game and Fish Commission are joint sponsors of W*E*T (Water Education Team) a pilot interactive water resources education program involving the local schools of Jasper, Marshall, and Saint Joe (fig. 1). The program is long-term, emphasizing environmental values and an understanding of the ecological balance of streams. Organizers hope the students will pass along the education to their parents and others.

In order to participate, the schools attend a 2-day training workshop where instructors treat students and teachers as equals. Both are taught about water as a resource, the three components of water quality monitoring (chemical, physical, and biological), and the methodologies used for collecting, analyzing, and recording water samples. Experts and guests from various agencies and organizations participate in the sessions (fig. 2).

Participants choose stations to monitor along various tributaries according to accessibility and logistics. Equipped with field gear, meters, and lab equipment, the schools sample each station every month and conduct follow-up lab tests. In addition, the schools also receive computers, software, and modems for networking and data entry.

Buffalo National River, Ozark National Forest, and ADPCE work closely with the schools to troubleshoot problems, replenish supplies, and analyze samples for nutrients. The students use EPA-approved methods to measure pH, dissolved oxygen, conductivity, temperature, turbidity, fecal coliform bacteria, and identify macroinvertebrates. Program sponsors provide annual refresher training and quality control checks.

The program has been a real success so far. Students and teachers have maintained enthusiasm and remained motivated; some have even taken on special projects. One senior at Jasper High School demonstrated leadership and initiative by designing a sampling regime for additional sites on the Little Buffalo River. Her

Continued on page 17

Tiger beetle continued from front page

Figure 2. Once resident at Gateway National Recreation Area, the northeastern beach tiger beetle was extirpated as a result of military activity and heavy pedestrian traffic. Restoration activities to return the beetle to the beaches of Sandy Hook, New Jersey, began last October.

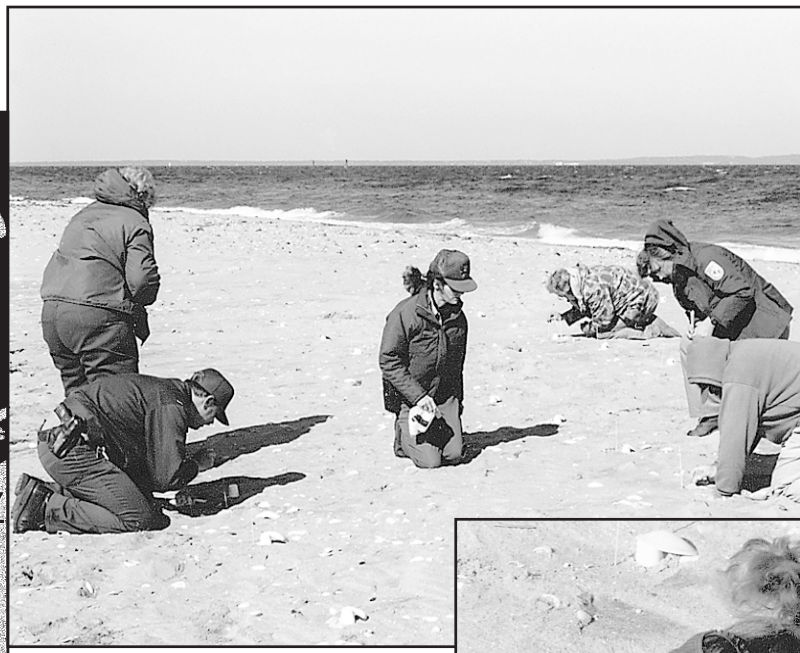


Figure 3 (inset, right). After overwintering twice, the half-inch long tiger beetle larva pupates in the bot-tom of a sand burrow that is up to 18 inches deep; the winged adult (fig. 1, page 1) emerges during the second summer.

Figure 5 (right). Restoration staff placed larvae beneath tiny paper cups until the young insects could dig their own protective burrows.

biological opinion concluded that during the restoration process the entire experimental population could be lost due to severe winter storms, accidental trampling, or the species' inability to adapt to relocation. We developed management recommendations and introduction procedures to minimize the possibility of an "incidental take" while establishing the new population.

On a warm night in early October the researchers collected approximately 800 tiger beetle larvae from the Chesapeake Bay population (fig. 3). The larvae, which live in vertical tunnels between the high tide and drift line (highest tide line where wood, vegetation, and other debris are deposited), were located by the reflection of their eyes in a flashlight beam. The larvae wait at the mouth of the burrow to catch small prey as they pass by. Project participants had to dig up each of the 800 larvae since they would drop back into their holes. This was no small task considering the larvae are only about a half-inch long and the burrow can be up to 18 inches deep. The researchers placed the beetle larvae in vials containing some sand and transferred the insects to the park along with 50 vials of laboratory-grown larvae.

Employees of the U.S. Fish and Wildlife Service field office in Pleasantville, New Jersey, volunteers, and park staff from all divisions helped to release the tiger beetle larvae on the park beach (fig. 4). We created eight 10 x 10 m plots and evenly spaced 100 larvae in each plot. As we released them from the vials, we covered the larvae with a small paper cup to protect them until they dug a vertical burrow (fig. 5). Over the following several weeks, the researchers returned to assess survival and to place tiny meal worms in the plots to supplement the larvae food supply.

The northeastern beach tiger beetle larvae pass through three developmental stages during a 2-year life cycle, overwintering twice as larvae, pupating at the bottom of their burrows, and emerging as winged adults during their third summer. Depending on the level of development and the survival rate of the introduced larvae, we hope to see some adult tiger beetles this summer and plan to update *Park Science* readers about our success in a subsequent issue. Beachgoers concerned over the possibility of more insects on the beach were relieved to learn that the tiger beetles rely heavily on greenhead and other biting flies as a primary food source.

Participating in this project gave us an opportunity to contribute to the conservation of a species threatened with extinction. Although some or perhaps all of the larvae may be lost during this attempt to establish a new population, the species will benefit overall because of increased public awareness, our improved knowledge of its habitat requirements, and improved restoration procedures.

Figure 4 (left). The restoration effort required collecting 800 larvae from the Virginia Chesapeake Bay and replacing them evenly in eight restoration plots on the New Jersey beach at Gateway. Staff hopefully await the return of the winged-adult beetle to Sandy Hook this summer.

Gateway beaches have always been a valuable resource. They may become even more valuable with the addition of the northeastern beach tiger beetle to the more remote sections of the park. This important step will bring us closer to recreating a truly natural beach ecosystem with a complete complement of native beach organisms.

Bruce Lane is a Supervisory Park Ranger in the Natural Resources Division at the Gateway National Recreation Area Sandy Hook Unit. His address is P.O. Box 530, Fort Hancock, NJ 07732; phone (908) 872-0115; fax (908) 872-7241. He can also be reached via NPS cc:Mail--"Bruce Lane NP-GATE".

project paper received state recognition and a $1,000 Future Farmers of America college scholarship.

The most important thing about this program is how the students feel about their efforts. The following quotes are taken from reaction papers written by students at the end of each year:

"W*E*T is completely different from what I expected. We do a lot more hands on and field work."

Jessie Baker

"I feel working with bugs is helping me decide what career I may want to pursue. When I first joined project W*E*T I would not touch any of the bugs and now I find myself falling in love with the cute little guys."

Nikki Dean

"I … acquired many new skills. I know how to classify and categorize organisms discovered in the water."

Juliena Arthur

"I learned a lot more than I expected, but the main thing I realized was that everything in the environment affects everything else."

Tara Dawn Cape

"I have … learned the usefulness and importance of teamwork. Everyone must give one hundred percent effort for the correct results."

Christy Grinder

"W*E*T taught me not only how to gather information, but … also … how to apply this information in real life."

Jennifer Richardson

"I have … learned how people are affecting the rivers …"

Laura Brinkmeyer

"I have learned to respect the water and not abuse the privilege of having such beautiful creeks around our community."

Reyna Martin

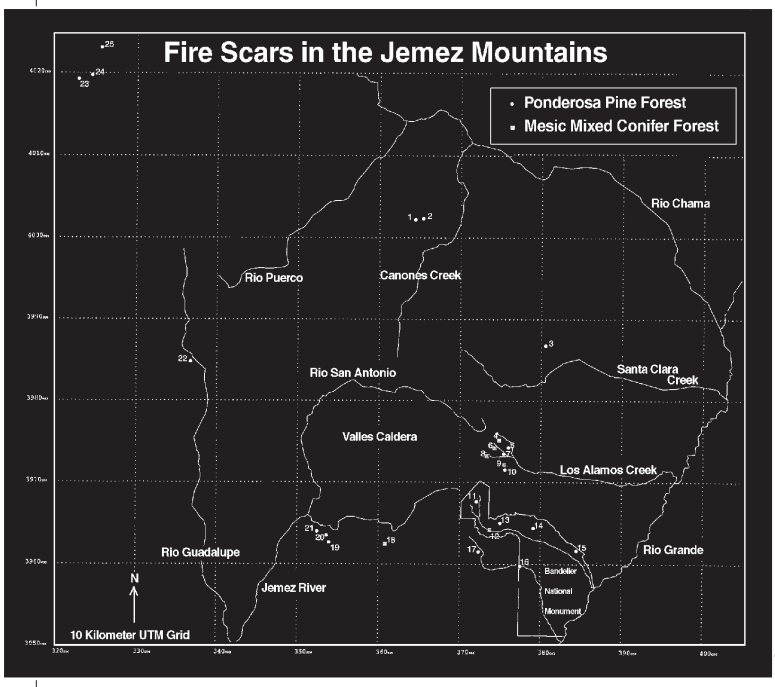
"I feel some responsibility for the polluting of our streams and land. I now try to be more careful with my actions because now I think of how they will affect our ecosystem."

Amanda Weaver

> "I feel some responsibility for … our streams and land. I now try to be more careful with my actions because I think of how they will affect our ecosystem."
>
> *Amanda Weaver*

As sponsors of W*E*T, we are extremely proud of our students and their teachers. We hope this learning program will contribute to the future success of these students and the long-term health of the Buffalo River and its tributaries.

David Mott is a Hydrologist and Michael Naranjo is a Biological Technician. Both are at Buffalo National River, Arkansas, and can be reached at (501) 741-5443, through NPS cc:Mail, or by e-mail: "david_mott@nps.gov" and "mike_naranjo@nps.gov", respectively.



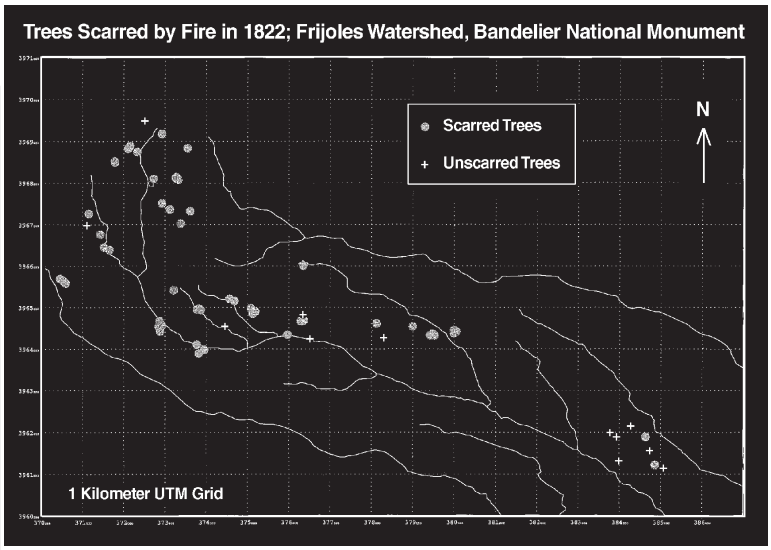


Figure 1 (left). Map of the location and general forest type of sites sampled for fire scars in the Jemez Mountains.

Figure 2 (above). Closeup of figure 1 sites 11-15 in Bandelier National Monument showing trees scarred by the 1822 Frijoles watershed fire.

Landscape-Scale Fire History Studies Support Fire Management Action at Bandelier

By Craig D. Allen, Ramzi Touchan, and Thomas W. Swetnam

Fire has long been recognized as a key process determining the ecological structure and function of many southwestern forests (Weaver 1951). Major changes in southwestern fire regimes over the past century (Swetnam 1990) are having correspondingly large ecological effects on southwestern forests, including those of Bandelier National Monument in the Jemez Mountains of northern New Mexico (Allen 1989). Ecologists and managers who seek to understand current landscapes require accurate information on the spatial and temporal variability in past fire regimes. This kind of information provides essential historical context that is needed to properly manage our modern park landscapes.

We are using dendrochronological (tree-ring) methods to reconstruct fire occurrence patterns over the last several hundred years across a variety of vegetation types, topographic situations, and geographic locations in the Jemez Mountains. The work is being accomplished through a cooperative effort between Bandelier National Monument, the National Biological Service, the Santa Fe National Forest, and the University of Arizona Laboratory of Tree-Ring Research (Touchan and Swetnam 1995). We have dated over 3,000 fire scars from 373 trees, snags, logs, and stumps at 25 sites located around an arc 50 km (31 mi) in diameter that circumscribes the Jemez Mountains (fig. 1). Elevations of sampled sites range between 2,000 and 3,000 m (6,562 and 9,843 ft, respectively). Each scar is dated to its precise year of formation, and in most cases even the season in which the fire occurred can be determined. We are using these data to develop fire histories at multiple spatial scales, building up from individual trees through clusters of trees to watersheds (fig. 2) and finally the entire mountain range.

Ponderosa pine *(Pinus ponderosa)* dominates most sample sites, although we also sampled mixed conifer forests that contained Douglas fir *(Pseudotsuga menziesii)*, white fir *(Abies concolor)*, and Engelmann spruce *(Picea engelmanni)*. We collected aspen *(Populus tremuloides)* cores from pure stands adjacent to some mixed conifer sites and crossdated them to determine postfire establishment dates. We also used dendroclimatic methods to reconstruct December-June precipitation back to 1653 A.D. using ring-width chronologies from nine sites in northern New Mexico.

The fire scar chronologies show that fire was frequent and widespread in the Jemez Mountains prior to the 1890s (fig. 3). For example, fire scar samples in Bandelier record 113 different fire years between 1480 and 1899 A.D. *Surface* fires burned in primarily grassy fuels from the lowest elevation mesa-top stands of ponderosa pine at 2,030 m (6,660 ft) to the summit of the Frijoles Creek watershed at over 3,000 m (fig. 2), with average intervals between widespread fires ranging from 5-15 years. In many years climate-synchronized fires burned throughout the Jemez Mountains (and even throughout the Southwest; see Swetnam 1990)–other years, smaller, patchier fires occurred. We believe that lightning caused the vast majority of these fires. Like elsewhere in the Southwest, the widespread surface fires ceased throughout the Jemez area in the late 1800s (fig. 3), apparently because intense grazing by large numbers of free-ranging livestock reduced the grassy fuels through which most fires spread (Swetnam 1990).

Major fire years tended to be dry in both ponderosa pine and mixed conifer forests in the Jemez Mountains. Adjacent ponderosa pine and mixed conifer forests often, but not

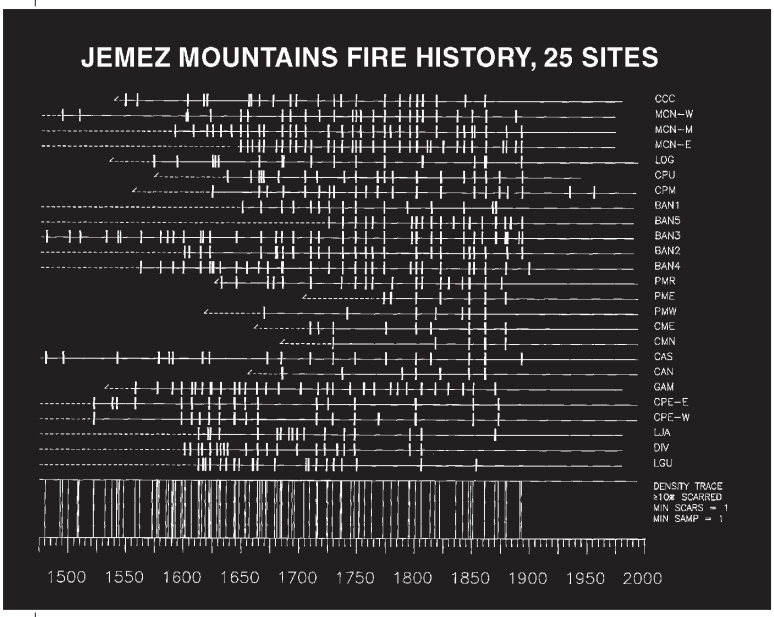


Figure 3. Composite fire history chart for major fires in the Jemez Mountains. Horizontal lines cover the maximum life spans of trees within each site. Vertical bars are composite fire dates recorded by scars on at least 25% of the trees within each site; thin vertical lines indicate fire dates on the time line. Note the synchrony of fire events between sites, and the cessation of recorded fires in the late 1800s.

always, recorded synchronous fire events. However, major fire years in ponderosa pine forests typically occurred with a 2-year lag after significantly greater winter-spring precipitation; this is not observed in local mixed conifer sites. This suggests that the buildup of fine fuels (such as herbaceous vegetation following a wet year) was an important precursor to spreading fire in ponderosa pine forests, whereas fuel moisture, rather than fine fuel availability, was more important in determining fire occurrence in mesic mixed conifer sites. The lags in fuel-fire relations, and the influences of persistent atmospheric phenomena on fuel accumulation and fire occurrence in the Southwest (such as the El Niño-Southern Oscillation [Swetnam and Betancourt 1990]), suggest that long-range fire hazard forecasting models could be constructed.

The network of 25 fire scar sample sites reveals significant spatial variations in past fire regimes across the Jemez Mountains. Ponderosa pine forest sites exhibited a range of high frequency surface fire patterns, with reduced frequencies observed: 1) at low elevation sites, which have inherently lower potentials for producing fine fuels; 2) at places that are topographically isolated from the larger matrix of pine forests; and 3) during times that livestock grazing likely reduced the quantity and continuity of local surface fuels. Past fire regimes in mesic mixed conifer forests included a combination of surface fires and patchy crown fires at 15-30 year intervals. Historical lightning fire records from the park indicate that in most years middle elevation ponderosa pine forests have a greater propensity for sustaining fires than other vegetation types.

Other significant findings include: some of the first quantitative reconstructions of fire history from several southwestern forest types, including riparian mixed conifer, ponderosa pine/piñon-juniper ecotone, spruce-fir; surprisingly frequent fire occurrence from a number of moist or high elevation forest types; proof that essentially all paleofires occurred in spring or early summer, whereas much prescribed burning today occurs in fall for control reasons; indications of possible Native American enhancement of fire frequencies in a few, particular time periods and places; and demonstration of the long-term coexistence of two sensitive species with fire (the endemic Jemez Mountains salamander [*Plethodon neomexicanus,* listed as state-endangered and federal Category 2 Notice-of-Review] and the federally-threatened Mexican spotted owl [*Strix occidentalis lucida*]).

Fire suppression during this century has significantly affected area ecology in a variety of ways, most obviously by allowing the buildup of unnaturally high densities of trees and amounts of ground fuels that were formerly thinned by frequent surface fires. Thus, as across much of the west, fire suppression has promoted conditions today that threaten the health of forests in the Jemez Mountains, with increasingly large, intense, and uncontrollable crown fires. In 1977, one such fire, the La Mesa Fire, burned through the heart of the Bandelier ponderosa pine forests. Scientists have recently completed a dozen linked research projects investigating the ecological effects of the La Mesa Fire and have presented findings on diverse topics (ranging from fire effects on avifauna and nitrogen-cycling to cultural resources) at a well-attended symposium in 1994; the resultant manuscripts are nearly ready for publication.

Summary

Landscape-scale fire history research is providing critical information to initiate, guide, and support extensive use of prescribed fire by multiple agencies to restore this keystone process to forest lands in the Jemez Mountains. Fire history data have been essential to allow fire management programs to (carefully) proceed with burning plans in occupied habitat of such sensitive species as Mexican spotted owl and Jemez Mountains salamander. Overall, this fire history research provides much of the underpinning for the new Bandelier National Monument Fire Management Plan, and it is being used to support similar fire management efforts on surrounding Santa Fe National Forest and Native American lands.

References

Allen, C.D. 1989. Changes in the ecology of the Jemez Mountains, New Mexico. Ph.D. dissertation, University of California, Berkeley. 346 pp.

Swetnam, T.W. 1990. Fire history and climate in the southwestern United States. *In* J.S. Krammes, Technical Coordinator. Proceedings of Symposium on Effects of Fire in Management of Southwestern U.S. Natural Resources, November 15-17, 1988, Tucson, Arizona. USDA Forest Service, General Technical Report. RM-191:6-17.

Swetnam, T.W., and J.L. Betancourt. 1990. Fire-Southern Oscillation relations in the southwestern United States. Science **249**:1017-1020.

Touchan, R.T., and T.W. Swetnam. 1995. Fire history in ponderosa pine and mixed-conifer forests of the Jemez Mountains, Northern New Mexico. Final report on file at Bandelier National Monument, New Mexico. 87 pp.

Weaver, H. 1951. Fire as an ecological factor in the southwestern ponderosa pine forests. Journal of Forestry **49**:93-98.

Craig Allen is a Research Ecologist with the National Biological Service stationed at Bandelier National Monument. His address is Jemez Mountains Field Station, HCR 1, Box 1, #15, Los Alamos, NM 87544. His phone number is (505) 672-9359. His Internet address is "craig_allen@nps.gov".

Ramzi Touchan and Tom Swetnam are Research Specialist and Associate Professor of Dendrochronology, respectively, with the Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721.

Figure 1. The 1994 fire season challenged park staff and cooperators with managing multiple incidents with different goals: the Starvation Creek (upper left) and Adair #2 widlfires (middle right) were contained, while the Howling Fire (middle left) was allowed to burn within prescription to reap ecological benefits.

Prescribed Natural Fire Management: Lessons Learned in the Glacier National Park Classroom

Resource and fire management integration necessary to reap ecogical benefits of fire

By Tom Zimmerman, Fred Vanhorn, Laurie Kurth, and Thad Stewart

The 1994 wildland fire season posed especially long and extensive blazes that challenged many fire managers in the western United States. Numerous fires grew quickly to large sizes and persisted for abnormally long periods of time. Few natural fires were allowed to continue as prescribed natural fires (see the glossary at the end of the article for an explanation of technical fire terms). However, fire managers in Glacier National Park, Montana, successfully managed an early season prescribed natural fire for nearly 15 weeks in conjunction with an above average wildfire workload.

Howling Fire chronology

On June 23, an early season lightning storm ignited a fire in the North Fork area of Glacier National Park near Sullivan Meadow. After initial evaluation and analysis, managers declared the fire a prescribed natural fire and prepared a fire situation analysis and monitoring plan. Early summer fires are uncommon in the park due to high elevations and typically wet conditions in June. Throughout June and July, the "Howling" Prescribed Natural Fire was monitored daily and showed very little activity. By early August staff mapped the fire at just 1 acre (0.4 ha).

The location and fuels of the Howling Fire, however, gave the fire potential to burn a relatively large area. Fire history in the North Fork area of the park showed that most fires burn from west to east due to the prevailing winds. Only once had a fire crossed to the west over the North Fork of the Flathead River into the Flathead National Forest. Glacier National Park fire managers felt that even though the Howling Fire had potential to become large, the probability of it staying within its anticipated boundaries was high.

The park used the latest fire spread prediciton techniques to aid in decision making. A prescribed fire behavior analyst performed a rare event and risk assessment probability, a procedure that provides probabilities of rare weather events affecting fire spread and growth. The park also used a new computer model, the Fire Area Simulator (FARSITE), to project long-term fire spread. A fire researcher verified, validated, and refined the model using documented cases of fire growth. The combined information aided considerably in the decision making process. However, due to pronounced regional and national fire activity, in-park resources and local fire management cooperators were limited.

On August 5, the fire management staff met with the superintendent to assess fire risks and benefits and to determine how to proceed in managing the Howling Prescribed Natural Fire. The superintendent decided to continue management as a prescribed natural fire; however, he felt that the park needed to meet the following conditions in light of the local and regional wildfire needs:

1. Establish a dedicated incident management team with key positions to be filled by nonpark personnel.
2. Give public information a high priority.
3. Make available as many research opportunities as possible.
4. Establish goals specific to the Howling Fire.
5. Monitor the fire closely and intensively.

By August 8, an incident management team made up of staff from other NPS units was in place. The team updated the fire situation analysis and maximum allowable perimeter (MAP). Initially, the team managed the Howling Fire primarily using park resources, and the park

central fire dispatch office continued to coordinate initial attack on new fires, but that was soon to change.

On August 12, a new fire start (Starvation Creek) required separate management by a type II team. By August 29, most Starvation Creek fire control actions had been completed and operations were turned back over to the park. At this time, the Howling Fire incident management team assumed responsibility for the entire North Fork area of the park (including the Howling Fire) due to resource shortages and the continued need for control actions and initial attack.

Also on August 12, a new fire had been discovered near Adair Ridge within the MAP of the Howling Fire. Due to national and regional preparedness level restrictions, this fire (Adair #2) was not managed as a prescribed natural fire. After taking unsuccessful initial attack actions, the team managed it using a confinement strategy, as potential costs, damage to park resources, and risks to firefighters were all high. On August 29, another fire (Anaconda) was discovered between the Howling and the Adair #2 fires and was also placed in a confinement management strategy.

Through mid-September, the Howling incident management team (now known as the North Fork complex incident management team) had managed a prescribed natural fire, two confinement strategy wildfires (both within the MAP of the Howling Prescribed Natural Fire) and a containment strategy wildfire (in conjunction with British Columbia Forestry in Canada[fig. 1]). On September 23, the park reassumed responsibility for the complex, and by September 25, the Howling, the Anaconda, and the Adair #2 fires had burned together. After an extended dry fall, snow fell on October 24.

Monitoring

One element critical to successful management of the Howling Prescribed Natural Fire was consistent monitoring of weather and fire behavior changes indicative of the fire exceeding the management boundary or threatening ranger stations within the boundary. Initially, fire crept through minuscule pockets of dry needles and the underside of downed logs (fig. 2). As vegetation began to cure in late summer, tracking live fuel moistures was critical to predict increased fire activity in the understory. A monitor familiar with both the global positioning system and the park GIS mapped the fire perimeter on ground and eventually by air. The Howling Fire demonstrated that experienced monitors with diverse backgrounds are essential to address the myriad of issues that arise.

Cultural resource protection and long-term research

Abundant archeological resources in one portion of the fire area required special attention. A struggling community of loggers, farmers, and bootleggers lived in the area from the 1890s-1930s. Although many antiques appear to have been removed, several fine examples of pioneer farm equipment, including a horse drawn plow, a thresher, and the remains of two wagons were still present (fig. 3). Prior to a backburn operation, monitors conducted an informal yet thorough survey to map the homestead sites and scattered artifacts. Melted glass, broken bottles, and charred fence posts were evidence of previous fire activity. The survey allowed monitors to actively keep fire away from several features, such as wagon wheels and running boards, which warranted protection. With careful observation and planning, the Howling Prescribed Natural Fire had little, if any effect on the archeological integrity of the area.

Ponderosa pine is of particular ecological interest in the fire area. Minimum ponderosa pine reproduction in the park has been attributed partly to fire suppression. In the Howling Fire area this species is present in stands of similar-aged spruce, fir, and larch trees. Vegetation regeneration, particularly ponderosa pine reproduction, will be measured in long-term fire effects monitoring plots established during the Howling Prescribed Natural Fire.

Management recommendations

NPS prescribed natural fire management guidelines can be improved to help parks deal more effectively with complex, long duration prescribed natural fires. First, as in wildfire management, incident management teams are valuable tools in prescribed natural fire management. As *wildfires* escape initial attack, pose significant threats, or have potential to burn for multiple burning periods, parks are directed to seek additional assistance and even encouraged to request incident management team support. It is logical that

Figure 2. The Howling Prescribed Natural Fire burned predictably through initially moist, then drier, forest understory for 15 weeks before being doused by late October snows.

Figure 3. Deliberate and thorough monitoring efforts followed by a successful backburn operation preserved several cultural artifacts, including this pre-1930s wagon wheel, while allowing the prescribed natural fire to burn.

Continued on page 22

parks should also be encouraged to employ outside assistance and even incident management teams when facing potentially lengthy *prescribed natural fires* and complex management circumstances, such as external influences.

The incident command team used in Glacier last summer to manage the Howling Fire for 75 of its 138 day duration, while helpful, also created a need for complex logistical support. This included providing transportation, food, lodging, and communication support for large numbers of personnel in remote areas. Thorough preplanning is required to provide adequate logistical support. Ensuring monitor and crew safety on the ground and in association with air operations must also be properly planned and implemented. Activating a management organization with strictly nonpark personnel permitted proper attention to these concerns and allowed for efficient and safe prescribed natural fire management.

Second, interagency constraints on the prescribed natural fire program should be changed to permit continued management, even during active fire suppression periods. Current preparedness plans have admirably fulfilled a purpose of guiding long-term fire management accountability. These plans, however, unnecessarily restrict or prohibit prescribed fire activities, particularly when such fires could be most ecologically beneficial. These plans should be changed as they presently limit many parks and wilderness areas to natural fires of only small size, short duration, and little ecological significance. Competition with suppression needs will cause prescribed natural fires to lose or be denied resources for monitoring, holding, and contingency actions. Dedicated prescribed natural fire resources would help alleviate this problem.

Other recommendations include:

1. Developing an incident command system organization and certification program that can be used to manage prescribed natural fires.
2. Hiring and training a dedicated 20 person prescribed fire support crew prior to the 1995 fire season.
3. Using the FARSITE predictive model for assessing prescribed natural fire potential on all future prescribed natural fires.

Table 1. Glossary of Selected Fire Terms

Burning Period—That part of each 24-hour period when fires will spread most rapidly.

Complex—Multiple incidents being managed by a single incident management team.

Confine—To restrict the wildfire within determined boundaries, established either prior to, or during the fire. These identified boundaries will confine the fire, with no action being taken on the ground until the fire is out.

Contain—To restrict a wildfire to a defined area, using a combination of natural and constructed barriers that will stop the spread of the fire under the prevailing and forecasted weather conditions, until out.

Control—A wildfire, aggressively fought through the skillful use of personnel, equipment, and aircraft to establish firelines around a fire to halt its spread and to extinguish all hotspots until out.

Incident Command System—Combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure with responsibilitiy for management of assigned resources to effectively accomplish stated objectives pertaining to an incident.

Incident Management Team—A team operating with a common organizational structure, with responsibility for the management of assigned resources to effectively accomplish stated objectives pertaining to an incident. Incident Command System resources (including teams) are "typed" (classified) according to their qualifications and skills to manage large or complex incidents.

Initial Attack—The control efforts taken by resources that are the first to arrive at the incident.

Maximum Allowable Perimeter—A spatial or geographic area defining the maximum prescribed extent of the fire.

Monitoring—Periodic collection of data regarding a fire such as location, size, weather, behavior, fuels, smoke production, and vegetation. Monitoring is used to document basic information, to detect trends, and to ensure that fire and resource management objectives are met.

Natural Fire—A fire of a natural origin (lightning, volcanic, etc.) that is allowed to burn to accomplish one or more resource management objectives.

Prescribed Natural Fire—Fire that meets management objectives and prescriptions to burn. Includes prescribed natural fire and management ignited prescribed fire.

Prescribed Fire—Fires ignited by natural means (usually lightning) that are permitted to burn under specific environmental conditions, in preplanned locations, with adequate fire management personnel and equipment available to achieve defined objectives.

Project Fire—A fire normally of size or complexity that requires a large organization and possibly several days or weeks to extinguish.

Resources—All personnel and major items of equipment available, or potentially available, for assignment to emergencies. Resources are described by kind and type.

Summary

During the Howling Prescribed Natural Fire, NPS managers gained new insights into natural fire management. These experiences have generated procedural change recommendations that will both significantly enhance our ability to successfully administer the prescribed natural fire program and influence changes in program guidelines that will affect all prescribed natural fire managers agencywide.

It is imperative that we continue to learn about prescribed natural fire management and continue to strive for the integration of fire and resource management. The 1994 fire season and the Howling Fire are excellent examples of how we have dealt with uncertainty, developed strategies for continued management, and continued to improve our abilities to manage natural fire in wildland ecosystems.

Tom Zimmerman is with the National Park Service at the National Interagency Fire Center, Boise, Idaho. Fred Van Horn is Fire Management Officer at Glacier National Park, Montana. Laurie Kurth is an Ecologist also with Glacier. You can reach her by phone at (406) 888-5441 or over e-mail through NPS cc:Mail or on the Internet at "laurie_kurth@nps.gov". Thad Stewart is a Fire Monitor at Zion National Park, Utah.

Announcing the New Grand Canyon Science Center

Organization joins science partners with resource management leadership

By David Haskell

Created in April, 1995, the Grand Canyon National Park Science Center is a new concept that responds to initiatives within the Department of the Interior and the National Park Service to improve agency efficiency, public service, and resource protection. Central to this effort is the need to work more closely with associated state and federal agencies, Native American tribes, conservation groups, and other organizations that share an interest in resource stewardship on public lands.

The NPS Strategic Plan (1994) provides a list of the most important things that the agency should do to meet current and future challenges. The first task is to base park management decisions on sound scientific information. In order to accomplish this goal the agency must redefine and strengthen the role of science in park management. The creation and operation of the Grand Canyon Science Center will assist the park and the National Park Service in achieving this goal.

The science center will operate differently than the previous park Resource Management Division. We will foucs on four areas in this process:

- The name change recognizes that resource management is a responsibility and function of all park divisions. By not having a park division called *resource management* we recognize the contribution other operational units and partners make in achieving our shared resource management mission. The science center will provide leadership, planning, and scientific knowledge of resources. Other park operational units will be engaged in resource education, protection, restoration, and other related activities.

- The creation of the science center acknowledges that science is a fundamental part of park management and operations. The quality and scientific credibility of science center programs are being improved by raising staff performance expectations and recruiting new employees with clearly defined scientific capabilities.

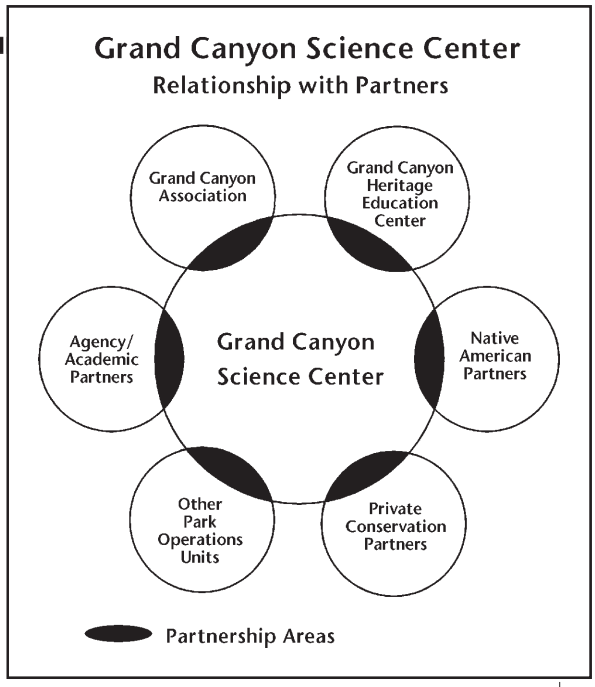
- Operational areas have been defined and are lead by qualified science program managers. These program areas are: research, geographic information systems and data management, natural science programs, cultural programs, social science-recreation programs, and administration.

- Center operations include the regular involvement and participation of six recognized categories of science program partners. These are the Grand Canyon Association, Native American tribes, academic and agency partners, citizen conservation association partners, and other park operational units.

In the context used to describe science center operations, we use the definition of *science* in Webster's Dictionary, which is "The systematic acquisition of knowledge through observation, study and experimentation." The center staff is made up of scientists, historians, curators, archeologists, and other professional subject matter experts, plus technicians who assist in carrying out field operations, and technical and administrative support staff. Together these people, in consultation with science partners, provide the scientific knowledge about park resources necessary to make knowledgeable and informed management decisions. This staff also formulates and prepares resource management plans and provides the leadership to carry out key portions of the park resource stewardship program.

The new science center will engage in many of the same activities that were being accomplished by the old Resource Management Division in the fields of natural, cultural, and recreational resource management. Science operations that are to be expanded include the addition of social science capability, expanding and improving the research program, which will be carried out primarilly by partnership agencies and contract research scientists, and the development of a comprehensive long-term monitoring program for both natural and cultural resources. The purpose of expanding the latter two operations is to greatly improve our knowledge and understanding of the condition of park resources. Periodically evaluating the status and trends of resource condition allows park managers to be more effective in reducing threats to resource health and visitor enjoyment before any threats become serious problems.

Accomplishing this newly defined mission for the Grand Canyon Science Center will be a challenge in these times of reduced federal spending, continued increases in park visitation, and intensifying threats to resource health. The National Park Service recognizes that accomplishing the agency mission will require harnessing the energy, creativity, and financial support of partnership agencies and organizations. To accomplish this task, a primary focus of the center operations is to develop well-defined partnerships and to routinely incorporate these partners into center operations.



David Haskell is the Director of the Grand Canyon Science Center. Reach him by calling (520) 638-7701 or sending e-mail through the NPS cc:Mail network or over the Internet at "dave_haskell@nps.gov".

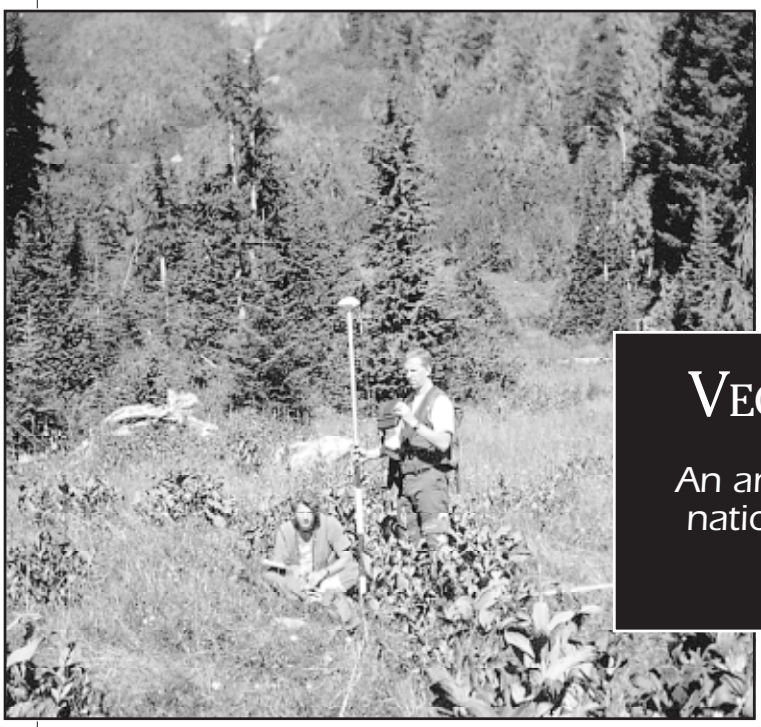


Figure 1. Pacific Meridian Resources personnel Ron Diver and Jeff Campbell (standing) collect vegetation data georeferenced by a global positioning system in the Low Divide area of Olympic National Park, Washington.

Vegetation Mapping in Northwestern

An ambitious project to develop a regional GIS databas national parks to develop interagency partnerships for management based on scientific principles

By June C. Rugh, David L. Peterson, and Jeff T. Campbell

How much old-growth forest remains for the northern spotted owl in the Pacific Northwest? What proportion of land area in each park is occupied by alpine vegetation? Which watershed has the largest percentage of Douglas fir crown cover?

These are questions that managers in Crater Lake, Mount Rainier, North Cascades, and Olympic National Parks will soon be able to answer with unprecedented accuracy, consistency, and state of the art documentation. The Columiba-Cascades System Support Office is working with Pacific Meridian Resources, Inc., to develop a comprehensive GIS database of vegetative, topographic, and landform data layers. Due for completion in September 1995, this database will increase our knowledge of ecosystems in the four parks, greatly enhancing resource managers' abilities to organize data, analyze relationships between resources in a spatial context, and assess the potential impacts of management decisions.

Until now, the rugged and remote landscapes characteristic of these parks have limited scientists in developing detailed, comprehensive data on vegetation and landforms. Pacific Meridian Resources is tackling this challenge by integrating existing monitoring and research data, extensive field reconnaissance, aerial photography, and satellite imagery into the regional GIS database. Using the various scales and resolutions of each of these database types, Pacific Meridian can obtain detailed information from more easily accessible areas. The detail can then be extrapolated to describe areas in remote locations determined to be similar from the satellite imagery and aerial photography. A GIS database encompassing all regions of the park will result.

Generally speaking, GIS databases describe the physical, biological, and cultural attributes of resources. They link computerized maps (location data) to computerized databases that describe the attributes of a particular location. This link makes possible simultaneous access to both location and attribute data for simulating the effects of management and policy alternatives. GISs are powerful tools, because a single operator can quickly search, display, analyze, and model spatial information. Moreover, maps and data can be updated more rapidly and accurately than with conventional methods.

The core of the Pacific Northwest project is an ecosystem database that focuses on two primary components: 1) characterization of forested and nonforested vegetative types across all park areas, as defined by criteria such as tree species, stem density, stand age, crown cover by species, dominant understory species in forested areas, and species cover in nonforested areas; and 2) characterization of topography and landforms, including development of data layers for slope, aspect, elevation, and landform type.

What makes the Pacific Northwest project different from others? After all, many national parks have descriptions of physical and biological components, with some already in digital GIS format. First, the innovative use of remote sensing technology will produce a detailed description of multiresource landscapes, allowing resource managers to address issues in an ecosystem context. This dynamic, spatial database will enable managers to assess forest stand dynamics and wildlife habitat with accuracy and thoroughness. Second, the database will provide a comprehensive framework on which more extensive and detailed information can be built, and which will be consistent from park to park. Most significantly, the project demonstrates a regional approach to ecosystem management by organizing data from the four parks into one contiguous database and by coordinating efforts with adjacent land managers–

the U.S. Forest Service, state resource management agencies, and private timber companies.

The use of satellite image classification facilitates the regional approach to GIS database development. Satellite imagery not only provides detailed, consistent information about NPS lands of interest, but also presents the same detail and consistency of information for lands adjacent to the parks. This insures compatibility between databases among different agencies, which in turn allows for greater potential in data sharing and collaborative resource management. Moreover, this cooperation reflects an increasing commitment on the part of resource managers to cross political boundaries in order to achieve common goals.

N PARKS

e will allow
ecosystem

THE TECHNICAL APPROACH

The technological hub of the project is a multistage sampling process. The process integrates existing data sources, new field data collection (fig. 1), Landsat Thematic Mapper satellite imagery, aerial photography, digital topographic data and other existing GIS data layers, and the knowledge and experience of Pacific Northwest ecology found within the Pacific Meridian project team and NPS staff. Database design involves two steps: 1) identifying database standards for both spatial and classification accuracy and 2) developing a preliminary classification system that identifies the types of variation in vegetation and landforms of interest to the anticipated database users.

Spatial or positional accuracy is defined as the expected deviance in the geographic location of an object in the database from its true ground position. The spatial database standards for this project will be largely a function of the scale and resolution of various data ranging from 30 m (33 yd) Landsat Thematic Mapping imagery and digital elevation data to 1:100,000 and 1:500,000 scale geology map data. All data will be coregistered with the satellite imagery to ensure spatial consistency. Classification accuracy is the probability that the class assigned to a particular location on the map is the same class that would be found at that location in the field. While traditional classification standards imply only true or false classifications, Pacific Meridian is working with NPS staff to incorporate *fuzzy sets* (flexible criteria) into accuracy standards, deriving a set of measures to analyze the nature, frequency, source and relative magnitude of map errors. This will provide us with more complete information on map reliability.

In developing the classification system, landforms are characterized by slope, aspect, elevation, and landform type, including substrata origin and type (such as bedrock type). Landform identification can be highly variable and can range from general descriptions of topographic shapes (mountain, plateau) to specific terms indicating depositional form and process (alluvial fan, glacial moraine). This project is producing a digital geomorphic landform layer that describes substrate origin and type.

Figure 2. Traditionally, landscape information is transferred from hardcopy maps and photos to the GIS through the painstaking process of digitizing. Contractor Pacific Meridian is investigating using a digital shaded relief data technique that would eliminate many of the hardcopy transfer steps.

Landform data can be developed through a variety of methodologies ranging from extensive field reconnaissance to digital data modeling to photo interpretation. The method deemed most efficient and suitable for this project is the interpretation of high altitude aerial photography and topographic base map data. We will interpret landforms from 1:80,000 scale National High Altitude Aerial Photography (NHAAP) and delineated directly onto 1:100,000 scale topographic maps. Interpretation will be aided by review of both the topographic maps and local geologic maps.

Pacific Meridian is also investigating the use of digital shaded relief data developed from 1:24,000 digital elevation area draped with satellite imagery. The digital images could be interpreted with the assistance of NHAAP photography and previously collected field data. Landform characteristics could then be delineated directly on the computer screen. This methodology would eliminate the need for many of the hardcopy transfer and digitizing steps required in the strictly photo-interpreted landform mapping methodology (fig. 2). Where feasible, landform classes will be verified during field reconnaissance efforts associated with the vegetation database development phase of the project. Based on scale limitations of the source data, the minimum mapping unit for landforms will be approximately 40 ha (99 acres).

We will characterize vegetation by several variables: stem density by tree species, stand age by species, tree diameter by tree species, crown diameter by tree species, crown cover by tree species, standing dead trees, dominant understory species in forested areas, and cover of herbaceous plant species in nonforested areas. In developing the vegetation characteristics database, we will use satellite images as a basis for determining the vegetation data themes through the integration of various ancillary data sources. The reason remotely sensed data (such as satellite imagery or aerial photography) can be used to collect vegetation information is because of the high correlation between variation in imagery and actual variation in vegetation.

Continued on page 26

Remotely sensed data is particularly effective for mapping the variation in tree canopy characteristics (such as crown diameter by species, crown closure by species) in forested areas, and the soil type, moisture, and nontree vegetation variation in nonforested areas (fig. 3). Thus, satellite imagery can be useful in characterizing much of the variation in vegetation across the national parks. Landform classes will be digitized directly from the topographic maps to form the final landform type layer. Furthermore, land cover classification data from satellite imagery can provide much more detailed intensive information than results from traditional photo-interpreted polygon classifications. For example, while a 5-ha polygon may summarize forest age, canopy cover, structure, and so on, satellite image classification provides information on the variation of forest age, canopy cover, structure, and so on without the 5-ha polygon area.

Vegetation characteristics that cannot be directly mapped from the imagery can be delineated through the development of relationships among the imagery, fire history, and landform characteristics. For example, tree diameter, which cannot be mapped from aerial photos or satellite imagery, is highly correlated with tree canopy diameter, which can be estimated from remotely sensed data. In addition, a multistage sampling process is used to determine the relationships of the imagery of forest canopy characteristics to nonforest cover types; canopy characteristics to subcanopy characteristics; and landform, fire history, and other environmental factors to forest canopy characteristics, forest subcanopy characteristics, and nonforest cover types. Multistage sampling employs the fact that strong relationships exist between some characteristics that are inexpensive to estimate (such as crown diameter) and other variables costly to estimate (such as tree diameter). We will use the combinations of these relationships to develop the database of vegetation characteristics.

Quantitative assessment of map classification accuracy involves comparing the map to reference data (from photo interpretation or field identification, for example), which is assumed to be correct. Because comparison of every spatial point is impractical, sample comparisons are used to estimate the accuracy of maps. Accuracy assessment requires: 1) the design of unbiased and consistent sampling and photo interpretation and field procedures, and 2) rigorous analysis of the sample data. We are using strict quality control and quality assurance procedures in both data collection and subsequent analysis to insure accuracy in the final dataset.

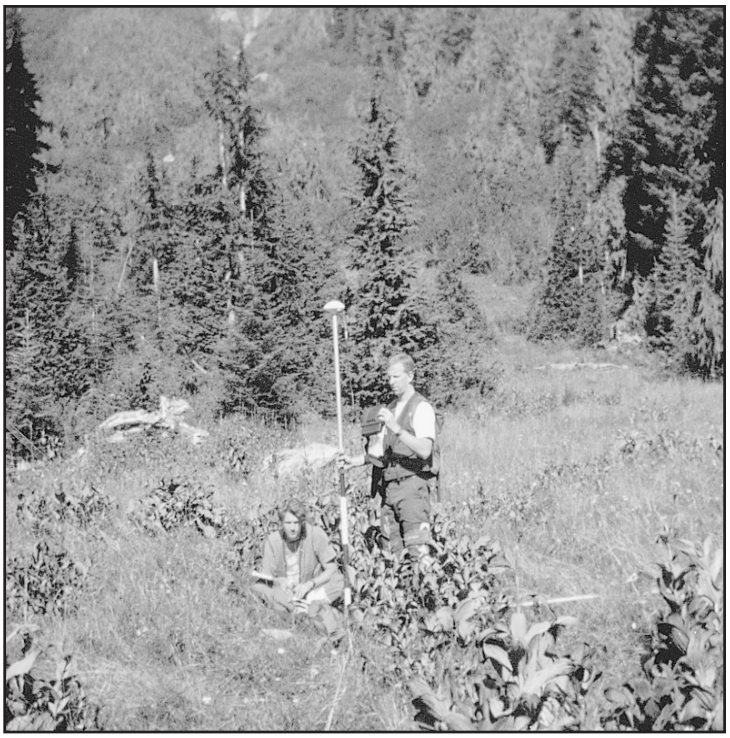


Figure 3. High altitude photographs, like this 1:24,000 scale photograph of Olympic National Park, show contrasts in vegetation types and landforms, and can be used to help GIS production staff classify vegetation.

Looking ahead

The vegetation mapping project currently underway in the Pacific Northwest is an important component of regional programs in inventory and monitoring, resource management, and science. It will also provide information for a wide range of uses. The new database will be a high-quality template for monitoring the condition of natural resources. It will provide a geographically based link to various disciplines within resource management, such as wildlife, hydrology, and fire. The database will also be an important tool for research scientists in identifying specific vegetative and geomorphic resources, and for georeferencing all future scientific activities in the parks.

The database will provide a framework for increased and more specific cooperation with other agencies and institutions. Ecosystems do not stop at park boundaries, and water and wildlife resources cross these boundaries freely. The availability of a consistent, compatible database will allow national parks to develop interagency partnerships for ecosystem management based on scientific principles. Broader landscape-regional assessments and management strategies will now be possible. Furthermore, the Columbia-Cascades Cluster will be able to cooperate in other similar vegetation efforts (planned or under way) by the National Park Service, National Biological Service, and other agencies.

Ecosystems are constantly changing–sometimes gradually, sometimes abruptly. The new database will be dynamic in order to track spatial and temporal changes in park natural resources, and it will facilitate continual updating over time. It will allow park managers and scientists to determine the influence of large-scale disturbances, such as fire, on park landscapes, and the potential impacts of long-term phenomena, such as climate change. Other uses, not yet envisioned, will certainly develop. The new database will be more than a mere vegetation map–it will be a powerful managerial and scientific tool for many years to come.

Rugh is a Technical Writer and Peterson is a Research Biologist at the University of Washington CPSU in Seattle. Campbell is a Remote Sensing Specialist and Project Manager at Pacific Meridian Resources in Portland, Oregon. Peterson can reached over the Internet at "wild@u.washington.edu" or by calling (206) 543-1587.

SAVING NATURE'S LEGACY: PROTECTING AND RESTORING BIODIVERSITY

Reed F. Noss and Allen Y. Cooperrider

A REVIEW BY R. GERALD WRIGHT

In their epilogue the authors lament the life of the "conference biologist," whose job it is to go to conferences, give lectures, and write obscure papers. These biologists have now written a book designed to share the science of conservation biology and the ideas it offers to protect biodiversity with others–particularly those *others* in the real world–as opposed to having the subject remain the domain of lecture halls and journals. It would be nice if this lofty goal could be achieved, but I doubt that it can be.

This book, however, will–or should–find a place on the desks and shelves of all professional biologists and resource managers. Noss and Cooperrider have written an excellent book whose greatest strength is its readable synthesis of the important aspects of the broad discipline of conservation biology. Also, judging by the number of times I have already seen the book cited in draft manuscripts, it appears to be one of the more influential books to come out among the proliferation of recent biodiversity writings. The book reads well. Although the principles that it discusses have broad geographic application, all of the case examples and most of the discussion of agency management practices are oriented to the United States, a factor that may enhance its appeal to NPS managers.

The origin of the book was the inability of the Keystone National Policy Dialogue on Biological Diversity to produce specific recommendations. The first two chapters introduce the concept of biological diversity and why it should be of concern. This is followed by a presentation of the basic concepts of biological conservation, threats to biological diversity, and the current status of diversity in North America. The meat of the book begins with chapter three, which is a critique of past and present resource management failures and a look to future strategies. Subsequent chapters, e.g., "Managing Forests," "Managing Rangelands," and "Managing Aquatic Ecosystems," include comparisons of traditional resource management practices in the given subject area with those advocated following the principles of conservation biology. These and other chapters make several recommendations for altering current thinking and integrating biodiversity conservation into resource management; they also often contain excellent case examples of how these recommendations can be applied.

I feel one of the strongest chapters is "Designing Reserve Networks." Although most of this material is not new, rather presenting material published elsewhere primarily by the senior author, its thorough compilation and synthesis in one place makes it a valuable reference. The chapter on "Managing Rangelands" is, likewise, very good. It presents, often in a new light, considerable information on the impacts of livestock grazing and livestock management practices on biodiversity. These insights are often highly provocative, and I trust would raise the hackles of at least some traditional range managers. Conversely, I thought the chapter on "Managing Forests" was one of the weakest. Although it critiqued some of the concepts of new forestry, the presentation discussion was less compelling than that of other chapters.

As one would expect of these authors, the book pulls no punches in its examination of the causes underlying the crisis in protecting biodiversity. The ignorance of the general public, the often irrelevant nature of university training, and the foibles of agency land management practices all receive equal and usually valid criticism. The book is an important reference for all individuals involved in the management of parks and protected areas and I highly recommend they read it.

Published in 1994, this 416 page book is available from Island Press, Washington, DC; (202) 232-7933.

Gerry Wright is the NBS Unit Leader of the Cooperative Park Studies Unit at the University of Idaho, Moscow. His phone number is (208) 885-7990.

Figure 1. Home to adaptable prehistoric peoples over the last 15,000 years, the Fishing Bridge Peninsula routinely gained and lost ground to a cyclically retreating and advancing Yellowstone Lake. The study area revealed a complex series of earlier shorelines, some higher, others lower, than the present-day shore at Storm Point.

Caldera Unrest, Lake Levels, and Archeology: The View from Yellowstone Lake

A habitat restoration project prompts cooperative natural and cultural resource research

By Kenneth P. Cannon, Kenneth L. Pierce, and George M. Crothers

Yellowstone National Park is rehabilitating the Fishing Bridge area on the north shore of Yellowstone Lake. This project will help maintain and protect critical habitat for the grizzly bear and preserve the quality of this diverse, local ecosystem (National Park Service 1984). During 1992-93, prior to the rehabilitation project and proposed reconstruction of the east entrance road, scientists from the NPS Midwest Archeological Center and U.S. Geological Survey conducted geoarcheological research on parts of the peninsula at Fishing Bridge. Although compliance legislation (Section 106 of the National Historic Preservation Act) mandated the research before the two projects could begin, we hoped to use this opportunity to learn more about the complex interactions of lakeshore level changes over time and prehistoric human adaptation to these changes (fig.1). We also hoped to use new techniques in geochemistry and immunological research to learn more about obsidian artifacts found within the study area and at other park sites. The following overview illustrates how geological and archeological observations can be integrated to interpret cultural remains and explain human adaptations to changing lake levels.

We assembled a team, including several researchers already familiar with Fishing Bridge, to provide expertise on local and regional paleoenvironmental patterns, mobility and subsistence patterns, landform history, and other topics. While preliminary, our work complements former studies in assessing the environmental circumstances that prehistoric humans lived with and adapted to.

Fluctuating lake levels

Central to understanding Yellowstone Lake level fluctuations and their effects on prehistoric humans in the Fishing Bridge area is the relationship between lake levels and caldera rise and subsidence at LeHardy Rapids on the Yellowstone River. Located 5 km (3 mi) downstream from the Yellowstone Lake outlet at Fishing Bridge, LeHardy Rapids is a bedrock threshold that controls the level of Yellowstone Lake by acting as a dam; the intervening stretch of river between the outlet and the rapids is at present very flat with a total gradient of only about one-quarter meter (less than a foot). From 1923-85, the Yellowstone caldera rose about 1 m (3.3 ft) beneath LeHardy Rapids (Pelton and Smith 1982). Since 1985, the same area has subsided at a rate of about 2 cm (0.8 in) a year (Dzurisin et al. 1990). Explanations for these changes include magma intrusion, tectono-magmatic interaction, and–our favored mechanism–geothermal sealing and pressure buildup followed by cracking and pressure release (see Pelton and Smith 1982; Fournier 1989; Dzurisin et al. 1990).

We wondered if these changes were part of a longer-term process that could be studied by dating evidence for lake levels both above and below the present level. An early

model for lake level changes proposed by Richmond (1976a, 1976b) argues for a progressive, gradual lowering from late Pleistocene through Holocene time (approximately 15,000 years ago through the present). He outlines two general ages for shorelines: a middle set of terraces 15.2-16.8, 12.2-13.7, and 9.1-10.6 m (50-55, 40-45, 30-35 ft, respectively) above present-day Yellowstone Lake formed between 5,000-8,000 years ago and a lower set of terraces 7.6, 4.6, and 3.0 m (25, 15, and 10 ft, respectively) above the lake formed more recently.

Archeological and geomorphological information gathered since Richmond's work suggests that lake history is more complicated. For example, Reeve (1989) looked at the distribution of late Pleistocene-early Holocene projectile points. He found that 10,000-8,000 years B.P., projectile points were common on shorelines that Richmond's chronology indicated should be younger than 5,000 years old. Hamilton (1985) recognized lower-than-present lake levels, and later specified that Yellowstone Lake was below its present level from approximately 9,200-5,400 years ago. He and Bailey (1990) also postulated that the lake was 5 m (16.4 ft) below present around 1600 A.D.

The ages we determined are at least twice as old as those suggested by most previous researchers (Richmond 1976a, 1976b; Meyer and Locke 1986; Locke and Meyer 1994). Shoreline ages have been quite difficult to determine with accuracy, because most are based on radiocarbon samples that are younger than the associated shoreline, and thus represent only minimum ages. We affirm the conclusion of Meyer and Locke (1986:20) that the "history of lake levels is apparently more complex than a simple decline over time."

In order to resolve dating problems like those raised by Reeve (1989) and to understand the impacts and implications of both higher- and lower-than-present lake levels on human habitation, we needed to better define the history of geomorphic changes. Using geomorphic studies and archeological excavations, we have identified, described, and precisely mapped relict landforms that record a cyclical pattern of uplift and subsidence on the north shore of Yellowstone Lake since deglaciation approximately 15,000 years ago. Each of these cycles created significant changes in the local landforms, environments, and resources available to humans who lived in the area.

Cycles of uplift and possible subsidence

The current uplift and backflooding cycle observed over most of this century has been going on for about 3,000 years. Backflooding has converted the 5 km (3 mi) segment of the Yellowstone River (from its mouth at Yellowstone Lake to the bedrock threshold at LeHardy Rapids) from a once vigorously flowing river into the present wide pool. Using hand coring techniques, we found river gravels 4 km (2.5 mi) upstream from Le Hardy Rapids that are now submerged beneath 4 m (13.1 ft) of mud and sand that started accumulating about 2,700 yr B.P. When deposited by the faster-flowing Yellowstone River, these gravels were several meters higher than the bedrock threshold at LeHadry Rapids. However, the uplift centered at LeHardy Rapids has been enough so that these gravels are actually lower than the bedrock threshold. We estimate that this river segment was tilted back toward the lake approximately 5 m (16 ft) in the last 3,000 years.

Additional evidence for tilt and increase in the level of Yellowstone Lake comes from a submerged valley located 21 km (13 mi) southeast of Fishing Bridge, near West Thumb. A core sample from 5 m (16.4 ft) below the present lake level has an age of 2,800 years B.P. When deposited, the sample material was part of a wetland adjacent to Yellowstone Lake. This shows that Yellowstone Lake here has also risen approximately 5 m in the last 3,000 years, and is consistent with our findings near Fishing Bridge.

Evidence that may define the next older uplift cycle is difficult to unravel, because Yellowstone Lake levels then were close to the present level. However, weakly developed soil and mid-Holocene (approximately 5,000 year old) artifacts observed within a meter (3.1 ft) above the current beach suggest that lake levels were near present levels approximately 5,000 years ago and were probably lower thereafter.

The next older uplift and backflooding cycle is recorded by an S-shaped meander 0-3 m (0-10 ft) above the Yellowstone River. West of the present river, the meander backflooded and Yellowstone Lake built a spit across it (Meyer and Locke 1986; Locke and Meyer 1994). East of the present river, a charcoal sample from between the river gravels and lake deposits shows that backflooding of the once vigorously flowing river was under way by 8,200 yr B.P. This backflooding cycle ended between 6,800-6,680 years ago when the lake level was as high as the prehistoric shoreline that is now preserved at the Fishing Bridge Museum (fig. 2, page 30). The amount of backflooding is the same as that determined for the current uplift cycle (beginning 3,000 years ago) and we think indicates a similar amount of uplift at LeHardy Rapids.

At least three river terraces formed after the glaciers melted and suggest that three additional backflooding cycles may have occurred between 8,500-15,000 years ago. The youngest of these three river terraces ties in with the shoreline at the Hamilton Store level (fig. 2, page 30). Ages determined on charcoal buried beneath dune sand indicate that this shoreline is at least 9,000 years old. In association with this shoreline, we also found Cody Complex artifacts dated between 8,750 and 10,060 B.P. (fig. 3a, page 31) that were used by people who occupied the area then (Frison 1991:table 2.2).

A geologic complexity with the Fishing Bridge area is additional tilting that is distinct from the uplift and subsidence of the central part of the caldera. Meyer and Locke (1986) show that the prehistoric shoreline at Hamilton Store (9,000 years B.P.) is downwarped 3 m (9.8 ft) within 1 km (0.6 mi) of Fishing Bridge, but that the Museum shoreline (about 7,000 years old) is not downwarped. An offshore graben (depressed crust bounded by faults) trends towards Fishing Bridge (Otis et al. 1977; Kaplinski 1991) and might be responsible for this downwarping. However, neither we, nor other researchers have found evidence for extension of this graben on shore.

In summary, we suggest that the central part of the Yellowstone caldera has been uplifting and probably subsiding cyclically. This *heavy breathing* has breaths several thousand years long. For the pattern of uplift and subsidence measured this century, that part between the center of uplift near Le hardy Rapids and Fishing Bridge measures only the crestal one-fourth of the total span. If the past patterns paralleled

Continued on page 30

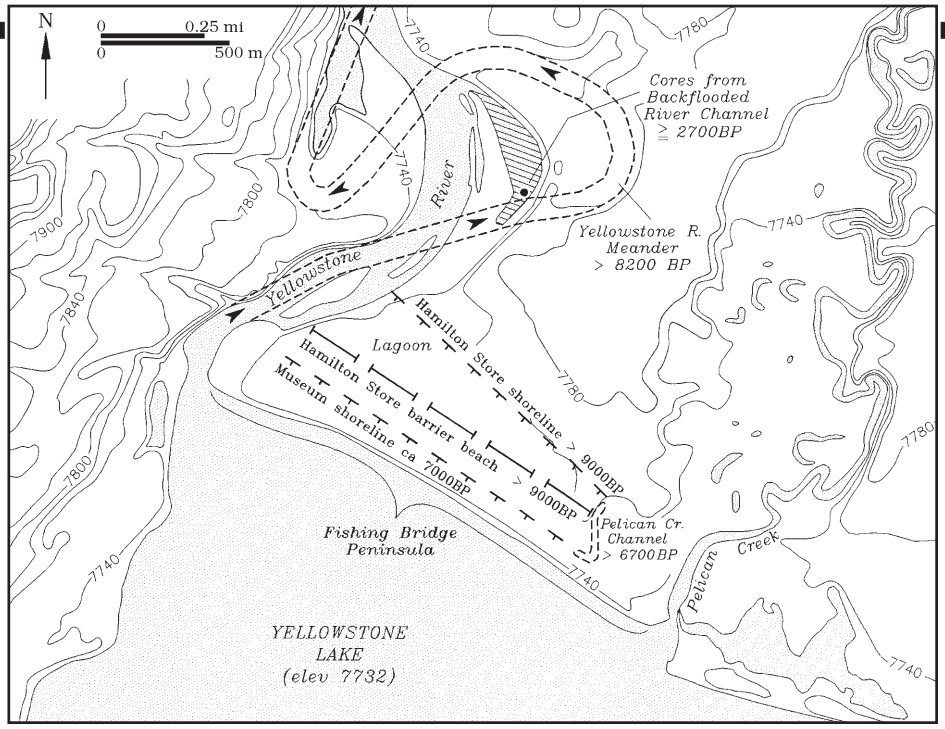


Figure 2. Map of Fishing Bridge Peninsula showing prehistoric shorelines and beaches of Yellowstone Lake, some older courses of the Yellowstone River, and contours (in feet above mean sea level).

those observed this century, the 5 m uplift of Le Hardy Rapids relative to Fishing Bridge is only one-fourth of the total uplift. If so, the total uplift for at least two of the cycles was about 20 m. Thus, the heavy breathing of the central part of the Yellowstone caldera has breaths of about 20 m spaced at intervals of perhaps 1,000-4,000 years.

Native American inhabitants of the Fishing Bridge peninsula around 10,000 years ago probably encountered landforms similar to those found at the mouth of Pelican Creek today (see fig. 1). The Hamilton Store shoreline was an active barrier beach, with a shallow lagoon immediately to the north. North of the lagoon, emergent beaches collected windblown sand, and several spits also extended westward into the lagoon.

At around this time, pollen records indicate that the lakeshore was dominated by open grasslands or steppe species. Common members included sagebrush, various grasses of the family Poaceae, sedges, and other herbs. Between 10,500 and 9,000 years ago, lodgepole pine *(Pinus contorta)* began to dominate forests in response to warming and has remained the dominant overstory species ever since (Whitlock 1993). Understanding climate and vegetative change is important for modeling population dynamics of human prey species, such as deer, bison, elk, and bighorn sheep.

Obsidian use

In addition to understanding the Fishing Bridge area paleoenvirnoment, our research also emphasized settlement and subsistence patterns and tool stone acquisition. Native Americans produced an abundance of stone tools from obsidian obtained from local volcanic exposures (Davis et al. 1992). Geochemical studies over the past 30 years have shown that volcanic flows have distinct chemistry, and by comparing trace elements of known geologic sources with those of prehistoric tools, researchers can develop procurement strategies of tool stone.

Earlier geochemical studies suggested that humans used only local Yellowstone Plateau obsidians in the manufacture of stone tools (e.g., Wright and Chaya 1985). However, over the last 10 years, improvements in trace element analyses and a greater knowledge of regional sources of volcanic glass have increased the number of source areas in the archeological record (Nelson 1984). Our studies have documented at least 10 distinct geochemical types among obsidian projectile points and tools found in Yellowstone. Although Obsidian Cliff is by far the most significant source, a substantial number of nonlocal sources occur (30%), some as far away as 280 km (174 mi) to the southeast in Idaho (Cannon and Hughes 1993). For instance, Paleo-Indian points were manufactured from a greater diversity of sources, and from sources at greater distance than for other time periods. This pattern would suggest greater mobility of these groups, which is consistent with other Paleo-Indian studies elsewhere in the west.

Blood residue analysis

Middle Rocky Mountain archeological sites are noted for poor preservation of organic materials. This has limited archeologists' abilities to understand subsistence patterns by direct evidence, such as the discarded remains of food items. However, recent studies have demonstrated that biochemical and immunological methods have the potential to identify animal species from residues (i.e., blood and tissue) remaining on stone tools (Newman 1990) and in soils (Newman et al. 1993). These techniques have direct implications for reconstruction of prehistoric subsistence patterns, tool use, and paleoenvironmental studies.

We used a modified version of crossover immunoelectrophoresis analysis. This technique was developed by the Royal Canadian Mounted Police Serology Laboratory (Ottawa) and the Centre of Forensic Sciences (Toronto) for identification of blood residue in criminal investigations. We used the technique to analyze stone tools for prehistoric blood residue (fig. 3a-g, page 31). The process returned positive anti-sera reactions for bison, deer, elk, sheep, rabbit, bear, cat, and canid for 23 of 78 analyzed artifacts (Cannon 1995). Diversity of faunal species, in contrast to the bison-dominated plains economy, has been a hallmark of prehistoric mountain economies (Frison 1991).

Summary

We have begun piecing together a very exciting record of geomorphic and tectonic change, which has directly influenced settlement and subsistence of prehistoric groups living on the Fishing Bridge peninsula for millennia. Environmental and vegetative changes continually provided hunter-gatherers living in the Yellowstone area new opportunities and challenges. The

challenge to archeologists and other Quaternary researchers is to decipher these patterns from the limited evidence we are presented. Our analyses are still ongoing, but our preliminary results are encouraging. We plan to publish a final report on our findings later this year.

Literature Cited

Cannon, K.P. 1990. Report of an archeological survey of the east entrance highway, Yellowstone National Park, Wyoming. Manuscript on file at the Midwest Archeological Center. Lincoln, Nebraska.

Cannon, K.P., and R.E. Hughes. 1993. Obsidian source characterization of paleoindian projectile points from Yellowstone National Park. Current Research in the Pleistocene 10:54-56.

Cannon, K.P., and M.E. Newman. 1994. Results of blood residue analysis of a late paleoindian projectile point from Yellowstone National Park, Wyoming. Current Research in the Pleistocene 11:18-21.

Cannon, K.P. 1995. Blood residue analyses of ancient stone tools reveal clues to prehistoric subsistence patterns in Yellowstone. Cultural Resource Management Bulletin.

Davis, L.B., S. Aaberg, and A. Johnson. 1992. Archeological fieldwork at Yellowstone's Obsidian Cliff. Park Science 12(2):26-27.

Dzurisin, D., and K.M. Yamashita. 1987. Vertical surface displacements at Yellowstone Caldera, Wyoming, 1976-1986. Journal of Geophysical Research 92(13):13,753-13,766.

Dzurisin, D., J.C. Savage, and R.O. Fournier. 1990. Recent crustal subsidence at Yellowstone Caldera, Wyoming. Bulletin of Volcanology 52:247-270.

Fournier, R.O. 1989. Geochemistry and dynamics of the Yellowstone National Park hydrothermal system. Annual Reviews of Earth and Planetary Sciences 17:13-53.

Frison, G.C. 1991. Prehistoric hunters of the high plains. Second Edition. Academic Press, New York.

Hamilton, W.L. 1985. Analysis of submerged terraces, Yellowstone Lake. *In* Yellowstone Physical Science Symposium, 3rd, Abstract with Programs. Yellowstone National Park, Wyoming.

Hamilton, W.L., and A.L. Bailey. 1990. Holocene deformation history of the Yellowstone Caldera at Yellowstone Lake inferred from abandoned shorelines and sediments. Report 90-3, Yellowstone Physical Science Laboratory, Division of Research, Yellowstone National Park, Wyoming.

Kaplinski, M.A. 1991 Geomorphology and geology of Yellowstone Lake, Yellowstone National Park, Wyoming. M.S. Thesis, Northern Arizona University, Flagstaff.

Locke, W.W., and G.A. Meyer. 1994. A 12,000-Year record of vertical deformation across the Yellowstone Caldera margin: The shorelines of Yellowstone Lake. Journal of Geophysical Research 99(810):20,079-20,094.

Meyer, G.A., and W.W. Locke. 1986. Origin and deformation of Holocene shoreline terraces, Yellowstone Lake, Wyoming. Geology 14:699-702.

National Park Service. 1984. Fishing Bridge and the Yellowstone ecosystem: A report to the director. U.S. Government Printing Office. Washington D.C.

Nelson, F.W. Jr. 1984. X-Ray fluorescence analysis of some western North American obsidians. Pages 27-61 *in* Obsidian studies in the Great Basin, edited by R.E. Hughes. Contributions of the University of California Research Facility No. 45. Berkeley.

Newman, M.E. 1990. The hidden evidence from Hidden Cave, Nevada. Unpublished Ph.D. dissertation, University of Toronto, Canada.

Newman, M.E., R.M. Yohe, H.E. Ceri, and M.Q. Sutton. 1993. Immunological protein residue analysis of nonlithic archeological materials. Journal of Archeological Science 20(1):93-100.

Otis, R.M., R.B. Smith, and R.J. Wold. 1977. Geophysical surveys of Yellowstone Lake, Wyoming. Journal of Geophysical Research 82:3705-3711.

Richmond, G.M. 1976a. Surficial geologic history of the Canyon Quadrangle, Yellowstone National Park, Wyoming. For use with map I-652. U.S. Geological Survey Bulletin 1427.

1976b. Surficial geologic map of the Canyon Quadrangle, Yellowstone National Park, Wyoming. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-652.

Thompson, R.S., C. Whitlock, S.P. Harrison, W.G. Spaulding, and P.J. Bartlein. 1993. Climatic changes in the western United States since 18,000 ^{14}C yr B.P. Pages 468-513 in H.E. Wright Jr., J.E. Kutzbach, T. Webb III, W.F. Ruddiman, F.A. Street-Perrott, and P.J. Bartlein, editors. *Global Changes Since the Last Glacial Maximum*. University of Minnesota Press, Minneapolis.

Whitlock, C. 1993. Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks. Ecological Monographs 63:173-198.

Wright, G.A., and H. Chaya. 1985. Obsidian source analysis in northwestern Wyoming: Problems and prospects. Plains Anthropologist 30:237-242.

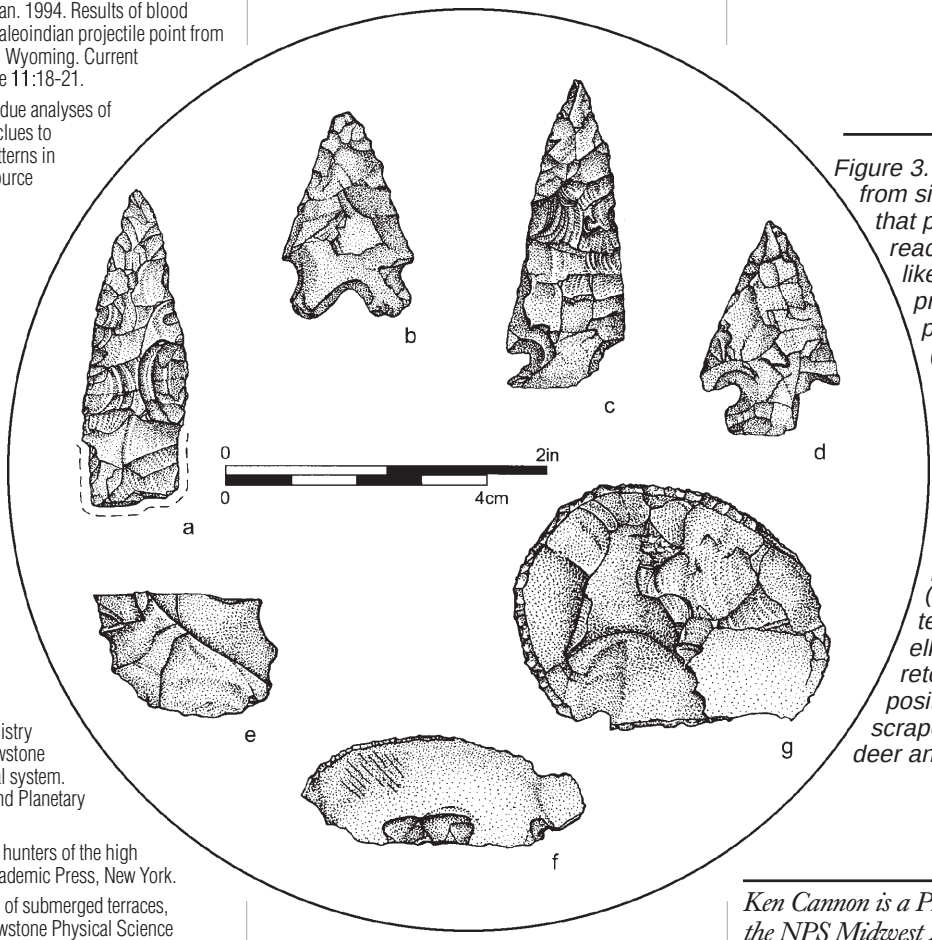


Figure 3. Flake stone tool artifacts from sites around the lakeshore that produced positive anti-sera reactions: (a) chalcedony Cody-like (ca. 9,000 years b.p.) projectile point that tested positive for rabbit anti-sera; (b) basalt Oxbow (ca. 5,000 years b.p.) projectile point; (c) chert Avonlea-like (ca. 2,000 years b.p.) projectile point that tested positive for deer anti-sera; (d) chert corner-notched projectile point basalt that tested positive for bear anti-sera; (e) retouched basalt flake that tested positive for deer and elk anti-sera; (f) chert retouched flake that tested positive for canid; (g) chert scraper that tested positive for deer anti-sera.

Pelton, J.R., and R.B. Smith. 1979. Recent crustal uplift in Yellowstone National Park. Science 206:1179-1182.

Pierce, K.L., K.P. Cannon, G.M. Crothers. 1994. Archeological implications of changing levels of Yellowstone Lake, Yellowstone National Park, Wyoming. Current Research in the Pleistocene 11:106-108.

Pierce, K.L., K.P. Cannon, G.M. Crothers, G. A. Meyer, and M. Rubin. 1993. Backflooding upstream from the resurgent dome of the 0.6 Ma Yellowstone Caldera—Two backflooding cycles in the last 8,000 years (abstract). Eos 74(43):592.

Reeve, S.A. 1989. Prehistoric settlement at the Yellowstone Lake outlet, Yellowstone National Park, Wyoming. Manuscript on file at the Midwest Archeological Center. Lincoln, Nebraska.

Ken Cannon is a Project Archeologist with the NPS Midwest Archeological Center in Lincoln, Nebraska. Since 1989, he has directed numerous archeological projects in Yellowstone. His phone number is (402) 437-5392 and his Internet address is "ken_cannon@nps.gov". Ken Pierce is a Geologist with the U.S. Geological Survey in Denver, Colorado, and his phone number is (303) 236-1244. George M. Crothers is a Ph.D. candidate in anthropology at Washington University in Saint Louis, Missouri; (314) 935-5252, e-mail: "gcrothers@artsci.wustl.edu".

Meetings of Interest

August 8-10 Contact the Office of Conference Services at Colorado State University, Fort Collins, CO 80523 for details of the Symposium on Repellents in Wildlife Management to be held in Denver, Colorado.

September 12-17 Portland, Oregon, plays host to this year's Annual Meeting of The Wildlife Society. Plenary sessions will focus on long-term research on keystone species with implications for ecosystem management. For more information, contact The Wildlife Society, 5410 Grosvenor Lane, Bethesda, MD 20814-2197; (301) 897-9770.

September 14-16 The northwest chapter of the Society for Ecological Restoration is sponsoring the conference Taking a Broader View to be held in Seattle, Washington. Session topics include: wetland, stream, arid lands, alpine, urban, and wildernes restoration; exotic plant and animal control, mining revegetation, coastal systems, restoration philosophy, and the role of native plant nurseries in restoration, etc. For more information, contact Tim White (206) 453-5000, Sono Hashisaki (206) 545-1117, or conference registration, 1207 Seminole Highway, Madison, WI 53711; (608) 262-9547.

September 17-20 Yellowstone National Park will host Symposium on Biodiversity, Ecology, and Evolution of Thermophiles (organisms that thrive in hot water) at the Old Faithful area. Participants will discuss biodiversity prospecting in national parks with special attention given to the recent debate over commercial development of publicly owned, financially valuable research specimens, such as *Thermus aquaticus*. For more information, contact Bob Lindstrom at (307) 344-2234 or through e-mail "bob_lindstrom@nps.gov".

October 1-5 Partners In Flight, the international neotropical migratory bird conservation organization, will hold an international workshop in Cape May, New Jersey. Entitled, Building Consensus for Action: Developing a Strategy for a National Conservation Plan, the talks will focus on research, monitoring, management, education, fundraising, and cooperation. For more information, contact Partners In Flight, c/o D. Lawrence Planners, 1125 Atlantic Avenue, suite 634, Atlantic City, NJ 08401; fax (609) 348-4433.

October 5-9 The National Recreation and Park Association will hold its annual conference in San Antonio, Texas. Contact the association for further information: 2775 S. Quincy St., Suite 300, Arlington, VA 22206; (703) 820-4940.

October 8-14 The Smithsonian Institution will hold a training workshop on GIS and remote sensing in Front Royal, Virginia. To participate, get in touch with Rose Meier, Conservation and Research Center, Smithsonian Institution, Front Royal, VA 22630; (703) 635-6500 and e-mail "nzpcrc01@sivm.si.edu".

October 18-22 The 53rd Annual Plains Anthropological Conference gears up this fall in Laramie, Wyoming. Contact Sue Powell at (307) 766-2124 or e-mail "olbconf@uwyo.edu" for more information.

BULK RATE
POSTAGE & FEES PAID
U.S. Department of the Interior
Permit No. G-83

PARK SCIENCE
Integrating Research and Resource Management
National Park Service
Natural Resources Publication Office
12795 W. Alameda Parkway
P.O. Box 25287 (WASO—NRPO)
Denver, CO 80225-0287

☆GPO 673—049