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USGS and NPS: Science Partners In the Parks

By Dallas Peck
Director, U.S. Geological Survey

This special earth and water science issue of *Park Science* is just the latest display of the long-term partnership between the U.S. Geological Survey and the National Park Service. Actually, the partnership between us, between the national parks and the earth, water, and mapping sciences, began long before there was a National Park Service or a U.S. Geological Survey.

That early partnership was based very much on exploration and discovery. The beauty and exciting geology of the landscape were natural magnets that drew some of the nation's first geologists to map, study, and defend the Crown Jewels before they were added to the protected public domain.

Two of these early explorers and defenders of the not-yet national parks, Clarence King in Yosemite and John Wesley Powell in the Grand Canyon, carried out scientific investigations that would help build careers that made them the first and second directors of the USGS.

Our century-old partnership has grown steadily. Since the USGS was founded in 1879, hundreds if not thousands of USGS scientists have worked or studied in national parks at some time during their careers. I am personally proud to be part of that tradition. Several decades ago I worked for 2 years at the USGS Hawaiian Volcano Observatory in Hawaii Volcanoes NP, monitoring eruptions of Kalauea Volcano. Someday, when my turn as Director of USGS is done, I hope to return to my field studies of Sierra Nevada granites in Yosemite NP.

Why have earth scientists spent so much time in the national parks? Because that is where the earth has revealed some of its best science. To study volcanoes, one must go to volcano country. To study granites, one heads for granite mountains. Scientists are far from immune to the beauty of the parks, but what draws us is the challenge of describing and exploring the forces and processes that built and continue to shape volcanic islands and mountain chains.

We could get into a chicken and egg argument: which came first, the beauty or the science? Was it beauty or science that drew the first explorers, that made the winning arguments to convince the public, that laid the groundwork for establishment of the first parks?

Continued on back cover

Tracking Dinosaurs in Virginia and Arizona--USGS Scientist Ron Litwin (left) discusses casts of dinosaur tracks with Dallas Peck, Director of the U.S. Geological Survey, and Eugene Hester, Assoc. Dir. for Natural Resources of the NPS (right). The dinosaur footprints, found during a 1991 civil engineering project in Manassas, VA, are typical of those found recently throughout the Culpeper Basin. The basin that lies between Frederick MD and Culpeper, VA is the same geologic age as Petrified Forest NP in Arizona. Cooperative research by USGS and NPS scientists on both sites is not only improving the understanding of dinosaur behavior, but also providing a clearer picture of weather and habitat conditions between 225 and 150 million years ago.

Hester and Peck unveiled the dinosaur tracks as part of a new display at the USGS National Center, Reston, VA. More than 10,000 people have viewed the tracks since the display opened in spring 1992.

USGS geologists found fossil pollen and spores from evergreen trees, mosses, ferns, horsetail rushes and other plant life in rock layers above and below the track site. These microscopic fossils are from the Early Norian part of the Triassic Period, approximately 215 million years ago. The group of pollen and spore fossils is nearly identical to those studied in rocks exposed in the Petrified Forest NP.

USGS and NPS scientists have collaborated on many geologic problems, whether the geologic history of Crater Lake, thermal changes of geysers at Yellowstone volcanic field, or the age of artifacts found in glacial deposits in Alaska. Members of both bureaus have much to learn from one another about the natural setting of our national parks, which comprise nearly a quarter of all land in the western United States.

PARK SCIENCE

NATIONAL PARK SERVICE

WINTER 1993

A report to park managers of recent and on-gong research in parks with emphasis on its implications for planning and management

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editorial

The 7th Annual Conference on Research and Resource Management in Parks and on Public Lands (Nov. 16-20, 1992 in Jacksonville, FL) spoke eloquently in the tongues of many public and private agencies to the increasingly complex nature of resource management today and to the urgent need for scientists and historians to *communicate* their findings....not just to one another, but to resource managers and to the public.

"Partners in Stewardship," the conference theme, was intended to intensify communication among scientists, historians, and the managers of natural and cultural resources. Speaker after speaker testified to the mounting complexity of air and water quality, the dwindling biological diversity, the uncertain consequences of global climate change, and the rapidly changing public perception of what constitutes recreation in public lands. A parade of spokespersons from NPS, USFS, USFWS, the Bureaus of Reclamation and Land Management, and from "watchdog" groups reminded the conference of the social, political, and economic factors that bear heavily on management of natural and cultural resources.

In the course of 5 days of plenary and concurrent sessions, (and some initial confusion over conference objectives) an emergent theme was the dawn of a third era in the evolution of protected areas: from preservation (John Muir) and conservation (Gifford Pinchot) to **sustainability** (the consistent new note throughout all areas of the conference.) The sharing of vision and experience added up to "staying ahead of the curve" of rapid change in our culture and recognition of how that change is writing itself on the face of our land and waters. In case after case, it became apparent that the implications of research findings must be communicated to the public users of protected areas, for out of the public's perceptions grow the public's expectations--and these are what, inevitably, **will be served**.

Gene Hester (NPS/AD for Natural Resources) described the binary vision (natural and cultural) currently being focused through such activities as GIS, I&M, and Resource Management Plans. He cited both the Vail conference (October 1991) and the NAS Report (August 1992) as having "helped us recognize two main questions: Do you know what your problems are? and Do you know what you're going to do about them?" The answers, he suggested, require the very best of both natural and social sciences.

Dr. Hester alluded to the 5-Year Strategic Plan, designed as implementation of the Vail and NAS agendas (see Denny Fenn article, p.17 this issue) and stressed the necessity of on-going linkage among scientists, historians, and resource managers.

A booklet of conference abstracts is available in limited quantities from the George Wright Society, PO Box 65, Hancock, MI 49930. Selected papers from the conference will be published in 1993.

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Channel Margin and Eddy Bar Deposition Along the Colorado River in Grand Canyon NP

by J. Dungan Smith and Edmund D. Andrews

The characteristics of biologically important, riverine environments depend directly on the nature of flow and sediment transport in the river channel, and on the mechanisms and rates of exchange of sediment between the deposits near the banks and the channel. Owing to the sensitivity of the riparian habitat to riverine processes, alteration of the river discharge or the sediment input can have a substantial impact on this important ecological zone. Consequently, the choice of dam release regimes should be guided by a scientifically founded, environmentally sensitive management plan. Such a plan should be based on a precise knowledge of the dominant flow and sediment transport processes in the river and on a comprehensive understanding of the interplay of these physical processes with the salient biological and chemical features of the riparian zone. Since 1983, the Glen Canyon Environmental Studies Office of the U.S. Bureau of Reclamation has supported a comprehensive set of investigations to determine the effects of operational flow releases from Glen Canyon Dam on the riparian and aquatic resources of the Colorado River. Many individuals representing several federal and state agencies have contributed to this effort. Research concerning the downstream changes in flow characteristics under various discharge regimes, the associated transport of sediment, and changes in important channel deposits has been the object of a cooperative effort by the NPS and the USGS. The goal of this research is to develop a comprehensive model that can be used to study the response of the riparian ecosystem of Grand Canyon NV to alternative flow regimes.

Canyon Geomorphology

The Grand Canyon began to form about 8-10 million years ago as the Colorado River cut deeply into the rising Colorado Plateau. As a consequence of the deep channel incision, debris from rock falls (talus) and bedrock, rather than fluvial sediment, are the most common bank materials. Furthermore, tributary channels are short and steep. Occasional debris flows and large floods in these tributaries add coarse material to the main channel in the form of deposits that partially block the channel. These constrictions cause backwater pools on the upstream sides, rapids over the top, and the cutting of deep pools into bedrock downstream of the debris deposits. Both the upstream and the downstream pools are depositional sites at moderate river flow, but the downstream pools become active zones of scour under prolonged periods of extreme discharge. Since closure of the Glen Canyon Dam in 1963, the peak flows have been too small to move the coarsest material.

The large load of suspended sand and irregular width and depth of the Colorado River results in a channel with numerous local areas of erosion and deposition. Connected bands of sand along the channel edge are called "channel margin deposits". In the Grand Canyon, these now provide the substrate for narrow zones of dense vegetation, which, in turn, form habitat for a wide variety of terrestrial organisms. Larger accumulations of sediment are deposited at the downstream ends of rapids where abrupt increases in channel width cause flow separation and hence, stream edge recirculation zones (called eddies). In these eddies the near-bank current is in the up-river direction, and the prolonged retention of sediment laden water entering them from the main channel results in rapid deposition of the suspended sand and silt. "Eddy bars" created beneath recirculation zones during periods of high flow and exposed when the river stage falls can be quite large and are a more suitable substrate for riparian vegetation than debris fans, (see Fig. 1).

Figure 1. An eddy bar deposit downstream from Nankoweap Canyon. Such deposits are comonly the only suitable camping sites for river trips. This bar was deposited by large discharges during 1983-85, and now (1992) thickly vegetated.

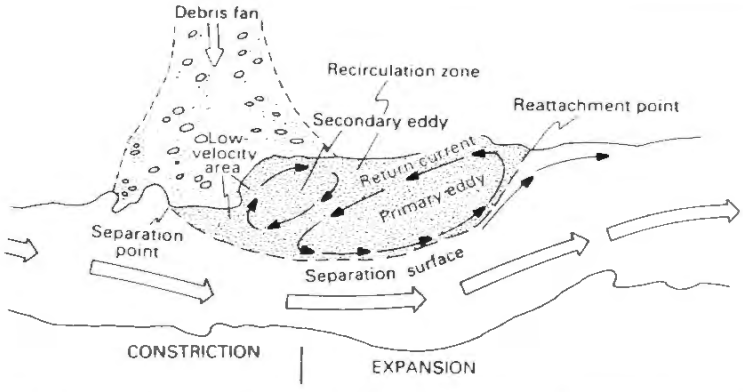

Figure 2. Flow pattern in a typical recirculation zone, *(figure from Schmidt and Graf, 1990)*

Flow and Sediment Transport

Daily, monthly and annual flows of the regulated Colorado River are very different from those of its free flowing predecessor. These changes in flow patterns have had a significant effect on the downstream environment. Prior to the construction of Glen Canyon Dam, the Colorado River through the Grand Canyon had an average annual discharge peak of more than 90,000 cubic feet per second (cfs) and, except during major flash floods in tributaries, discharge and river stage changed slowly from day-to-day. Operation of Glen Canyon Dam has reduced the maximum annual peak discharge to less than 33,000 cfs in most years, but has greatly increased the daily range of discharge. Depending on electrical power demand, daily fluctuations of the river stage can reach 14 feet. This change from seasonal to daily variation has had a significant effect on the riparian environment. In addition, the main supply of sediment to this reach of the Colorado River is now deposited behind Glen Canyon Dam. The annual predam sediment flux past the mouth of Bright Angel Creek (near Phantom Ranch) was 95 million tons of sand, silt and clay. Today only about 11 million tons per year of sediment, on average, are supplied annually by tributaries to the Colorado River downstream from Glen Canyon Dam. Although these changes in river discharge and sediment input are large, Glen Canyon Dam still can be operated to maintain critical river resources, including

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Coastal Geology and National Parklands:

Robert B. Halley and Richard W. Curry

More than 50 percent of all Americans live within 50 miles of our Nation's oceans or the Great Lakes. As population increases along the coasts, so does pressure on coastal resources. More than a dozen National Parks and the many national seashore areas share common concerns with the USGS Coastal Geology Program about the impacts of man and nature on these sensitive areas. Coastal environments are typically in a continual process of change. This change may be so slow as to be imperceptible on the human scale, becoming apparent only over periods of geologic time. Or, coastal change may be catastrophic and as violent as recently exemplified by Hurricane Andrew. Nature presents the challenge to humankind of incorporating these processes of change into plans for conservation and preservation.

Geological processes play important roles in coastal evolution and ecosystems. In many areas, coastal erosion is the most visible coastal process. Erosion presents a hazard along developed coasts and is a process which modifies many undeveloped coastal areas. Less apparent, but no less important, pollutants associated with fine-grained sediments travel through coastal systems to accumulate in low energy areas such as coastal swamps and lagoon floors. Coastal wetlands, important nurseries for marine and terrestrial wildlife, are altered by natural sedimentation and infilling, by sea-level change and by erosion of protective barrier islands. A thorough understanding of these coastal processes is required to accurately predict their future effects and to evaluate the success of management plans.

Issues concerning coastal geology and pollution merge in peninsular Florida where urban and agricultural demands impact the Everglades and Biscayne NPs. In Florida, as well as in many other states, the USGS Coastal Program and the NPS have obvious common ground for coastal research. Additionally, because of its tropical climate, coastal issues in south Florida have counterparts in National Park areas of Puerto Rico, U.S. Virgin Islands, Guam, and other tropical regions associated with the United States.

One example of coastal research sponsored jointly by the USGS and NPS examines the history of runoff in southeastern Florida. Runoff is an important environmental variable in coastal systems. In south Florida, runoff strongly influences the salinity of nearshore environments. Natural and anthropogenic nutrients are brought to coastal water bodies by runoff. Increasingly, human-made (anthropogenic) pollutants such as heavy metals may also be intro-

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CHANNEL MARGIN. . .CONT'D FROM PAGE 3

channel margin and eddy bar deposits.

Deposition and Erosion of Eddy Bars

When a river channel widens abruptly, the inertia of the rapidly moving fluid near the center of the channel causes this high velocity core to continue more or less straight downstream, departing or "separating" from the abruptly diverging bank. Flattening of the downstream component of the river surface slope, however, also causes the high velocity core to decelerate and spread laterally. Eventually the core of rapidly moving fluid reaches the bank or "reattaches". Adjacent to that bank between the points of separation and reattachment the fluid moves in the upriver direction (recirculates) Figure 2. Typically the high velocity core decelerates at an increasing rate, causing the boundary between the slowly moving fluid in the outer part of the recirculation zone and the more quickly moving fluid at the outer edge of the high velocity core to curve towards the bank. This curvature causes a net outward flow near the river surface and a net inward flow near the bottom, producing an extremely effective trap for suspended sand which travels in higher concentration near the river bed. Once this sand is carried into the recirculation zone where the turbulence levels are substantially lower than in the main channel, it settles to the bottom and moves as bed load, that is, by rolling and hopping along the bottom.

Only during periods of exceptionally high flow is sand carried through the recirculation zone in suspension, and even then most of the material is retained in and deposited beneath the eddy. This process operates on all scales, but small embayments fill rapidly with sediment and the deposits often are washed out again as the stage rises. Such small-scale deposits usually are preserved only when produced by very high-stage events, and preservation is aided substantially when relatively dense stands of vegetation become established between infrequent large floods. The outer edges of these channel margin deposits are eroded by subsequent flows of lower stage, causing cut banks that give the impression of extremely rapid erosion. These channel boundaries, however, are very dynamic and rapid erosion at one range of discharge is often followed by rapid deposition. Conversely, slow erosion often is a consequence of negligible deposition.

Channel margin deposits and eddy bars are eroded by several mechanisms. The most effective of which occurs when flow overtops an upstream obstacle resulting in elimination of the recirculation zone and a return to downstream flow near the bank. This situation usually produces a large local increase in the sediment transport rate and, hence, erosion of the previously deposited material. Sand deposits also can fail and slump into the channel when erosion removes the supporting toe of the sand bar. This mechanism is enhanced by an elevated water table that creates excess pore pressure in the deposit, when river stage falls quickly. Wind erosion of exposed eddy bars also is an effective process degrading these deposits.

The continued presence of high stage channel margin and eddy bar deposits in the Colorado River through Grand Canyon NP depends on their occasional reconstruction during high discharge events. These deposits, in fact, consist of sediment grains for which the downstream movement has been interrupted temporarily. Although a particular sand bar may appear to persist for years or decades, there is a continued exchange of sediment between the deposit and the river. Eddy bar deposits exist where there is sufficient deposition in the long term to replace local erosion. A proper accounting of the complex interplay of processes responsible for bar deposition and maintenance, each occurring at a rate that depends on the flow and available supply of sediment, requires a combination of precise field observations and carefully constructed, fluid dynamic models.

Conclusion

There is a very close relation between the discharge history of a deeply incised river in an arid region, and the riparian environment of that river. Owing to the incision and the need for water in surrounding areas, such rivers are prime candidates for impoundment. Unfortunately, the environmental effects of flow regulation on such rivers can be considerable and until recently these effects have not been carefully assessed when planning dam operations. The Glen Canyon Dam, which discharges into the Marble and Grand Canyons, is an obvious example of a structure that could be managed more efficiently using recently procured scientific knowledge. Extensive research currently being carried out concerning flow, sediment transport, eddy beach deposition and maintenance of riparian habitat in this segment of the Colorado River is producing a sound foundation for environmentally sensitive management of this dam. It is likely that this research will lead to knowledge and operational models that also can be used effectively for river management in other national parks and recreation areas.

Smith and Andrews are with the USGS in Denver, CO.

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An Example from Biscayne NP

duced with runoff. Understanding the history of runoff in Biscayne NP provides valuable evidence of the tolerance of tropical coastal ecosystems to influences from adjacent land areas.

Arguably the greatest anthropogenic impact in south Florida is the modification of its natural hydrogeology by a system of canals, salinity barriers, impoundment dams, water conservation areas, and pumping stations (Klein, 1973). The "drainage" of the Everglades for agricultural use began at the turn of the century. Disastrous floods in 1926 and 1928 prompted continued modification for flood control, as did the 1947 flood which beralded the establishment of the Florida Water Management Districts (Huser, 1989). By the time Everglades Park was established, the opportunity to collect detailed information about the natural state of south Florida hydrogeology had passed. Knowledge of the natural state of south Florida hydrogeology must be reconstructed through historical records, geological records, and modeling efforts.

During the rainy summer and fall, the water table in the Everglades rises above the ground and runoff occurs as sheet flow over topographic low areas along the coast. Prior to this century, most of the flow was to Florida Bay and the Gulf of Mexico. Eastward flow was blocked by a topographic feature known as the Atlantic Coastal Ridge. Most development after 1900 has taken place on the relatively high ground of the ridge which attains elevations of 8 meters above sea level. Drainage of the Everglades was facilitated by dredging canals through the ridge. Many of these canals drain into the Atlantic though Biscayne Bay. During the dry winter months saltwater intrusion is prevented by salinity gates at the canal mouths and by maintaining water levels in the canals from impoundments inland.

Florida groundwater typically contains dissolved soil acids that fluoresce in the visible range when excited by ultraviolet light (Averett and others, 1987). During times of increased runoff from the land, these fluorescent compounds mix with coastal marine waters and are transported to nearshore reefs. There, the soil acids are incorporated into the growing coral skeletons and preserved in the aragonite skeletal matrix. Several species of corals produce annual density variations in their skeletons which, like tree rings, can be used to date skeletal intervals. This science, known as sclerochronology, has shown that some coral species may grow for several centuries (Hudson and others, 1976), and may provide a record of runoff from adjacent land areas based on fluorescence data.

Figure 1 illustrates density and fluorescent images for a coral sample from Biscayne NP. The figure represents a portion of a coral record that spans 117 years. Image analysis of the entire record provides a relative fluorescence record for more than a century shown in Figure 2. The record can be divided into three time periods. The period 1870 - 1920 is characterized by low fluorescence punctuated by occasional years of high fluorescence. This pattern is similar to the pattern of measured rainfall in south Florida and is thought to represent the natural variability of runoff. The years from 1920 to 1955 span the drainage and flood control periods and reflect frequent high runoff years associated with dredging. During the late 1950s and 1960s water management practices were instituted to conserve runoff during the wet season to maintain dry season water levels. This period is recognized in the fluorescence record by the absence of years characterized by high fluorescence from about 1955 to 1987. Coral fluorescence therefore provides a proxy record of runoff into Biscayne NP and a measure of the natural variability in the south Florida hydrogeological system before it was altered.

Coral fluorescence provides a geological avenue for the investigation of freshwater influxes into coastal reef ecosystems. Other projects within the USGS Coastal Program carry out applied research on a variety of problems related to coastal erosion and pollution. Readers are encouraged to browse Sallenger and others (1992) for a more complete description of program activities.

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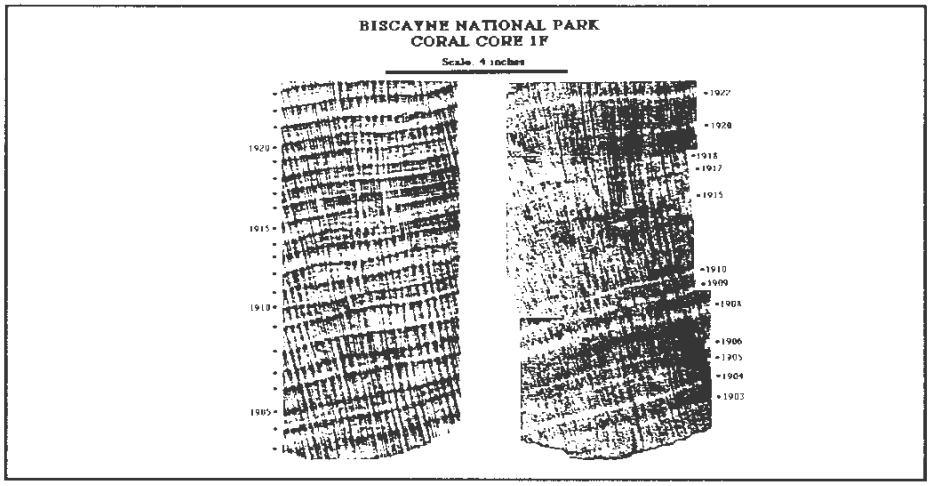

Figure 1. Images of coral skeleton samples. Image on the left is an x-radiograph revealing density variations that define annual banding in this sample of *Montastrea annularis*. Image on the right is the same sample in short-wave UV light. Light bands are fluorescing and are given dates based on density bands exhibited by the x-radiograph. Annual growth increment averages 1 cm.

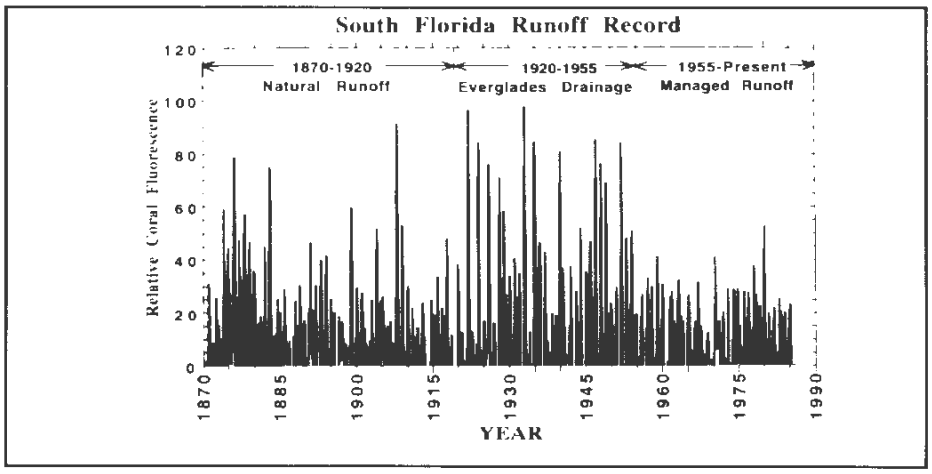

Figure 2. Plot of the relative fluoresence of annual skeletal growth intervals between 1870 and 1987. Fluorescence intensity is a proxy for fresh-water runoff from south Florida into Biscayne NP nearshore reefs.

Volcano Studies in National Parks

--USGS helps NPS to keep a watchful eye on restless volcanoes while improving our understanding of how volcanoes work--

James Riehle, Raymond Herrmann, Charles Bacon, Barbara Samora, and Christina Heliker

Of 65 U.S. volcanoes that have been active over the past 2,000 years (Wright and Pierson, 1991), about 20 are within or near a national park or monument (Fig. 1). One park, Yellowstone, was the site of extensive volcanism as recently as 70,000 years ago and continues to be restless as evidenced by slow ground deformation there. An active volcano in a park can challenge park managers: eruptions are both a grand natural spectacle and a scientific laboratory, but they can threaten park visitors and facilities as well.

Eruptions involve a variety of processes. A lava flow can bury everything in its path. A vent and associated ground deformation can develop where none had been before, damaging roads and facilities. Explosive eruptions such as Mount St. Helens (1980) typically have widespread impact: airborne ash can fall thick enough to collapse roofs miles from the volcano, pose a hazard to aviation, and can be a nuisance up to hundreds of miles away. Fast-moving pyroclastic flows incinerate or suffocate anything in their path and are mobile enough to jump ridges. Floods and landslides can occur even without an eruption; mudflows in the Philippines, for example, have resulted from rain-induced erosion of 1991 ash deposits of Mount Pinatubo. The mudflows have forced thousands of villagers to evacuate their homes and will recur for years.

Geologic information is of value to park managers for siting and design of facilities and trails, for preparing emergency plans prior to natural disasters, and for interpreting the geologic history of a park. Information about volcanoes is the focus of the USGS Volcano Hazards Program (VHP), which has grown since 1980 in response to eruptions or volcanic unrest. VHP scientists are working with NPS managers and resource specialists in several parks, providing hazard maps, advising about eruptive activity, and helping with interpretation. Equally important, studies of volcanoes in these parks serve to better our understanding of how volcanoes work and to improve monitoring techniques. Three parks serve to illustrate the benefits of these cooperative efforts.

A) Hawaii Volcanoes NP (HVNP)

The USGS Hawaii Volcano Observatory (HVO), the oldest volcano observatory in the U.S., is located at the summit of Kilauea Volcano. Kilauea and nearby Mauna Loa are partly within HVNP. Because these volcanoes are frequently active, HVO has been fertile ground for the development and testing of volcano monitoring techniques that can be used throughout the world. HVO studies have also expanded our understanding of how basalt magma forms, rises, and erupts. HVO staff offer lectures and field trips to HVNP staff and have provided a volcanic hazard map that is used by park planners (Wright and others, 1992).

The present ongoing eruption of Kilauea began in 1983 (Heliker and Wright, 1991). During eruptions, HVO staff constantly share new information with park staff. Based on HVO predictions, HVNP rangers close roads to the public and evacuate areas where and when lava is likely to break out. HVO also warns of likely sites of ground subsidence caused by underground movement of magma. Park managers and staff rely on HVO interpretations to determine safe viewing areas for visitors and to take preventive measures to control forest fires set by lava flows.

B) Crater Lake NP (CLNP)

Crater Lake is sited in a caldera, a basin formed when a volcano subsided due to rapid

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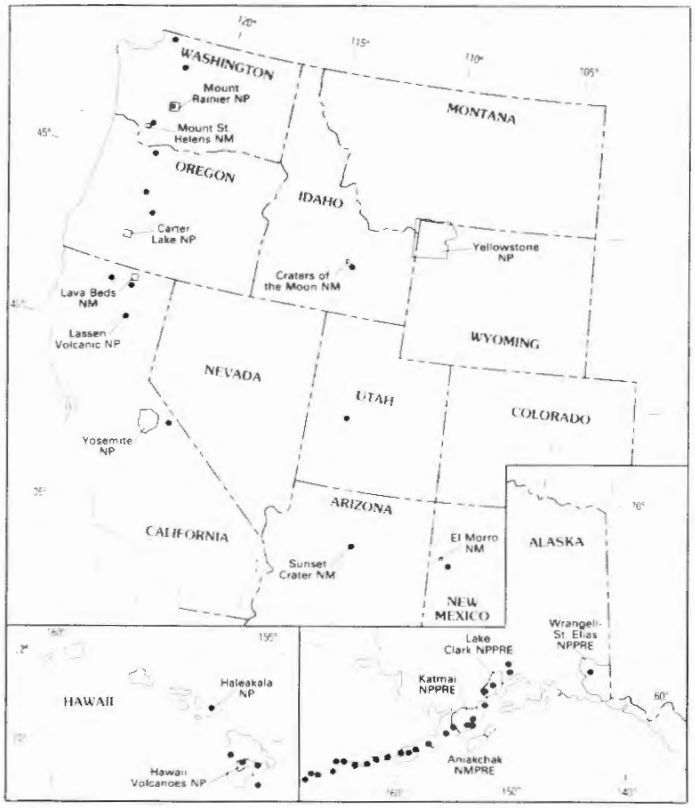

Figure 1. Index showing U.S. volcanoes active in the past 2,000 years (dots; after Wright and Pierson, 1991) and nearby national parks or monuments. NP = national park; PRE = preserve; NM = national monument.

Figure 2. View of Mount Rainier from the Tolmie Peak fire lookout in the northeast corner of Mount Rainier National Park. Note the steep slopes and extensive cover of snow and ice. Photo courtesy of Mount Rainier National Park.

Long-Term Monitoring and Research in Lake Powell

By G. R. Marzolf and Charles W. Wood

Lake Powell, the reservoir behind Glen Canyon dam, is at the heart of the Glen Canyon National Recreation Area (NRA) and is one of the nations's largest reservoirs. Recreation and tourism on Lake Powell, in Glen Canyon NRA, and in Grand Canyon NP are increasing rapidly.

Given historic conflicts over water shortage in the southwest, Lake Powell is one of the most visible reservoirs in terms of water economics and policy. The Glen Canyon dam is crucial for controlling water supply to the Lower Basin of the Colorado River and for generating hydropower. Superimposed on all of this are multiple and overlapping state and federal responsibilities for management and monitoring for compliance with water quality standards and regulations.

Lake Powell is a complex limnological system whose hydrologic regime causes considerable year to year variation in water quality and quantity. The chemically variable flows of the Colorado River into this deep, voluminous reservoir cause a complex interaction between thermal and salinity induced density structure. The high spring flows cause high spatial variability in chemical constituents and biological productivity.

Quality of water the Colorado River downstream from Glen Canyon dam is dominated by these processes in Lake Powell. The discharge volumes and flow velocities of the river discharging from Lake Powell are usually so overwhelming that any subsequent physical, chemical, and biological processes do not change either temperature or the concentrations of most constituents in the entire reach from Glen Canyon dam to Lake Mead. There may be tributary influences during infrequent and unpredictable flooding, but most of the time Lake Powell discharge dominates the water quality of the river.

Figure 1. Lake Powell is located in the canyon country of Utah-Arizona. Access to pristine wild lands is part of its recreational attraction.

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VOLCANO STUDIES. . .CONT'D FROM P. 6

emptying of a subsurface magma chamber during a large explosive eruption. USGS investigations at CLNP are focused on the processes by which magma accumulated beneath the volcano and then catastrophically erupted 7700 years ago. Geologic mapping of the volcano and radiometric dating of pre-caldera lavas have improved our understanding of the volcanic history prior to the catastrophic eruption. Results will aid in evaluation of the hazards posed by the volcano and will lead to a better understanding of explosive volcanism elsewhere in the world.

Related studies at CLNP include deformation monitoring. Distances between bench marks on opposite sides of the caldera, and elevations along three road segments, are measured periodically in order to detect changes in horizontal distances and ground tilt that might be related to impending volcanic activity. Other studies, funded partly by the Geothermal Research Program of the USGS, are aimed at understanding the hydrothermal system of hot subsurface fluids that developed after the caldera formed. All post-caldera lavas were vented on the caldera floor, many of them beneath Crater Lake. Post-caldera lavas have been sampled and hydrothermal features on the lake floor have been observed by use of a manned submersible in cooperation with NPS and NPS-sponsored investigators.

C) Mount Rainier NP (MRNP)

Mount Rainier is arguably the most hazardous volcano in the conterminous U.S.: its steep slopes are weakened by fumarolic alteration, it is extensively covered by glaciers, and it is close to a major population area. The most recent eruptions occurred in the late 1800's and an eruption is likely within a few centuries (Crandell, 1973). The volcano poses a major hazard to Puget Sound and Columbia River drainages because of the potential for large mudflows of meltwater generated during an eruption. Even without eruptive activity, landslides and avalanches have occurred several times in the past few thousand years (Crandell and Mullineaux, 1967). Mount Rainier is the second most seismically active volcano in the Cascade Range (Norris, 1991) and is seismically monitored by the University of Washington and the USGS.

The volcano is sited within MRNP and is a potential threat to park visitors and facilities. Additionally, parts of Puget Sound communities outside MRNP are built on mudflows as young as 500 years (Scott and others, 1990). The NPS, USGS, and other state and federal agencies hope to better determine the nature of the hazards posed by Mount Rainier. NPS personnel and state, federal, and university geologists met recently to discuss ways to enhance monitoring, to improve our understanding of how the volcano works, and to translate these studies into a comprehensive disaster-response plan (Swanson and others, 1992).

Reihle is with the USGS, in Reston VA; Herrman is with the NPS, Fort Collins CO; Bacon is with USGS, Menlo Park CA; Samora is with the NPS Mount Rainier NP WA; and Heliker with USGS, Hawaiian Volcano Observatory HI

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General Background

In the United States, about 2,500 reservoirs with capacities of 5,000 acre feet or more, provide about 480 million acre feet (MAF) of storage, thus, about 25 percent of the annual runoff can be stored. Storage capacity is dominated by large reservoirs. Almost 90 percent of the total storage occurs in 574 of the largest reservoirs. At full pool volume of 27 MAF, Lake Powell is one of the largest of these, capable of storing up to three years discharge of the river.

The Colorado River drains about 8 percent of the United States. The basin is an arid region where economic development and populations have been limited historically by the availability of water. The river flows through areas managed by the NPS, including free-flowing river reaches and reservoirs. These represent public commitment to resource preservation and recreation. The construction of the reservoirs represents similar commitment to water conservation and development for economic growth. These dual commitments have generated tension and conflict for more than a century. When management goals are incompatible, decisions are more difficult and better information is required. Thus, long-term monitoring and research on Lake Powell respond to real policy and management needs and respond to recent calls for "science for the parks" and "science in the parks" (NAS 1992).

Characteristics of reservoirs

Reservoirs differ from natural lakes in several respects. The drainage basin of a natural lake is typically about 10 times the area of the lake itself, but the drainage basin of most reservoirs is relatively larger (500 times the area of the reservoir is not uncommon). Impoundment changes many natural patterns in rivers. While the resulting reservoirs exhibit many of the same phenomena as occur in natural lakes, they tend to be more affected by water depletions and direct human uses, such as power generation.

The goal of coordinated work among scientists in the Park Service and the USGS is to better understand natural river/reservoir phenomena in order to help (1) document changing water quality conditions, (2) evaluate the implications of all possible management decisions, (3) evaluate the implications of no management actions, and (4) support and evaluate the performance of management actions.

Examples of natural and man induced aging phenomena in reservoirs.

Extinction of endemic species and the invasion of exotic species:

The recent decline of native fishes in the Colorado River is well documented. Four species of this unique fish fauna, now federally listed as endangered, are known to occur in Lake Powell and in associated inflow habitats during at least some part of their life cycle. Effort to prevent their eventual extinction must include investigation of water quality and other water-related habitat requirements. The fate of other aquatic organisms in the face of environmental change is less well known.

Scenic beaches have attracted heavy public use, predicted to increase to six million by year 2000.

Habitat alteration, such as impoundment, also creates new environments, often suitable for invading species. Furthermore, inadvertent transfer of species from native environments to new ones has increased. These may seem to be innocuous events but in some instances exotic species have caused major water resource problems.

Invasions become problems when invading species that have one or more damaging life history features are released from natural control mechanisms and respond with explosive population growth. A recent example in Lake Powell is the Asian clam, *Corbicula*, that spread through the United States in the 1960s. The introduction of predaceous fishes for sport also may have unintended negative effects.

Sediment accumulation:

Sediment deposits represent "interim sinks" for nutrients and contaminants that, prior to impoundment, were transported to the sea. Materials such as organic pesticides, toxic by-products of industry, trace metals and salts from irrigation return flow, agricultural and domestic fertilizers, etc., are of increasing concern to many water users. Between 1963 and 1986, 1.1 billion tons of sediment was deposited in Lake Powell's deltas. Lake Powell's location in the arid west and the fact that it receives return flow from irrigated agriculture suggest that sediments in Lake Powell may represent an extreme case where the study of nutrients and contaminants might be particularly useful.

Eutrophication:

Eutrophication occurs naturally as lakes accumulate nutrients that stimulate biotic productivity but human influence hastens the process and has been implicated in a wide range of problems that degrade water supplies and recreational resources.

The transport of nutrients by rivers has not caused wide-spread eutrophication problems in rivers, however, because planktonic biota are not characteristic of flowing water. Upon impoundment, however, plankton density increases rapidly and responds immediately to nutrient and contaminant inflows. Reservoir eutrophication is more an immediate response to the impoundment of flowing water than an accelerated process in a pre-existing lake. This issue has an additional twist in the case of Lake Powell because of increased recreational use as described below.

Current and emerging issues

Lake Powell is increasingly popular for recreational boating and angling. Public use of Lake Powell for recreation has increased annually reaching 3.2 million visitors in 1992, 1.5 million of these as visitor nights camping on the shores, with a projected increase to 5 to 6 million annually by the end of 1999.

A consequence to Lake Powell of this popularity is the problem of waste management in a pristine area. The list of potential contaminants includes human excreta from chemical toilets or from lakeside camping, waste water that is used for domestic washing in galley, shower, and sinks, as well as fuel spills and trash (paper products, cans, and lost equipment). There are few public access points that have the capability to treat sewage. The present facilities for handling sewage and trash are heavily taxed and inadequate to deal with the projected use.

Historically, increasing salinity associated with irrigation return flows after the construction of diversion works has been the primary water quality concern. Most available information was collected for salinity evaluation and modeling and other aspects of water quality work received less attention.

Water quality monitoring at shoreline sites on Lake Powell recently confirmed contamination by fecal bacteria in excess of established standards for body contact recreation. Addi-

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tionally, waste-water discharges could potentially affect eutrophication, particularly in embayments and canyons with limited circulation. With growing use, these problems are expected to increase.

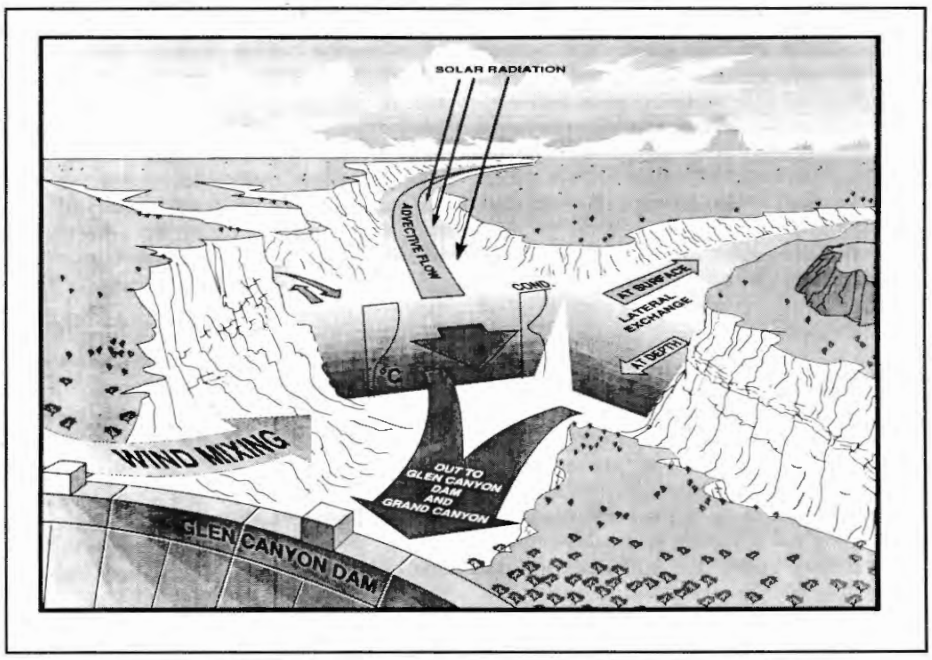
As Lake Powell was filling in the 1970s, research supported by the National Science Foundation laid the ground work for extensive work in Lake Powell, but the value of consistent and coherent long-term monitoring and research was not yet persuasive. Since Lake Powell filled in 1980 the river has had unusually high flow in 1984, 1985, and 1986 and unusually low flow since 1987. Currently, because of drought, Lake Powell is about half of its full volume. It is unfortunate that such a program was not in place to document trends and learn through this unusual decade.

Present conceptual understanding of Lake Powell relies heavily on these data, but full interpretation is difficult because attention since the '70s was focussed singularly on salinity problems to the exclusion of biological and chemical processes. Recently new concerns about the quality of inflow waters are related to irrigation, waste disposal and petroleum or mineral development in the upper basin. Because attention to preserving the integrity of this water resource is urgently required, the Park Service and the USGS have joined with the other agencies to address that issue.

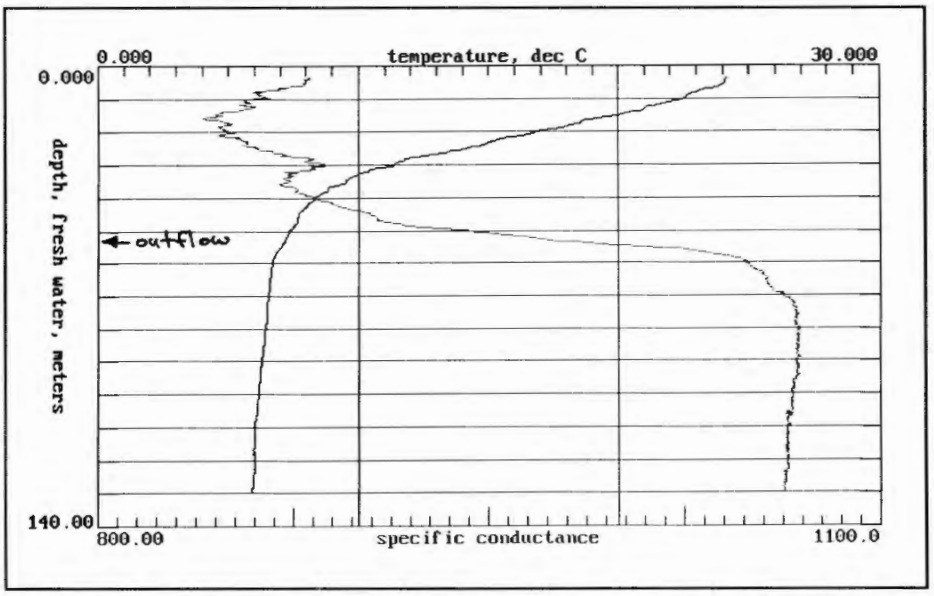
The NPS has the primary management mandate for Lake Powell and surrounding lands. Even so, other agencies have regulatory and management responsibilities and research interests. State Departments of Environmental Quality and of Game and Fish or Wildlife in Arizona and Utah, the NPS, the USGS, the Bureau of Reclamation, and the USFWS all have legal mandates for elements of operation, management, study, and understanding of Lake Powell.

The opportunity to coordinate programs, maximize the efficient use of funds already being spent to address Lake Powell's problems, and to develop new cooperative proposals for monitoring and research is extraordinary. Several interagency meetings were held at Glen Canyon NRA in 1992. They resulted in a plan for interagency monitoring and research that includes expanded water quality monitoring under existing programs by NPS and Reclamation, and a new effort to investigate contaminants in gamefishes by the USFWS. The USGS was given the charge to develop an integrated plan that serves monitoring requirements *and* also addresses the information gaps identified by participants in these work sessions.

Marzolf is with the USGS Water Resources Division; Wood is with the NPS Glen Canyon NRA.



Events and patterns in the lake are dominated by the hydrologic regime of the Colorado River; imposing a strong longitudinal effect on chemistry and biology. Superimposed on this effect is the vertical pattern resulting from insolation and density stratification associated with salinity; an important vertical structure in this deep reservoir. Third is the lateral component represented by processes in the tributary canyon embayments, hypothesized to be the most active biological areas in the lake.



A vertical profile of temperature and conductivity (an index of salinity) in Lake Powell near Glen Canyon Dam. The depth of the outflow to the Colorado River varies with lake level. These profiles were measured on July 24, 1992 when the outflow was at a depth of 52 meters.

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Energy and Mineral Resources in and near NP Lands

By Thomas S. Ahlbrandt, Kathleen K. Krohn and Gary C. Curtin

The USGS conducts energy and mineral resource assessments and related research throughout the U.S., including areas within existing and proposed National Park Service lands. The results of these activities provide objective scientific data on which stewardship decisions can be made. The USGS Office of Energy and Marine Geology (OEMG) conducts resource assessments and research in coal, oil, and natural gas, whereas mineral resource assessments and research are conducted by the Office of Mineral Resources.

The Branch of Coal Geology of OEMG conducts research that addresses coal availability and coal quality in coal fields throughout the U.S. (Fig. 1), as well as fundamental geologic controls of coal formation. Surface and subsurface data are used to determine coal quantity, which is compiled by rank, thickness, amount of overburden, and reliability of data. Additional aspects of coal quality (e.g., sulfur content) and geological, land use, and technical restrictions are commonly incorporated to estimate *coal availability*. Although formal coal resource assessments of NPS land have not been routinely performed, many products of the coal investigations program have been applied to answer specific questions concerning existing or proposed park areas. Recent examples include the pre-acquisition coal resource analysis of New River Gorge, West Virginia, and the mapping of both the Chaco Canyon area of New Mexico and the Bryce Canyon NP in Utah.

Prior to establishment of the New River Gorge as a National River, the USGS performed a coal resource assessment of the area. The resulting report, published in 1977, concluded that there are 13 coal beds of sufficient thickness and distribution to allow resource estimation, and that total remaining resources of the 440 sq km. park were estimated to be 151 million tons. The U.S. Bureau of Mines subsequently used this resource estimate as a basis for determining that slightly more than 44 million tons of the coal resources could be considered reserves (economically recoverable). These results provided essential information used to make the decision to include the New River Gorge in the National Park system.

The Chaco Culture National Historical Park has recently been mapped as part of both regional and local mapping projects. Among the products of this research effort published during 1979-1987 by the USGS, the latest map focuses specifically on interpretation of the depositional environments of Cretaceous strata exposed in the canyons, cliffs, and washes of the park. Although these studies determined that only limited coal resource potential exists within the park, they provided clear evidence that the area was a swampy coastal plain approximately 80 million years ago. These conclusions thus provide both resource information that can be used for strategic decision-making and paleogeographic information that can be used for interpretative purposes within the park.

The 1991 publication of the geologic map of Bryce Canyon NP and vicinity is an excellent example of cooperative USGS-NPS work. The report accompanying the map characterizes the entire stratigraphic sequence in the area, including two formations that have the potential of containing significant coal horizons. These are thinned extensions of important coal-bearing sequences to the east (Kaparowits Plateau) and to the south (Knab area) of the park. Although major coal deposits are not expected to underlie the park, this study provides fundamental information about park resources.

It is the responsibility of the Branch of Petroleum Geology of OEMG to assess the oil and gas resources of the Nation, both onshore and in state waters. Those results are incorporated with those of the Minerals Management Service, which conducts similar assessments for offshore federal waters, to produce a comprehensive national assessment. The latest geologic insights and updated oil and gas production data are incorporated to periodically update these estimates. In the most recent national assessment, published in 1989, the USGS for the first time separated the results for Federal, Indian, and native lands (Fig. 2). It showed that the majority of undiscovered, conventionally recoverable oil and gas resources remain on federally managed lands, either onshore or offshore.

The USGS is currently updating the national oil and gas assessment, with completion scheduled for January 1995. For the first time, unconventional resources such as coal bed methane, low permeability reservoirs (e.g., tight gas), gas hydrates, deep basin resources, fractured reservoirs, and heavy oils will be included in the resource estimates. Because many of these resources reside on federal lands liaison positions have been established between the Branch of Petroleum Geology and the NPS, Forest Service, Bureau of Land Management, and Minerals Management Service to facilitate communication regarding the ongoing assessment. The liaison for the NPS is Bruce Heise, who has been involved in several workshops and briefings on the ongoing assessment. In addition to these activities, Bruce is contributing on behalf of the NPS to a USGS Circular entitled *Oil and Gas Resources on Federal Lands*, to be published as part of a series of circulars addressing Public Issues in the Earth Sciences.

The results of the national oil and gas assessments provided the NPS with unbiased estimates of the remaining oil and gas resource potential of our nation, compiled on the scale of geologic provinces and regions. USGS estimates are commonly used as an objective and independent source of information on which land use and other management decisions regarding Federal lands are based. For example, USGS estimates of oil and gas resources in the Arches NP area are currently being used by both the NPS and the Utah Geological Survey to understand the oil and gas potential in that area as input into land management decisions.

The basic building block used in the national assessment to aggregate resource estimates to province, regional, and national scales is the *play*, defined as a group of geologically related, known or undiscovered accumulations and/or prospects that have similar characteristics of hydrocarbon source, reservoir, trap, and geologic history. A compendium of plays identified during the 1989 assessment is currently being published in four volumes as USGS Bulletin 2034, *Petroleum Exploration Plays and Resource Estimates — Onshore United States*. The

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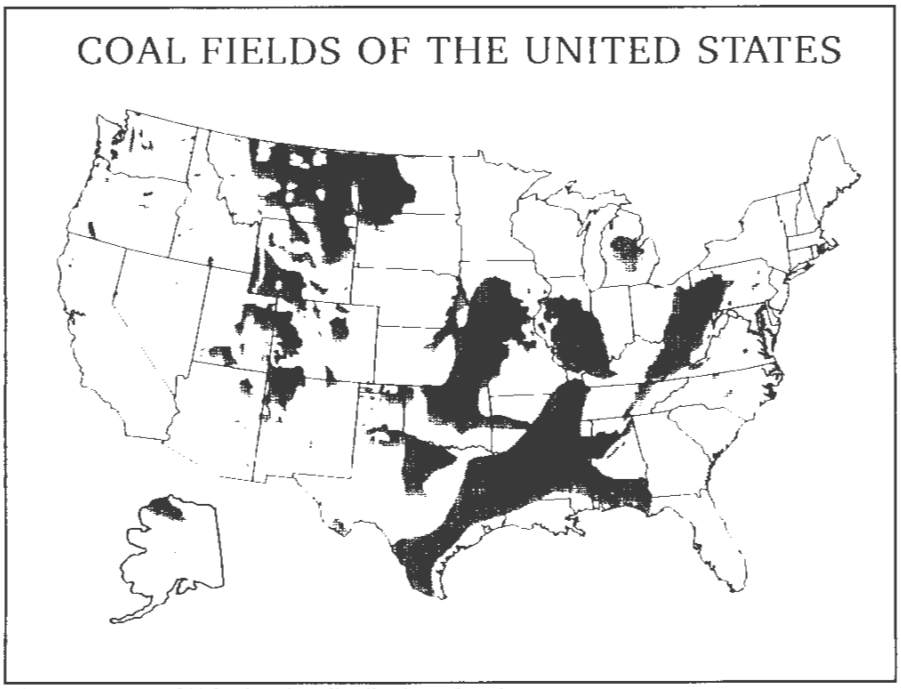

Figure 1. Map of U.S. showing distribution of coal resources.

Geologic Maps and Digital Data Sets: Their Role In Management and Preservation of NPS Lands

Beneath a surficial veneer of soil and vegetation is the highly varied assortment of rocks and sediments that constitute the outermost part of the Earth's crust. Rocks and sediments vary in composition, structure, age, mode of origin, and many other ways; these variations occur both laterally and vertically within the crust. The spatial relations of the many different kinds of rocks and sediments that can be distinguished at or near the Earth's surface are graphically portrayed through the use of geologic maps.

Geologic maps are among the most useful scientific tools available for the interpretation of Earth history. The Earth's crust has been built up, bit by bit, and through an immense amount of time, by processes as diverse as sedimentation on the sea floor, volcanic eruption, and deep-seated crystallization of molten magma; it has been deformed and modified by such processes as folding, faulting, and metamorphism; its surface has been shaped by the destructive forces of uplift and erosion. Geologic maps depict the rocks, sediments, and geologic structures (such as faults and folds) that have resulted from these processes, and which thereby record the history and evolution of the Earth's crust.

In addition to their basic value as records of Earth history, geologic maps provide information critical for a broad spectrum of practical applications. For example, the maps depict the variations in the composition, structure, and other characteristics of rocks and sediments that are directly related to the operation of the Earth's natural processes and the distribution of natural resources. Variations in the composition of rocks close to the ground surface, for example, control the composition of the overlying soil, which in turn affects the nature of the vegetative cover.

Variations in the composition and structure of rocks exposed on sloping ground control the susceptibility of such ground to erosion and downslope movement, which determines the risk to areas below from damaging debris flows and landslides. Variations in the permeability and porosity of rocks control the distribution and flow of ground water, which determines the availability of such water and its susceptibility to contamination from ground-penetrating pollutants. By forming a basis for documenting such variations, geologic maps help us avoid the negative effects of these variations or use their positive effects to our advantage, and thus achieve a more harmonious interaction with the land we live on.

Because of their unique information content, geologic maps have an important role to play in the stewardship and preservation of NPS lands, both as educational tools and as tools for balanced land and resource management. As educational tools, geologic maps can help park visitors gain insight into the geologic history and processes by which the land has been and continues to be formed. Geologic maps can also provide an indispensable framework for additional research into specific aspects of Earth history or geologic processes, the results of which can have implications that extend well beyond the boundaries of individual NPS land units.

As management tools, geologic maps contain information needed for many fundamental aspects of park management such as resource inventories, assessments of risk from geologic hazards (for example, earthquakes, landslides, volcanic eruptions, and floods), ground-water contamination studies, hazardous materials issues, construction planning, and land acquisition. In areas subject to rapid or even catastrophic geological change from the occurrence of natural hazards, accurate geologic maps also can serve as sources of baseline information for monitoring such changes through time and for predicting the effects of future changes.

Like many other types of mapping, geologic mapping is currently undergoing a major shift from the production of conventional maps on paper to the development of geographically-referenced, digital databases through the use of geographic information system (GIS) technology. More than just a computer-generated picture, a digital geologic map compiled for use in a GIS is a fully attributed data set that can be

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NP Energy and Mineral Resources Cont'd from p.10

geologic information and resource estimates presented at the play level should be useful to the NPS in updating anticipated activity levels and potential resource information on a level of detail that has not previously been available from the USGS.

The USGS Office of Mineral Resources has made many mineral-resource assessments within and adjacent to National Park lands during the past 18 years. These studies also have provided modern information on the geology, geochemistry, and geophysics of these areas.

An example of such activities that provides information for Park Service planning and other activities is the recently published mineral- and energy-resource assessment of the Mount Katmai, Naknek, and western Afognak quadrangles, Alaska, which includes Katmai NP. This assessment provides the most up-to-date information on the geology, regional geochemistry, and descriptions of known mineral occurrences together with estimates of undiscovered metallic mineral resources. The geothermal and petroleum resources of the region also are summarized in reports describing the results of the studies.

The USGS also provides mineral-resource and related geological information as planning aids for proposed national parks and monuments such as the proposed legislation H.R. 5594, *Sequoia National Monument Act*. Based on existing data, the USGS has compiled maps showing the geology and mineral occurrences of tracts that would make up the proposed Sequoia National Monument, California. The known mineral occurrences also are described and a preliminary assessment of the mineral resources of the area has been made to aid planning and definition of the boundaries of the proposed National Monument.

Ahlbrandt, Krohn and Curtin are with the USGS in Reston VA.

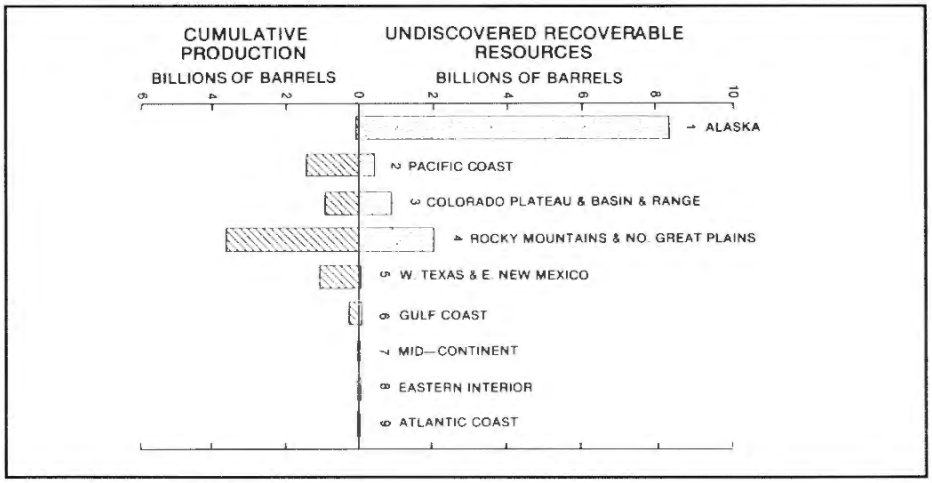

Figure 2. Bar graph showing cumulative production and estimated undiscovered recoverable oil resources on onshore Federal lands, compiled by 9 regions.

Measuring Colorado Water Quality in the Grand Canyon NP

By H.E. Taylor, R.C. Averett and L. Mazzu

The Glen Canyon Environmental Studies (GCES), a program under the Bureau of Reclamation, was created in 1983. Agencies and organizations participating in the GCES program include the USFWS, the Arizona Game and Fish Department, Arizona State University and environmental consultants to these participants. More recently, the USGS has played an important role in this effort.

These studies, under the auspices of GCES are designed to provide information on the effects of the Glen Canyon Dam and its operations on the downstream resources of the remaining Glen Canyon and Grand Canyon of the Colorado River. The information gained from such studies will be used in the environmental impact statement (EIS) analysis currently underway and in other management decisions regarding future development of water quality monitoring programs. Decisions will be made on which flows are necessary to maintain the natural processes of this riverine system. These studies have been done by the GCES with the cooperation of the Bureau of Reclamation and the NPS.

Because the interactions of sediment, river flow, water chemistry and biology, are four of the most important factors influencing the health and recreational value of the ecosystem of the Colorado River, the USGS has and continues to contribute a great deal of hydrologic research effort to GCES.

The first synoptic study under GCES focused on water chemistry and biology on different reaches and tributaries of the Colorado River and under different flow regimes downstream from Glen Canyon dam. These studies provide detailed information on water quality spatially and by flow level. Such information should assist the National Park Service not only in determining locations for long-term monitoring throughout the river corridor but also in refining management objectives that may drive decisions regarding the release of water from Glen Canyon Dam.

Synoptic sampling is used to assess, in a comprehensive manner, the characteristics or conditions of a system, such as the Colorado River, at a fixed point in time. Sampling is coordinated and carried out simultaneously at several carefully predetermined locations. These sites are selected to provide the maximum amount of information regarding important inputs or disturbances to the system.

The purpose of this type of experiment is to permit the development of a general understanding of the system and to provide a large data base of information for use in defining the spatial characteristics in as much detail as possible. In addition, the data base is useful for establishing protocols and direction for much more detailed and specific future investigations and research studies.

In the case of large river systems, repetitious sampling, closely spaced in time, can provide additional information regarding short-term variations in chemical and biological water quality in relation to a variety of physical variations including hydrologic, meteorologic, and diel conditions. Executing water-quality synoptic experiments during different seasons of the year can also provide information concerning long-term temporal variations. Collectively, this information can provide a rapid and compre-

Table 1. Chemical determinations made on synoptic samples

Nutrients	**Trace Elements Cont'd**
Nitrate	Boron
Phosphate	Cadmium
Ammonium ion	Chromium
Dissolved nitrogen	Cobalt
Dissolved phosphorus	Copper
Dissolved organic carbon	Iron
Major ions	Lithium
Calcium	Lead
Magnesium	Manganese
Sodium	Mercury
Potassium	Molybdenum
Silica	Nickel
Chloride	Selenium
Sulfate	Strontium
Trace Elements	Thallium
Aluminum	Uranium
Arsenic	Vanadium
Barium	Zinc
Beryllium	

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Geologic Maps and Digital Data Sets, Cont'd from p. 11

analyzed, searched, or combined with other GIS data to produce derivative maps and data sets designed to address specific research or management problems. Geologic data can be combined with topographic data, for example, to produce derivative maps of slope stability and landslide potential; with hydrologic data to produce derivative maps of ground-water contamination potential; and with soil and vegetation data to produce derivative maps of land cover useful for forest, range, or wildlife management.

Thus, through GIS technology, geologic maps are being transformed from traditional graphic displays into digital data layers that can be used interactively with other types of data in a wider variety of applications than has been possible in the past. This analytical capability, plus the ease with which digital data sets can be updated and revised, clearly point to a future in which the production of geologic maps in digital format will be the norm rather than the exception.

The development of a nationwide, digital database of geographically-referenced geologic information is the principal objective of the U.S. Geological Survey's National Cooperative Geologic Mapping Program, which was established by Congressional legislation enacted on May 18, 1992. The database will be developed through the design and execution of geologic mapping projects and supporting scientific investigations that meet prioritized Federal and State needs for geologic information. The program is intended to foster communication and cooperation between the producers and users of geologic-map information so that the areas in most urgent need of this information can be identified and the production of the information in those areas accelerated.

An essential factor for the timely development of a nationwide, digital geologic-map database is increased cooperation between the USGS and other Federal agencies that either use or produce geologic information. The NPS has an obvious interest in high-quality, digital geologic information for multiple-purpose GIS applications, particularly in light of the ongoing establishment of the new NPS's Inventory and Monitoring Program and the NPS's long-standing commitment to public education in matters relating to the natural environment. The growing USGS-NPS partnership for geologic data-base development in NPS lands should benefit both agencies by accelerating progress toward mutual objectives.

The partnership builds on a long history of project-level cooperation between the USGS and the NPS, one that has resulted in the publication of geologic maps and related interpretive studies of many individual NPS land units over the years. In the past three years alone, for example, the USGS has published geologic maps of Yosemite, Rocky Mountain, Grand Teton, and Bryce Canyon NPs. The production of geologic maps, digital geologic data sets, or both is currently ongoing in several other NPS units, including Kings Canyon, Sequoia, and Great Basin NPs and Chiricahua National Monument. Despite such individual successes, an even broader framework for cooperation is needed in the future to facilitate logistics and funding, to encourage the application of uniform standards of geologic mapping and data-base development, and to ensure that the work is conducted in a prioritized manner that satisfies the needs and mandates of both agencies.

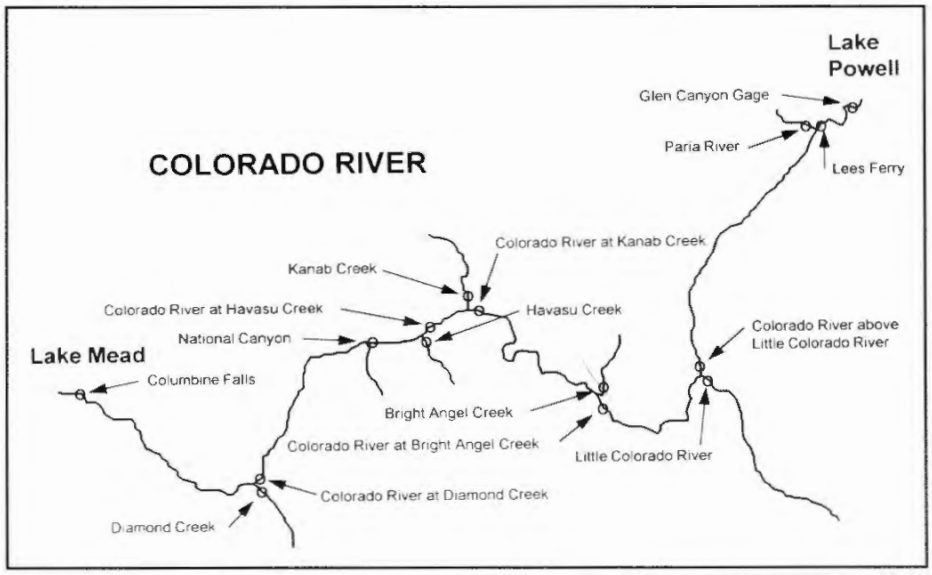
For further information on available geologic-map data and ongoing USGS geologic mapping projects, for discussing potential cooperative studies, and for information about the National Cooperative Geologic Mapping Program, contact:

John Sutter (703) 648-6964
Paul Stone (703) 648-5276
U.S. Geological Survey
908 National Center
Reston, VA 22092
FAX (703) 648-6937

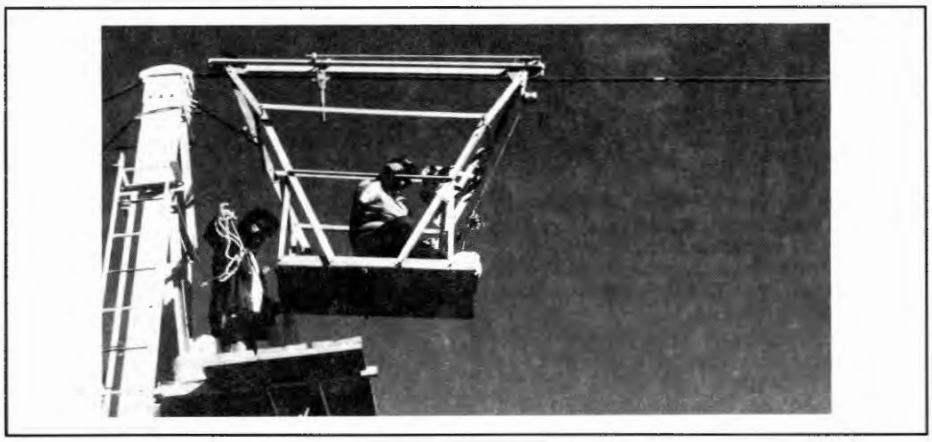
hensive analysis of the status and variability of the water quality in a large and complex river system. Differentiation of unstable properties, the significance of the magnitude and diversity of important components, and the sensitivity of their response to physical variables provide a systematic way to evaluate present and future water-quality conditions.

Such a water-quality synoptic experiment was conducted on the Colorado River, Nov. 5 and 6, 1990. Ten mainstream river stations and 6 tributary stations (at confluence) were selected for water-quality measurements and sample collection for chemical and biological analysis. A total of 470 river kilometers (the tailwater of Glen Canyon Dam to Columbine Falls) was included in the synoptic experiment. Included also was the forebay of Lake Powell formed by Glen Canyon Dam where the water that would ultimately be released into the river was sampled.

Samples collected by wading used the DH-81 Sampler



Colorado River showing sampling station localities and river miles from Lees Ferry for the 11/5/90 USGS water-quality synoptic studies. o-indicates sampling localities



Cableway, used in synoptic experiments for water sample collections on the Colorado mainstream.

Sixty-eight people (all but four from the USGS) participated in the synoptic experiment. At each mainstream sampling station, or combination mainstream-tributary station, a team leader was designated. The team leader was assigned the responsibility for directing the sampling, processing samples, and recording field data. Training of team leaders and team members on field measurements and sample collection was performed on Oct. 29, 1990, at Lees Ferry, AZ. Three training sessions, including 3 to 4 hours of classroom instruction and riverside equipment demonstration and use, were presented by scientists from the USGS National Research Program.

After training and equipment testing, personnel were transported to their assigned sampling locations. Personnel were at their stations by late Saturday, Nov. 3, 1990. Sunday, Nov. 4, 1990, was used to establish local sampling schemes, and field-measurement sites, and to practice measurements and sample collection.

Of the 10 mainstream Colorado River sampling stations, 6 have cableways that cross the river for discharge measurement and sample collection. The cableways were used in the synoptic experiments for water-sample collection. At stations where a cableway was not available, sampling and measurements were performed using a winch and boom mounted on a boat. In small tributaries, samples were collected by depth-integrated discharge-weighted procedures. The samples from the cableways and by boat were collected by the D-77 sampler, modified to permit use of the collapsible-bag technique as described by Meade and Stevens (1990). Samples collected by wading used the DH-81 sampler. In both cases, sampling equipment was designed and configured to maintain the integrity of samples for low-level trace-element analysis.

Field measurements and sample collection began at 6:00 am on Monday, Nov. 5, 1990, and continued every 6 hours thereafter, until and including midnight, Nov. 6, 1990. This scheme provided 8 measuring and sampling times over a 48-hour period, accommodating diel variations and fluctuating river stage caused by variable water release from Glen Canyon Dam. All subsequent water samples for chemical and biological analysis were field-filtered and preserved, if necessary, at the time of collection. The samples were shipped chilled to the USGS National Research Program laboratory at Arvada, CO, for laboratory analysis (Taylor and others, 1990).

Field measurements at each station included river and tributary discharge, temperature, alkalinity, specific conductance, pH, dissolved oxygen concentration, and Secchi-disk depth. About

Continued on page 14

NPS/USGS Cooperative Biochemistry Studies

By Larry Jackson

In 1983 the USGS and the NPS signed an interagency agreement which facilitates joint investigations of the influences of human-induced (anthropogenic) atmospheric emissions of trace metals and sulfur on vegetation and soils in and near selected NP lands. Studies are in progress or have been completed at Theodore Roosevelt, Big Thicket, Redwood, Great Smoky Mountains, Everglades/Biscayne, Wrangell-St. Elias, and Denali NPs and the Santa Monica Mountains NRA. Studies have focused on developing baselines for various chemical elements to be used in assessing environmental degradation, in examining spatial trends of plant and soil chemistry with respect to contamination sources, and in investigating biogeochemical processes that influence our ability to discriminate between elements of natural and anthropogenic origin.

While study designs and specific objectives differ from one park region to another, establishing baseline geochemical and biogeochemical levels has been an important starting point for each project. Elemental content of soils and vascular plants, lichens, and mosses have been used to establish modern-day baseline ranges and to examine the spatial and temporal variability of specific element concentrations. Regardless of the source of contamination, it is difficult to assess the extent of contamination without an understanding of a background value. It is virtually impossible, however, to obtain a true "background" value. The historical data simply do not exist. Attempts have been made at estimating background values by analyzing certain plant specimens, by making comparisons with the most pristine locations from around the world, and by a variety of other techniques.

An alternative to estimating a true background element concentration (before any human impact) is to determine a contemporary baseline range against which future changes may be measured. For the areas in which we have had research projects, there are almost no chemical data that indicate the magnitude of element concentrations or the spatial or temporal variability against which comparisons may be made. Although the elemental content of a particular plant species may have been measured at a different location, differences between regions and even between micro-habitats may significantly affect the elemental content of plants or soils. Hence, we have worked to establish a reference point for a particular region at a specific time. In our work, this has been defined usually as the 95 percent expected concentration range for an element in a specific plant species, plant part, or soil horizon at a specific time.

Seasonal cycling of elements or other episodic changes in element content may produce a significantly different baseline range; thus, it is important to understand the processes controlling element mobility in an environment in order to use ranges that are measured for one particular point in time. In addition to establishing elemental baseline ranges, these studies have helped to understand the impact from point pollution sources (such as from a chemical spill) and non-point pollution sources (such as from the widespread application of insecticides) and to define future research needs for biomonitoring programs.

The establishment of element baseline ranges is typified by our work in Theodore Roosevelt, Redwood, and Denali NPs where lichens and mosses are being used as air quality monitors. Scales of spatial variability in element concentrations in *Parmelia sulcata* and *Parmelia chlorochroa* in Theodore Roosevelt NP, *Hypogymnia enteromorpha* and *Usnea* spp. in Redwood NP, and *Peltigera aphthosa* and *Hylocomium splendens* in Denali NP were examined using analysis of variance sampling designs. Baseline element concentration ranges were determined for those elements which did not exhibit large geographical concentration trends and for which analytical measurement error was not a large proportion of the total element variability.

Similar studies have been done in Everglades NP and Santa Monica Mountains NRA to establish baseline element concentration ranges for vascular plants. In the Santa Monica Mountains *Ceanothus megacarpus* and *Rhus laurina* were sampled and analyzed. Large seasonal differences in some nutrient and nonessential element concentrations were observed in the two chaparral species. In addition, some spatial trends were noted which may be due to their proximity to anthropogenic emissions or differences in the geochemistry of the soils throughout the region. These seasonal and spatial trends make the establishment of baseline ranges difficult. These trends also point to the importance of understanding the processes controlling biogeochemical cycling in an individual environment in order to have an effective biomonitoring program.

Jackson is with the USGS in Denver, CO

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Measuring Colorado Water Quality, Cont'd from P. 13

780 field measurement were made during the synoptic experiment. Water samples were collected for analysis of chemical and biological characteristics and suspended-sediment concentration. Chemical determinations are listed in Table 1. Biological determinations included drift biomass collected with 100 mm orifice-diameter nets at all sites and 0.5 M orifice-diameter nets at selected sites; benthic invertebrates at the lowest flow in the main stem Colorado River and at sampling-time flow in the tributaries; phytoplankton and zooplankton abundance; and, at several stations, chlorophyll a concentration (Averett and Iwatsubo, in press). About 2,300 water samples were collected for chemical and biological measurements. In addition to the specific determinations, team leaders and team members were careful to make detailed notes on river conditions, including floating material in the river, and to take pictures of the river and sampling sites at the time of the synoptic experiment.

Summary

Synoptic sampling provides a way of rapidly evaluating water quality in large river systems. These data are especially useful in guiding future research directions. By designing time variation in the synoptic sampling, additional information can be obtained regarding temporal changes in chemical and biological properties.

Taylor and Averett are with the USGS in Boulder, CO; Mazza is with the NPS at Grand Canyon, AZ

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Fossils, U.S. Geological Survey and the Public Lands

By John Pojeta, Jr.

Knowledge of fossils is critical to understanding Earth history and past life. Fossils allow geologists to establish time lines by which scientists can correlate past events, and fossils are the direct evidence of the evolution of species over the past 3.45 billion years.

Within the National Park Service (NPS), the U.S. Geological Survey (USGS) has two formal ongoing cooperative studies at Petrified Forest National Park (PFNP) and Dinosaur National Monument (DNM). Fossilized spores and pollen are being recovered from the Mesozoic Chinle and Morrison Formations. These plant microfossils are analyzed to interpret the geological history and paleoenvironments of these formations, which are geographically widespread in the Western Interior. These formations crop out in the northern and southern Rocky Mountains and in the Colorado Plateau region. The rocks contain economic deposits of uranium and vanadium, and are renowned worldwide for the diverse and well-preserved Mesozoic fossils they contain.

The research on the Chinle Formation at PFNP is a topical study in support of the National Cooperative Geologic Mapping Program. The USGS project is led by Ronald J. Litwin, who works cooperatively with Park Superintendent Gary Cummins, Chief Ranger Kerry Isensee, and Park Paleontologist Vincent Santucci. The exposures of the Chinle Formation at the Park have provided the opportunity to establish the fossil pollen transition across the boundaries of two of the stages in the Late Triassic near the beginning of dinosaur evolution. Previously, similar studies of Late Triassic pollen and spores were done at Manassas Battlefield National Park, Virginia.

The DNM studies are coordinated by Christine Peterson (USGS, Denver) and Dan Chure (Park Paleontologist, DNM.) Pete Peterson (USGS, Denver) is the senior scientist in this multidisciplinary examination of the biostratigraphy and lithostratigraphy of the Upper Jurassic Morrison Formation. Ron Litwin is examining the fossil pollen and spore succession from all major dinosaur quarry sites in the Morrison Formation in the west. Until this work commenced, the documented record of pollen from the Morrison was sparse. However, more than a dozen new pollen sites have been discovered to date, and over 150 samples are currently under study.

The USGS is the Federal agency charged with collecting, studying and publishing reports about fossils. Throughout most of the 113-year history of the USGS, paleontologists have been placed in a separate administrative unit. For much of the 20th Century, this unit has been called the Paleontology and Stratigraphy Branch (P&S). At the present time, P&S has 51 paleontologists.

Paleontological expertise in P&S covers most aspects of research on fossils. Studies of invertebrate fossils are performed on clams, snails, ammonites, and various smaller groups of mollusks throughout the known time ranges of these shells; Paleozoic brachiopods; graptolites; trilobites; and Paleozoic corals. Vertebrate studies include Cenozoic mammals and trace fossils, dinosaurs, and Triassic trace fossils. Paleobotanical research is conducted on both plant and pollen fossils from Paleozoic, Mesozoic, and Cenozoic rocks. Micropaleontological studies include pollen, marine and fresh water diatoms, ostracodes, nannofossils, foraminifera, dinoflagellates, conodonts, and radiolarians, throughout most of the known time ranges of each of these groups.

Within the USGS, paleontological studies are important to the success of a number of programs including National Cooperative Geologic Mapping, Global Change and Climate History, National Mineral Resource Assessment, Evolution of Sedimentary Basins, Coal Investigations, Oil and Gas Investigations, Offshore Geologic Framework, and Earthquake Hazards Reduction.

In addition to cooperative projects with NPS, the P&S Branch also carries on studies in support of other government agencies including Department of Energy at the Savannah River Plant and the USAID Coal studies in Pakistan. In cooperation with the Water Resources Division of the USGS, the Branch is also conducting stratigraphic studies in Abu Dhabi of the United Arab Emirates. In the recent past, P&S has conducted studies for the Department of Defence at Enewetak Atoll and for the Department of Energy at Yucca Mountain.

The P&S Branch also regularly identifies fossils for a wide variety of organizations and individuals, including other USGS research projects, universities, State geological surveys, individual citizens, and other Federal agencies. In this last category, P&S has most recently worked with the Bureau of Land Management (BLM) the Forest Service (FS).

In May 1992, the USGS, BLM, NPS, and FS, signed a Memorandum of Understanding (MOU) for "Management of Fossils on Public Lands." This MOU created an interagency working group known as "The Federal Interagency Paleontological Working Group" (FIPWIG). This working group consists of: Chief, Branch of Paleontology and Stratigraphy (USGS); Chief, Division of Recreation, Cultural, and Wilderness Resources (BLM); Chief, Wildlife and Vegetation Division (NPS); and Geology Program Specialist, Minerals and Geology Management Staff (FS), or their delegates. The USGS delegate to FIPWIG is the permanent working group chair. FIPWIG meets early each fiscal year to identify and prioritize anticipated needs of the land managing agencies. Additional meetings can be convened as required.

Also in May 1992, Public Law 102-285 the "National Geological Mapping Act of 1992" was enacted. Among other things, this act established the "National Cooperative Mapping Program" (NCMP). One of the program objectives of NCMP is "Development of a...national paleontologic data base.... Representative categories of interdisciplinary support shall include...paleontologic investigations that provide information...to a national paleontologic data base..." The National Paleontological Data Base (NPDB) will be maintained by the USGS as authorized by the legislation.

Since its founding, the USGS has been assembling data on the Nation's fossils, and these data form the core of the NPDB. The data base already has information on about 250,000 fossil localities from which information can be supplied to land-managing agencies. New research is continually expanding the data base, and a dedicated effort is being made to make the NPDB as complete as possible.

Pojeta is with the USGS in Reston, VA

Figure 1: Senator Gore and Mrs. Gore with USGS scientists examining dinosaur footprints in Upper Triassic lake deposits near Culpeper, Virginia.

Modeling the Effects of Climate Change on the Thermal Structure of Yellowstone Lake

By Steve Hostetler with Introduction by John Varley

In 1868, explorer Legh Freeman called Yellowstone Lake "... the largest and strangest mountain lake in the world." Indeed, current scientific research concentrates on many of the lake's more complex and subtle enigmas. The lake is cold yet it straddles a geological hot stove. The outlet of the lake is continuously being raised and lowered by geothermal activities. The great depths of the lake are still being surveyed by robot camera; and, over the past year, a diatom unique to the lake was described, and the first underwater geyser was found in the lake. Today Yellowstone Lake supports an abundant population of Yellowstone cutthroat trout that are a primary food source for wildlife (pelicans, osprey, eagles, bears) and are the basis of an important sport fishery. The many facets of Yellowstone Lake make it a priceless natural treasure.

Modeling Study

The annual cycle of water temperature plays a key role in the water balance and productivity of Yellowstone Lake. The surface water temperature and the water balance of the lake are linked through evaporation. Productivity is influenced by characteristics of the temperature structure such as duration and thickness of ice cover, onset of stratification in spring, the strength and duration of stratification through summer, and turnover in autumn. An investigation of the temperature structure of Yellowstone Lake has been underway for the past 15 months together with investigations of the water budget and productivity of the lake. The findings of these studies will be used to reconstruct the climate of the basin over the historical record and for the Holocene. These investigations are cooperative studies that involve personnel from the National Park Service, USFWS, USGS, the University of Minnesota, the University of Oregon, Oregon State University, and the Philadelphia Academy of Sciences.

The goal of the lake modeling study is to apply a previously developed thermal model (Hostetler and Benson, 1990; Hostetler, 1991). The model is one-dimensional and is used to simulate thermal structure, evaporation, and ice cover in response to meteorological conditions (solar radiation, atmospheric radiation, air temperature, humidity, and wind speed). Over the past 15 months the meteorological data has been collected hourly at a site on the northern shore of the lake; data collection will continue for another 1 or 2 years. Profiles of water temperature and data on the duration of ice cover, ice thickness, and depth of snow on the ice also are being collected to provide information to compare with results of model simulations.

Results from a 449-day (June 28, 1991 to Sept. 9, 1992) simulation indicate that the model is able to predict the thermal characteristics of the lake, including lake surface temperature (Fig. 1) and ice cover for the winter of 1991-92 (Fig. 2). Preliminary comparisons of simulated and observed data (USFWS, unpublished data, E. Theriot, Philadelphia Academy of Natural Science, personal communication) indicate that the model closely simulates the actual surface temperature of the lake for the period. The simulated date of fall turnover in 1991 was Oct. 12, a date within the estimated period of actual turnover. The onset of total ice cover over the lake was simulated to be December 18, a date within a few days of the observed onset (Dec. 13; J. Lounsberry, A. Siebecker, NPS, personal communication). The winter of 1991-92 was the warmest on record in Yellowstone Park. As a result, the maximum ice thickness of 0.85 m was less than normal (> 1 m) and simulated values agree well with a mid-winter measurement (C. Whitlock, University of Oregon, personal communication). Another result of the warm, relatively dry winter was that break-up of the ice occurred earlier than normal. The date of break-up simulated by the model (May 4) is within a few days of the observed break-up (May 7). Following break-up, cool, windy conditions prevailed and the lake was observed to mix for a period of more than 2 weeks. This period of mixing is captured by the model and is indicated by the slow rise of water temperature that was simulated until about the first of June, 1992.

Because the lake model simulates evaporation in response to climatic conditions, it also will be used to evaluate the present and past water balances of Yellowstone Lake. Knowledge of the water balance is important to making estimates of lake level. A field project is currently in progress at the lake to evaluate the water balance.

The thermal model will be used to investigate the effects of climate on the productivity of Yellowstone Lake in several ways. For example, the onset and level of spring productivity under ice depends on the intensity of light (solar radiation) penetrating the ice, and the associated convective mixing that is initiated by heat from the penetrating radiation. The model can be used in sensitivity tests to link climatic-determined conditions of the ice (e.g., presence or absence of late spring snow) with productivity. For Holocene climate reconstructions of the lake, the model and data set will be used to reproduce thermal characteristics (e.g., spring mixing, onset and strength of stratification) that are favorable to diatom assemblages identified in sediment cores obtained from the lake.

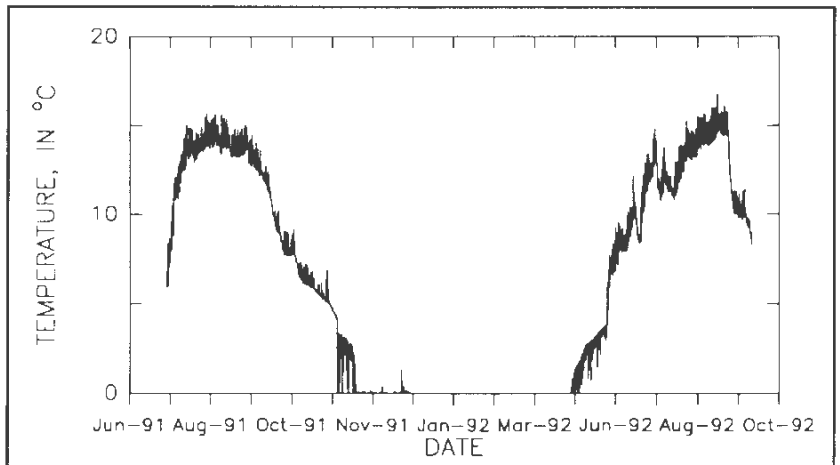

Figure 1. Simulated hourly values of the surface temperature of Yellowstone Lake.

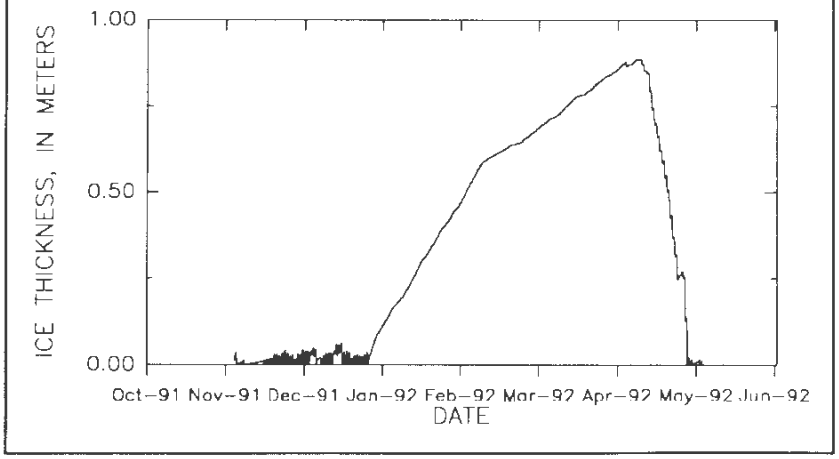

Figure 2. Simulated hourly values of the thickness of ice on Yellowstone Lake.

Hostetler is a research hydrologist with the USGS in Boulder, Colorado; Varley is head of research at Yellowstone NP.

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information crossfile

Yellowstone Science is the title of a new quarterly publication devoted to the natural and cultural sciences and edited at Yellowstone NV by Paul Schullery. Volume 1, Number 1, Fall 1992 is a 24 page issue, featuring articles on Global Climate Change in Greater Yellowstone (by William Romme and Monica Turner), Bugged Bears and Collared Cougars (by Mark Johnson), Confidence in the Past (an interview with paleoecologist Elizabeth Barnosky), News and Notes, and Dennis Knight's review of Don Despain's book, **Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting** (Roberts Rinehart Publishers, Boulder, CO, 1990. 239 pages; $14.95 paper).

* * *

"Social Science and Protected Area Management: The Principles of Partnership," a plenary session speech delivered at The World Parks Congress in Caracas in February 1992 by Gary Machlis, will be carried in a future issue of the George Wright Society FORUM. Machlis proposes that the management of protected areas is necessarily the management of people. "In the past decade," he told the Congress, "there has been a growing realization that biological and social systems are inextricably intertwined. Hence, the social sciences have emerged as a partner to conservation biology and protected areas management. Issues include visitor management, sustainable development, economic impact and equity, the social impacts of tourism and more; in short, many of the issues central to contemporary conservation."

Machlis poses these questions: "What exactly have the social sciences (anthropology, economics, geography, psychology, political science, and sociology) contributed that is 'usable knowledge' for protected area managers? What contributions can be expected in the future? How should the social sciences be organized to deliver insight and expertise to the protected area movement?" For Machlis's answers, read FORUM.

* * *

From Gary Sullivan in the Midwest Regional Office comes word of several information sources he recommends:

The Young Entomologists' Society International Entomology Resource Guide (Fourth Edition), updated, expanded, and revised, with emphasis on insect study through educational resources and materials; $10.00 postpaid; mail order and payment to Young Entomologists' Society, Dept. RGN, 1915 Peggy Place, Lansing, MI 48910-2553;

Index of Mosses, 1963-1989 contains 8,500 names and includes all new taxa from the rank of genus and below. Monographs in Systematic Botany, Vol. 42, 656pp, hard bound, June 1992; $25.00, $2.00 shipping. Prepay to Dept. 11, Missouri Botanical Garden, P.O. Box 299, St. Louis, MI 63166-0299;

The Manual of Natural History Curatorship, edited by Geoff Stansfield, John Mathias, and Gordon Reid, will be available from HMSO Books in early 1993, providing a comprehensive introduction to the philosophy, administration, and management of natural science museums and natural science collections. Contact HMSO Publications Centre, P.O. Box 276, London SW85DT;

The Aquatic Plant Information Retrieval System (APIRS) collects information about aquatic plants. Free of charge, users may request and receive computer generated bibliographies. APIRS depends on direct contributions from users to maintain this service. Please send reprints, book announcements, newsletters, etc., to Center for Aquatic Plants, Institute of Food and Ag Sciences, U/FL, 7922 NW 71st St., Gainesville, FL 32606.

Sullivan also sent news of a new facility, the Museum of Biological Diversity, dedicated at Ohio State University in Columbus on Dec. 3, 1992. It encompasses more than 55,000 square feet of collections, labs, and graduate instructional space and is to house all the university's biological collections. For more information contact Tod F. Stuessy, Museum Director, College of Biological Sciences, OH/State/U, 484 W. 12th Ave., Columbus, OH 43210-1292;

And news of the National Museum of Natural History's 1993 Research Training Program for students interested in systematic biology and natural history research. This 10-week intensive program, May 22-Aug. 1, includes a research project, lectures, discussions, tours, field trips, lab and collections work, and the opportunity to learn from Smithsonian scholars. Contact: Mary Sangrey, Program Coordinator, NHB 166, Smithsonian Institution, Washington, DC 20560, (202)357-4548.

* * *

Restoration Ecology, the new journal of the Society for Ecological Restoration, will present its first issue at the beginning of 1993. It will emphasize the technical and scientific elements of restoration and will include refereed research papers, reviews, and reader opinions. The journal's editor-in-chief is William Niering of Connecticut College. Edie Allen of San Diego State University is serving as associate editor.

Climate Change Conference

David L. Peterson, Research Biologist (U/WA CPSU), attended the International Conference on Mountain Environments in Changing Climates, in Davos, Switzerland in October 1992. He presented a paper titled "Recent changes in the growth and distribution of subalpine forests in western North America." The highly interdisciplinary meeting was attended by scientists from climatology, geosciences, biology, and sociology.

Peterson also visited with scientists at the Swiss Federal Institute for Forest, Snow, and Landscape Research in Birmensdorf. Dr. John Innes, director of the Swiss forest survey, hosted this visit, as well as a pre-conference excursion in the Swiss NP.

Director Accepts Academy Report Recommendations

The National Research Council (NRC) of the National Academy of Sciences (NAS) on Aug. 19, 1992 released its report titled "Science and the National Parks," and set off a flurry of activity within the Park Service. Director Ridenour convened a field managers' task force on Sept. 24-25, to develop options for the NRC report's top recommendations. Task force members included Gene Hester, Bob Baker, Stan Albright, Bob McIntosh, Tom Ritter, Dale Engquist, Dave Mihalic, Rob Arnberger, Don Falvey, Ralph Tingey, Cindy McCleod, Jim Larson, and Jim Sherald.

Director Ridenour participated extensively in the group deliberations and the task force presented its options to him on September 25. The Director sent a memo on Oct. 7, 1992 to the ADs for Natural Resources and Budget and Administration, the AD for Legislative and Congressional Affairs, and the Director of the Office of Policy, directing them to implement several of the NRC report recommendations in accordance with the options identified by the field managers' task force.

Specifically, Director Ridenour authorized that a "Research in the National Parks" bill be drafted and submitted to Congress by Jan. 15, 1993 that would establish a mandate for science in the NPS. The recommendation to seek a strategic funding increase for science will be addressed by first completing a Servicewide assessment and quantification of need no later than Sept. 30, 1993. Meanwhile, the FY 95 budget call will handle science needs, using the interim data base that also was utilized for the FY 94 budget formulation. The Director ordered that the controversial recommendation to create an independent science arm in the Service be dealt with by adopting what had been termed the "Western Region" model of research supervision and program management. Specific recommendations for organizational changes needed to accommodate this significant action were due to the Director by Dec. 31, 1992.

The Service will delay final decision on hiring a Chief Scientist of national repute until after necessary role and function statements and organizational structures are identified and accepted. In the interim, Dr. Hester has been authorized to proceed with filling a "Visiting Senior Scientist" position to help with these actions.

Support was given to establishing a "parks for science" program, a competitive research grants program, and a basic resource information system for the Service. The NRC recommendations to create an independent line item in the budget for research funding and to create an independent science advisory board were not accepted for a variety of reasons, but the underlying objectives will be attempted by alternati

***Denny Fenn**, Deputy AD, Natural Resources*

REGIONAL HIGHLIGHTS

Mid-Atlantic Region

The Region welcomes several new Resource Managers: Denise Cook, formerly superintendent of Natural Bridges National Monument, joins the Regional Office staff as a Natural Resource Manager responsible for air, water, and rare and endangered species; Ken Stevens, formerly Resource Specialist at Bandolier National Monument, is the new Resource Manager at New River Gorge National River; and Carl Zimmerman, formerly Resource Manager at Gulf Islands National Seashore, is the new Resource Manager at Assateague Island National Seashore.

The Region's resource managers met at Virginia Tech last spring to discuss regional resource management issues and RMPs, followed by a Social Science Short Course that examined the application of social science to park management. Topics included carrying capacity, visitor management, tourism, park economic impact, and park neighbors.

* * *

Virginia Tech CPSU Leader Jeff Marion participated in an international workshop on visitor carrying capacity, held in Belize, Central America and sponsored by the World Wildlife Fund. He gave a paper, "Tourism impacts to protected areas: Procedures for the development of monitoring programs," and took part in a panel on similar topics at the First World Congress on Tourism and the Environment, also held in Belize.

* * *

Copies of 2 papers presented to the Northeastern Recreation Research Conference, "Trail inventory and assessment approaches applied to trail system planning at Delaware Water Gap NRA" and "Campsite impact management: A survey of NPS backcountry managers" are available from Jeff Marion at NPS/CPSU, Virginia Tech/Dept. of Forestry, Blacksburg, VA 24061-0324.

* * *

The Region has established Geographic Information System technical support agreements with Penn State University and NC/State University. The 2 schools will help the Region's parks develop and operate ATLAS-GIS and GRASS-based GIS programs. NCSU recently hosted a regional planning session attended by Regional Office, park, and university staff, to begin development of a work plan.

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Intensive long-term research conducted by U/VA scientists has documented the acidification of streams in Shenandoah NP. Acidity levels are approaching the biologically critical level of 6.0 in 1 stream and have exceeded this level in another. Chronic acidification has been documented from analysis of weekly samples from these streams, beginning in 1979. A significant new research program to record, analyze, and predict biotic responses to the acidification has begun. An integrated multidisciplinary analysis of chemical/biotic linkages will be used to examine fish community responses to stream acidification.

* * *

Research to develop I&M protocols for vertebrate surveys in parks has been initiated at Penn State U. This research will evaluate existing literature, develop or modify existing I&M protocols, and field test recommended protocols on selected MAR parks. Protocols will be organized by management information needs: presence/absence, relative abundance, and species distribution.

* * *

Two Mid-Atlantic Region employees recently took part in an exchange with Russian NPs through a joint effort of the NPS Office of International Affairs, Delaware Water Gap NRA, and the Student Conservation Association. Maria Burks, superintendent at Fredericksburg and Spotsylvania County Battlefields National Military Park, and Elizabeth Johnson, Chief of Research and Resource Planning at Delaware Water Gap, traveled to Vodlozero NP to assist with park planning, development, and operational issues. The newly created park encompasses 1.5 million acres of rivers, lakes, bogs, and virgin forest within which are hidden the remnants of historic and prehistoric civilizationsd of both the Karalia and Archangelsk regions of Russia (bordering Finland).

Pacific Northwest

"The contribution of sociology to biodiversity research and management" is the title of an article in **Biological Conservation** (1992, **62**, 161-170), by Gary E. Machlis, NPS/CPSU at U/ID in Moscow, ID and professor in the departments of Forest Resources and Sociology. Like all scientific and environmental issues, Machlis notes, biodiversity is partially a socially constructed problem. Case study and comparative multinational data suggest that the causes of biodiversity decline are a largely socio-economic, and solutions will require interdisciplinary approaches. The paper discusses how sociology can make contributions to biodiversity research and management, including (1) better understanding and management of habitat change; (2) improved research and decision-making methodologies; (3) development of a theoretical synthesis; and (4) analysis of the social organization of conservation and conservation biology.

* * *

An expansive exhibit on the discovery of fossils and the ongoing management of paleontological resources of John Day Fossil Beds NM is on display this year at the High Desert Museum 6 miles south of Bend, OR. Recent finds at John Day include a new rodent, the size of a modern ground squirrel; a mouse-deer and two canid species, including one that may represent a new species.

A new dating procedure, being used at the Berkeley Geochronology Center in California, shows promise of being able to date prehistoric samples of volcanic tuff to an accuracy of within 100,000 years. This methodology (called the single-crystal laser fusion argon/argon method) should help paleontologists like Ted Fremd (at John Day) figure out how all the species being found fit together chronologically.

* * *

A 5-year effort to evaluate the potential for the Cascade Range of Washington to support a viable population of grizzly bears has concluded that a probable population of 10 to 20 bears does inhabit the Cascades. Numerous sightings and observations of tracks have occurred, and a GIS evaluation of habitat has led the USFWS to determine the population is "recoverable." With the Washington Dept. of Wildlife as the lead, the USFS, NPS, USFWS, and the Government of British Columbia are working together in this project as a subgroup of the Interagency Grizzly Bear Committee.

For more information, contact Kathy Jope at (206)553-5670.

National Capital Region

The Region recently joined with the Michigan State University Pesticide Research Center and the MI/State/U Foundation in sponsoring the 1992 International Dutch Elm Disease workshop, "Recent Approaches to the Dutch Elm Disease Problem." The last Dutch elm disease conference was held in 1981; in the interim, considerable progress has been made in cellular and molecular approaches to understanding and controling the disease. The workshop brought together from around the world old and new generations of Dutch elm disease researchers, so that acquaintances could be made and both old and new information shared.

Forty-five participants from 6 countries attended. Sessions covered conventional approaches to disease management, principally breeding for resistance; application of the pathogen toxin to elm tissue cultures for rapid selection of resistant trees; and molecular approaches for characterizing the host and the pathogen. Workshop proceedings will be published.

Awards were presented by Dr. Gordon Guyer, president of MI/State/U, to 3 retired researchers: Dr. Hans M. Heybroek, Institute for Forestry and Nature Management Research, Wageningen, Netherlands; Dr. Richard Campana, Department of Botany and Plant Pathology, University of Maine; and Dr. Francis W. Holmes, Shade Tree Lab, University of Massachusetts. Each award was an inscribed plaque made from a cross section of a limb of the 165 year old Adam's Elm, removed from the White House grounds in 1991. The agencies sponsoring the workshop received similar plaques.

The National Capital Region and MI/State/U are working through a Cooperative Agreement on molecular and biochemical aspects of Dutch elm disease management. Dr. Mariam B. Sticklen of the MI/State/U Pesticide Research Center, and Dr. James L. Sherald of the National Capaital Region's Center for Urban Ecology, are program managers.

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REGIONAL HIGHLIGHTS

Western Region

A review was held in Tucson, AZ Sept. 1-4, 1992 to evaluate the Saguaro NM air quality biological effects research program. The review's evaluation and recommendations will assist in establishing the direction for air quality research at the monument. Copies of the report may be had from the NPS CPSU, U of AZ, (602)670-6885.

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The following reports have been published by the CPSU at U/AZ:

Tech Rpt #46, "Status of non-native plant species, Tonto NM, AZ, by B.G. Phillips.

Tech Rpt #47, "Mammals of the woodland and forest habitats in the Rincon Mountains of Saguaro NM, AZ," by Russell Davis and Ronnie Sidner.

Tech Rpt #48, "Case study of research, monitoring, and management programs associated with the saguaro cactus (*Carnegia gigantea*) at Saguaro NM, AZ" byJoseph R. McAuliffe.

These reports or a complete publication listing may be had by contacting the CPSU at U/AZ, (602)670-6885.

Water Resources Divison

The Water Resources Division has moved to a new location: 1201 Oakridge Drive, Suite 250, Fort Collins, CO 80525; (303) 495-6200.

Southwest Region

Other agencies are continuing to "get the word" about Integrated Pest Management. Jerry McCrea, REgional Biologist, recently sent a "start up" package about IPM to the Lower Colorado River Authority in Austin, TX. Earlier in the year, he sent a similar package to the Texas Parks and Wildlife Dept.

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The Africanized honey bee (AHB) continues to be in the news. Padre Island National Seashore was the third park in the region to have a confirmed identification. The park staff successfully removed the colony from a park structure after removing some of the siding from the building.

The staff has recently participated in the regional workshop on the AHB, which included hands-on training in an apiary. The course was conducted in August, 1992 in San Antonio; 17 SWR personnel attended. Dave Vekasy of San Antonio Missions NHP was course co-coordinator.

Education is a key tool in AHB management. An article on the subject, written by the Regional Biologist, was published in *Contact*, the Southwest Region's interpretive newsletter. An information package, which contained the article, was prepared and distributed at the regional IPM coordinators' meeting in September 1992 in WASO.

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Museum IPM was the subject covered in a workshop co-sponsored by the Midwest and the Southwest Regional Offices. This course, the inspiration of Steve Cinnamon of MWRO, was held at Haskell Indian Junior College in Lawrence, KS Aug. 31-Sept. 4, 1992. Our course was the first NPS class to be conducted at this DOI training center...a nice facility that others may want to consider as a training site. Twenty-four NPS personnel attended, representing 24 parks and 4 regions (MWR, SWR, PNR, and RNR).

* * *

The Regional Biologist recently attended a multi-agency noxious weed meeting convened by the State of New Mexico and held in response to the 1990 Farm Bill's noxious weed provisions as well as to a memorial passed by the NM legislature. The thrust of the meeting was to encourage private landowners to manage noxious weeds, thus helping to reduce weed pressure on public lands. Four working groups were established with these objectives: (1) review of a draft noxious weed list, (2) investigation of educational opportunities, (3) weed mapping, and (4) identification of funding options. The Southwest Region is on the education working group.

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The CPSU at Albuquerque is installing a Community GPU Base Station for use by nearby parks. The post-processing of GPU data increases accuracy of field observations and will complement field activities in numerous NM parks.

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El Malpais National Monument (ELMA) is the center of some wildlife management activity. The BLM recently declared its desire to introduce bison adjacent to the monument, where the animal is not native. The animals are currently on Fort Wingate, in western NM; the base is scheduled for closure. The SWR's Division of Environmental Coordination and Division of Natural Resources Management and Science worked together closely to present the case for why NPS policy would not support such an action. BLM's response is pending.

El Malpais is one of 2 SWR parks being studied by the NM Dept. of Game and Fish as possible reintroduction sites for bighorn sheep. Bandelier National Monument is the second site. In the case of ELMA, a particularly interesting aspect of the study is that bighorn tissue is preserved in one of the park's caves, which will allow DNA testing to determine whether the desert or Rocky Mountain subspecies was native to the park. ELMA is one of only 4 areas where bighorn were known to inhabit lava flows. Native Americans report hunting bighorn in the area as recently as the 1950s.

North Atlantic Region

Paul A. Buckley, NPS Senior Scientist at the Coastal Research Center, University of Rhode Island, is the author of an invited chapter in the recently published book, *Wildlife 2001: Populations* (1992 Elsevier). The paper, "Modeling Metapopulation Dynamics for Single Species of Seabirds," is the first application of this new approach to population dynamics in seabirds using stochastic models known as RAMAS/space and RAMAS/stage. Generic albatrosses, cormorants, and terns were modeled, with unexpected and provocative results. Metapopulation modeling will be of increasing importance in grappling with the problem of fragmented populations in national parks and their environs.

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Two new regional resource management specialists have joined the North Atlantic Region. Leslie Pointer moved from Chief of Resource Management at Yosemite to become Branch Chief of Resource Management; Susan Alberts is the new IPM Coordinator.

Bruce Connery also has jointed the Acadia NP resource management staff as the I&M Coordinator.

Jim Allen, Coastal Geomorphologist, and scientists from Rutgers University and the University of Southern California conducted a highly instrumented study of bayside beach erosion and sediment transport at Fire Island National Seashore with funding from NSF and NPS. He also helped SWRO develop a plan for recreational use of the eroding Laguna Madre beach at Bird Island Basin, Padre Island National Seashore.

Southeast Region

In the days immedidately following Hurricane Andrew, the NPS assembled a professional resource assessment team to measure the ecological "vital signs" of south Florida national parks. Twenty-three scientists from a variety of disciplines examined resource conditions in order to prescribe immediate actions to stabilize threatened resources and identify long-term activities to assure continued health of park ecosystems. They examined the geographic limits and impacts of storm influence on coral reefs, seagrass beds, hardwood hammocks, mangrove forests, sawgrass marshes, pine forests, historic shipwrecks, and archeological sites. They also determined the status of endangered species such as panthers, crocodiles, and bald eagles. Air and water quality and organic debris and sediments that shape biological communities were studied.

A final executive summary of the report is available; the full report will be published after peer review is complete.

Team members included the following:

Resource Assessment Coordination: Gary E. Davis (Assessment leader), Laurie Parker, and Cameron Shaw.

Marine Resources: James Tilmant (Teach leader),. Richard W. Curry, Jay Zieman, Ronald Jones, Thomas Smith, and Alina Szmant.

Freshwater Resources: Charles T. Roman

(Team leader), Joel Trexler, Mark Flora, Nicholas Aumen, James Schortemeyer, Robert Fennema, and Ben McPherson.

Upland Resources: Lloyd L. Loope (Team leader), James Snyder, Mike Duever, and Alan K. Herndon.

Archeology: George Smith (Team leader), Larry Murphy, Guy Prentice, and John Cornelison.

GIS: Donald Myrick and Michael Rose.

Peer Review Group: Michael Soukup, William B. Robertson, Jr., Ariel E. Lugo, Stuart L. Pimm, Robert Ulanowitz, John Ogden, and Peter Glynn.

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The South Forida Water Management District, the Florida Dept. of Environmental REgulators, U.S. Justice Dept., and agricultural parties have agreed to the use of an outside mediator in the ongoing lawsuit regarding the Everglades restoration program. The mediator would work with the groups involved to try to reach consensus on the restoration program.

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The GIS Specialist in the Southeast Region has been relocated from the regional office to Clemson University in South Carolina. Neil Guse, Clemson CPSU Director, will be serving as program coordinator for GIS and will supervise the GIS Specialist position.

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Through a project funded jointly by NPS, the U.S. Army Corps of Engineers, and the South Florida Water Management District, a native Australian insect is being studied as a biological control agent for the Melaleuca tree. The weevil *Oxyops vitiosa* has been quarantined at the USDA Agricultural Research Center in Gainesville, FL, where it will be tested to insure that no natiove plant species would be adversely affected by its dispersion.

Melaleuca, recently designated as a noxious weed by the USDA, displaces wetland vegetation and wildlife habitat and has had adverse effects in the Big Cypress National Preserve and Everglades NP.

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Personnel chanages in the Office of Science and Natural Resources:

Tbrough a cooperative agreement with Tbe Nature Conservancy, a database manager has been hired for the Region's Biological Conservation Database. The comprehensive computerized database tracks information on plants and animals, focusing on rare and threatened species. Clifton Eakes began in this position in November. His most recent previous position was Natural Areas Specialist for the Mississippi Natural Heritage Program

Bob Hickman bas joined the Regional office staff as resource management plan coordinator, publications coordinator, and project management coordinator. He has 20 years or experience in the Nortb Atlantic, Midwest, and National Capital Region parks.

Brendhan Zubricki was hired to fill the vacant air/water quality coordinator position for the Region. Brendhan worked for the CPSU at U/RI on water quality issues.

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Recently published technical reports include:

Claxon, P.G. and H.L. Renwick. 1990. Bibliography of Scientific Research for Gulf Inslands National Seashore. CPSU, Rutgers- The State University of NJ. NPS/SER/93-01.

Claxon, P.G. and H.L. Renwick. 1990. History of Scientific Research for Gulf Islands National Seashore, CPSU, Rutgers-The State University of NJ. NPS/SER/93-02.

McCracken, G.F., C. Parker, and S. Guffey. 1992. Genetic Differentiation and Hybridization between Hatchery Stock and Native Brook Trout in Great Smoky Mountains NP. NPS/SER/93-05

Rikard, M. 1991. A Water Quality Study at the Congaree Swamp National Monument of Myers Creek, Reeves Creek and Toms Creek.NPS/SER/93-06.

Midwest Region

New faces and/or positions in the Region:

Sue Jennings transferred from Blue Ridge National Parkway to a Resource Management Specialist position at Saint Croix National Scenic Riverways; Sam Lamie has entered government service as a Cartographic Technician at Voyageurs NP; Ed Childres transferred to Indiana Dunes NL as a Cartographic Technician from the Soil Conservation Service; Joe Myer has transferred from the SER to serve as Regional GIS coordinator at the newly established GIS Regional Technical Support Center at the Great Lakes CPSU, U/WI, Madison; Bob Manasek has become Resource Management Specialist at Scotts Bluff National Monument; Bob Brander, formerly Apostle Islands NL ecologist, has accepted a term appointment as Great Lakes Coordinator.

New to the Research staff at Indiana Dunes NL are Dr. Paul M. Stewart, aquatic ecologist, and Dr. Ralph Grundel, animal ecologist. Stewart was on the staff at Indiana U/Purdue U at Fort Wayne; Grundel was on the staff at U/CA, Berkeley.

Stewart has been appointed scientific liaison in cooperation with the USFWS to examine sites along the St. Croix for zebra mussel infestation and to recommend measures to retard its spread in the river basin.

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Dr. Richard Wbitman, Chief Scientist at Indiana Dunes NL, has been appointed to the U.S. Great Lakes Policy Committee, which will address the 5-Year Strategic Plans for the Great Lakes. As a result of last year's Environmental Roundtable meeting, a resolution was signed by 13 Midwest states and federal agencies on interagency cooperation. Whitman is team leader for a working group on Interagency Research Needs Assessment for Environmental Management.

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Tbe Region has finished a draft publications plan outlining a strategy for establishing 3 series and for designing review procedures and standards. The plan is availahle for review by other Regions; please contact the Regional Chief Scientist if interested.

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A 2-day training session, held at Sleeping Bear Dunes Sept. 15-16, 1992, addressed dune systems management issues in the Great Lakes. Staff from Sleeping Bear Dunes, Indiana Dunes, and Pictured Rocks attended together with nearby staff from both State and Federal agencies.

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Dr. Richard Whitman, Indiana Dunes NL Chief Scientist, presented a paper, "Composition, spacial-temporal distribution and environmental factors influencing the interstitial beach meiofauna of Lake Michigan" at the XXV SIL International Congress in August 1992 in Barcelona, Spain. The paper, authored by Whitman, Kevin Kennedy, and Mary Andrzejewski, has been submitted for publication to Vereinigung Fur Theoretische und Angewandte Limnologie. Whitman gave a related paper at the 8th International Meiofauna Conference in Washington, DC, also in August.

* * *

The following papers by Indiana Dunes staff have been accepted for publication:

Bowles, M.L., R. Flakne, A.K. McEachern, and N.B. Pavlovic. In Revision. Status and restoration planning for the federally threatened Pitcher's thistle (*Cirsium pitcheri*) in Illinois. **Natural Areas Journal**.

Brown, J.S. and N.B. Pavlovic. 1992. Evolution in heterogeneous environments: Effects of migration on habitat specialization. **Evolutionary Ecology** 6:320-382.

Cole, K.L., K.F. Klick, and N.B. Pavlovic. 1992. Fire temperature monitoring during experimental burns at the Indiana Dunes. **Natural Areas Journal** 12: 177-183.

McEachern, A.K., M.L. Bowles, and N.B. Pavlovic. In Press. Recovery planning for the threatened Great Lakes tbistle *Cirsium pitcheri* according to a metapopulation model. In Bowles, M.L. and C. Whelan (eds). **Recovery and Restoration of Endangered Species**. Cambridge U Press, Cambridge, MA.

Pavlovic, N.B. In Press. Disturbance-mediated persistence of rare plants: restoration implications. In: Bowles, M.L. and C. Whelan (eds.) **Recovery and Restoration of Endangered Species**. Cambridge Press.

Pavlovic, N.B., M. DeMauro, and M.L. Bowles. 1992. Perspectives on Plant Competition--Plant collection rate should be positively correlated with plant population size: Reply to the 1-in-20 rule for plant collection. **Plant Society Bulletin** 38(1):8.

Whitman, R.L., D. Fagre, N. Pavlovic and K. Cole. 1992. Applications of Landscape Ecology to Urban Park Management. U/MA Press.

MAB Notes

The Sonoran Institute recently sponsored a regional forum on "Land Use Changes in the Western Sonoran Desert Border Area." The 150 participants--including representatives from U.S. and Mexican agencies, the Tohono O'oodham Nation, and citizens from local communities--met in Ajo, AZ in October and reviewed major resource issues facing the region, including the implications of the North American Free Trade Agreement. The "town hall" approach was an outgrowth of discussions over the past several years to consider ways to implement the biosphere reserve (BR) concept in this multi-cultural region.

The possible imminent establishment of a large BR in the Pinacate-Gran Desierto area of Sonora (adjacent to the Organ Pipe Cactus NM BR) provides incentive and opportunities for strengthening transborder linkages among BRs.

Bill Gregg addressed the forum on cooperative approaches to coping with borders. In his keynote, Hubert Hinote, Executive Director of the Southern Appalachian MAB Cooperative, discussed the experience of the Southern Appalachians in organizing cooperative projects to meet regional needs. The forum resulted in a consensus on the need for improved mechanisms for trinational cooperation in generating and sharing information on regional issues, and a recommendation for follow-up assessment to see how this could be accomplished.

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In September, the International Union of Forestry Research Organizations, in cooperation with U.S. and Canadian agencies and organizations (including the NPS) sponsored an international symposium on "Ecology and Management of Larix Forests." The symposium drew participants from more than a dozen nations and provided a comprehensive review of the state of knowledge of the ecology, genetics, and management of Larix forests, which occur in boreal and alpine environments throughout the northern hemisphere.

Gregg and Pat Halpin (U/VA) gave a poster, focusing on opportunities for cooperative research in BRs. The poster identified 20 BRs containing one or more species of Larix, and included results of potential life zone shifts in Larix BRs, based on various global circulation models. Gregg and Stan Krugman, BR coordinator for the USFS, co-chaired a seminar on BRs, emphasizing the ongoing small watershed research program in BRs in the U.S. and the former Soviet Union, and the EuroMAB biological inventory database.

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The EuroMAB pilot project to prepare biological inventory databases in BRs is underway. The project was finalized at a July meeting of MAB representatives from countries participating in the *Biosphere Reserve Integrated Monitoring Program*, which Mike Ruggiero attended. The formats for the NPS Biological Inventory Status (BIS) and the biological inventory (NPFLORA and NPFAUNA) databases were adapted for use in EuroMAB BRs. The formats are being used to prepare pilot BIS and vertebrate inventory databases for a selected BR in Canada, the Czech and Slovak Federated Republic, France, Germany, Russia, Rumania, Spain, Sweden, the United Kingdom, and the U.S. The MAB Secretariat has sent each country instructions for preparing the databases, which were scheduled to be returned to USMAB by the end of 1992. The experience of preparing the pilot databases will help EuroMAB countries determine a future strategy for preparing and managing biological inventory data from BRs.

Bill Gregg, *MAB Coordinator, NPS Washington Office*

Rocky Mountain Region

The Region has joined the Colorado River Endangered Fishes Recovery Implementation Program. Four endangered and 2 candidate species are the subject of considerable effort to stave off extinction: razorback sucker, bonytail chub, humpback chub, and Colorado squawfish are endangered; roundtail chub and flannelmouth sucker are candidates. Ed Wick of our Fort Collins office has the lead in this effort.

* * *

Anthropological field research projects have begun in Glacier NP and in the Bighorn Canyon NRA. These are the first systematic efforts to collect baseline data on ethnographic resources within these park units. Dr. Brian Reeves (U/Calgary) and Dr. Larry Loendorf (Loendorf and Assoc.) will work closely with park staffs and members of the Native American community presently using park resources for traditional cultural purposes The results will provide information on present use of natural resources within these parks and a cross cultural perspective on resource values to inform the development of natural resource management options.

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In honor of its 20th anniversary, Fossil Butte National Monument in 1992 hosted the Third Conference on Fossil Resources in the NPS. The 2 previous conferences were held by Dinosaur National Monument and Petrified Forest NP. Conference topics have dealt with paleontological issues such as promoting paleontological research in NPs, increasing NPS technical staff, fossils in the field, laboratories and museums, interpretation, law enforcement issues including theft and vandalism, and paleontological issues outside the Park System.

Final products of the 1992 conference are a technical report including abstracts, selected papers and a field trip guide, and a letter to the NPS Director describing the status of NPS fossils and recommendations for future actions. The Fourth Conference on Fossil Resources is planned for 1994 and will be hosted by Florissant Fossil Beds National Monument.

Limburger Cheese Attracts New Species To Pit Traps at Oregon Caves

Compared to most surface environments, caves tend to be low energy/low food environments. They usually lack much wind, light, freeze-thaws, or organics; thus it is fragile minerals and species with low metabolisms that normally thrive underground. Foot traffic, lights, clothing lint, tunnels, and vandalism are high/energy/food impacts on caves. Visitors or altered airflow bring in skin flakes, dust, spores, or detergent-rich lint, all of which foster exotic plant growth.

In Oregon Caves, Carlsbad Caverns, and probably many other commercialized caves, exotic animal communities have developed on lint deposits and exotic plants. Studies in Carlsbad Caverns and Mammoth Cave indicate that an unnatural increase in food causes the "paradox of enrichment," where surface-adapted insects move in and outcompete smaller and slower moving cave-adapted insects. The extinction rate from these impacts depends in part on whether caves are evolutionary "islands" or whether most of the recruitment of species occurs from small cracks surrounding the cave. Finding out which of these biogeography models best applies to cave communities is a hot topic of current hiospeleological research.

Year-round baselines are needed to understand the evolution of cave communities and human caused impacts on them. Unfortunately, until a few months ago, all that was known about Oregon Caves' fauna were records such as "small white spider seen in Neptune's Grotto." The first macroinvertebrate survey of Oregon Caves began in late August 1992. Eighteen pit traps were placed in the cave to help determine the effects of cave entrances, humidity, and nearness to the cave trail on cave populations and species composition.

The use of limburger cheese as an attractant already has yielded some 20 species, at least 2 of which are undescribed and are among the most restricted endemics in the Park System. The first endemic is in the genus *Speoseya*, a millipede genus known by only 2 other specimens. The second is a water mite which probablyh is parasitic on an unknown animal. The traps are sampled and reset every 20 days. This will continue until summer 1992, when the program will be tied to a 5-months-long Earthwatch project.

John Roth, *Resource Management Specialist, Oregon Caves National Monument*

Support Tools for I&M Decision-making: Moving from the Ideal to the Real

By June C. Rugh and David L. Peterson

Editor's Note: This article (the second in a series of two) represents a research effort on the part of the Pacific Northwest Region to offer an approach for developing a dynamic, technically rigorous inventory & monitoring program within each park. Based on state-of-the-art methods and analyses, it offers practical strategy and support tools that will facilitate I&M program development among parks.

With the help of the interdisciplinary planning team described in the previous article (*Park Science*, Fall 1992), most parks will be able to develop a broad inventory and monitoring (I&M) "ideal" plan that encompasses a diversity of projects. However budgetary and personnel constraints mean that decisions must be made about the relative value and feasibility of various projects within the overall plan. This is a complex process involving a wide range of issues and hundreds of individual decisions; lacking a systematic approach, many of those decisions may be made with limited knowledge or by intuition alone. The support tools discussed here--the Analytic Hierarchy Process and supporting software, Expert Choice1--are the core of a new analytical framework for I&M planning, providing both strategic and technical support for resource managers.

The Analytic Hierarchy Process (AHP) is a structured approach to decision-making that allows resource managers to incorporate a large number of criteria and judgments *including* those based on experiential knowledge or intuition. Decision-makers are able to weigh the contributions of each option and arrive at a final assessment (or priority) that is both consistent and defensible. Applied to I&M program development, this approach focuses on three specific steps: (1) Identify I&M projects; (2) Prioritize projects; and (3) Maximize total I&M program value over all projects.

First, decision-makers identify potential I&M projects that would fulfill program objectives. Second, these projects are prioritized based on their total contribution to the I&M program goals. AHP is used as a systematic technique to determine those priorities, which represent the definable *value* each project brings to the program as a whole. Third, budget and personnel limitations are worked into program planning in order to maximize the total I&M program value over all implemented projects.

Park personnel need not be familiar with the technical details of the AHP and related software; the regional I&M coordinator would operate the software, working with resource managers to derive model inputs and evaluate model outputs. However some conceptual background can clarify AHP's role in I&M planning. The principal ideas of AHP are (1) the use of *hierarchies* to structure decision-making, and (2) the application of *judgement measures* and *formal mathematics* to express and quantify individual preferences.

As a basic paradigm, the hierarchy is particularly useful because it is stable, resisting disruptions; it accommodates additions easily; its components can be arranged in a modular fashion, allowing efficient modifications, and finally, the hierarchy is capable of incorporating a large number of elements economically.

To construct a hierarchy, a primary goal is placed at the top. For example, the *goal* in Figure 2 is to choose the most desirable car; the *criteria* for this decision are initial cost, maintenance costs, fuel costs, resale value, status, comfort, and reliability. (Additional tiers of *subcriteria* would be added in a more involved case.) *Alternatives* are the actual car models being considered and compared: VW, Honda, Chevy, and Cadillac.

Pairwise comparisons among hierarchy elements at any level provide a ratio scale ranking of these elements. First, the main criteria are compared with respect to the goal. Here, personal judgment comes into play; the decision-maker enters judgments as to the relative value of initial cost vs. maintenance costs, initial cost vs. resale value, and so on. Thus, the initial cost might be judged to be moderately more important than maintenance costs.

The next step is to compare the alternatives with respect to each criterion; the user records judgments for VW vs. Honda with respect to initial cost, and so forth. Throughout this process, the more subjective elements such as intuition, experience, or personal preference

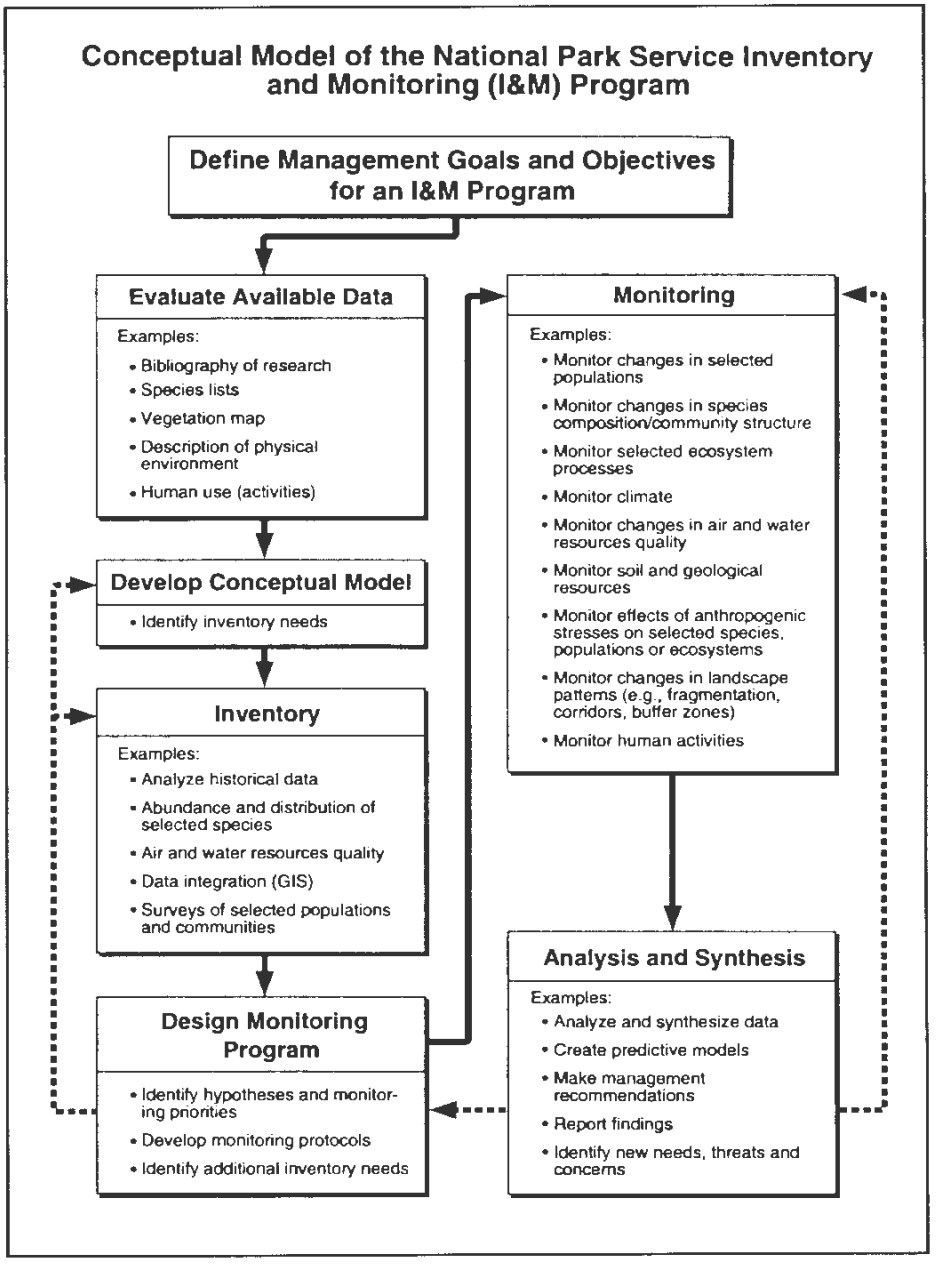

Figure 1 Conceptual overview of the inventory and monitoring process in natural park areas.

NPS-75: Guideline For the Service

By Gary Williams

In September 1992, The NPS issued **Natural Resource Inventory and Monitoring Guideline (NPS-75)**, a document developed by the A/D for Natural Resources to provide Servicewide policy, guidance, and direction to parks designing and implementing comprehensive natural resource inventory and monitoring (I&M) programs. NPS-75 represents official NPS policy and I&M efforts at all NPS organizational levels should be consistent with guidance provided in that document.

The NPS-75 guideline is largely conceptual in nature. It is not, and was not designed to be, a "how to" manual. Rather the I&M Program National Committee, which guided NPS-75 development, determined that technical protocols on how to implement specific steps of the I&M process should be developed independently over time and provided in the form of supplements to NPS-75. The Prototype Monitoring Park component of the Servicewide I&M Program represents one major effort designed to develop those protocols in a scientifically valid and expeditious manner.

In this and a previous article published in the Fall 1992 issue of *Park Science* (pp 1-4), June Rugh and Dave Peterson offer some conceptual ideas on how an I&M program might be planned and implemented by individual parks. In several respects, their ideas parallel and complement the I&M project planning and development process outlined in NPS-75 (Fig. 1). For example, whereas NPS-75 suggests a Science Advisory Team as an effective way to develop an I&M program for a given park, Rugh and Peterson promote the use of Regional interdisciplinary teams. There is no reason those could not be essentially one and the same.

Regarding the identification of individual I&M projects, Rugh and Peterson advocate the use of "brainstorming sessions" whereas NPS-75 suggests a structured, step-down process might be used. Lastly, in their current article, Rugh and Peterson describe how the Analytic Hierarchy Process might be used to prioritize individual I&M projects to insure consistence with established park goals and objectives. Guidance in NPS-75 is much less quantitative but recommends that a risk analysis involving an assessment of the nature of resource threats and the vulnerability of resources to human-induced impacts be an important basis for establishing monitoring priorities and objectives.

There are no universal techniques for I&M efforts related to total ecosystem management. Many different ideas and approaches need to be tested. Readers should realize that the ideas provided in these articles describe a research approach being field tested in the Pacific Northwest Region for implementing the guidance provided in NPS-75. As the Servicewide I&M Program progresses, additional approaches will likely be field tested elsewhere in the Service as well.

Williams is Director of the Servicewide I&M Program at WASO.

Support Tools. . .cont'd from p. 22

are as systematically quantified as objective factors such as cost. With sets of these pairwise comparisons, a ratio scale emerges that captures the priority of the related elements with respect to the comparison criteria.

Further options, such as combining judgments concerning several criteria, are available as well. Figure 3 illustrates the AHP as applied to the process of rating I&M projects.

When applied to I&M planning, AHP would enable managers to define criteria for priorities in a straightforward yet versatile way. For example, priorities may be set for part of an I&M plan based on economic and biological factors. The biological factors may be subdivided into several subfactors, such as endangered species status, susceptibility to air pollution, and geographic distribution. Each of these subfactors can be further divided into yet another set of subfactors for a finer resolution. This hierarchical process can continue for many levels to include all possibilities that should be considered, with rankings assigned to each level of the process.

The linkages become complex after only a few levels and cannot be tracked efficiently with pencil and paper. For this reason, AHP has been incorporated in the software package Expert Choice[1]. This software allows the user to apply hundreds of qualitative and quantitative assessments simultaneously to establish linkages and calculate final priority rankings quickly and accurately. It also enables a resource manager to explore the nature of decisions used in the I&M planning process.

The knowledge database created can be changed or updated at any time, making it an exemplary tool for I&M decision-making. Moreover, the model can accommodate any agenda the park might wish to include. This is particularly pertinent to resource management planning by federal agencies, which often requires consideration of political issues.

Most important, AHP/EC does not *make* decisions for managers, but instead *facilitates* the process of decision-making. By providing a framework in which I&M and resource management planning issues can be addressed and quantified explicitly, these tools offer resource managers unprecedented decision-making power, versatility, and accountability.

When allocating resources within I&M program planning, the goal is to do the most I&M work possible within established budget and personnel limitations, with "most" defined as the greatest total program value. This means that an individual project's value to the program alone can determine the most effective

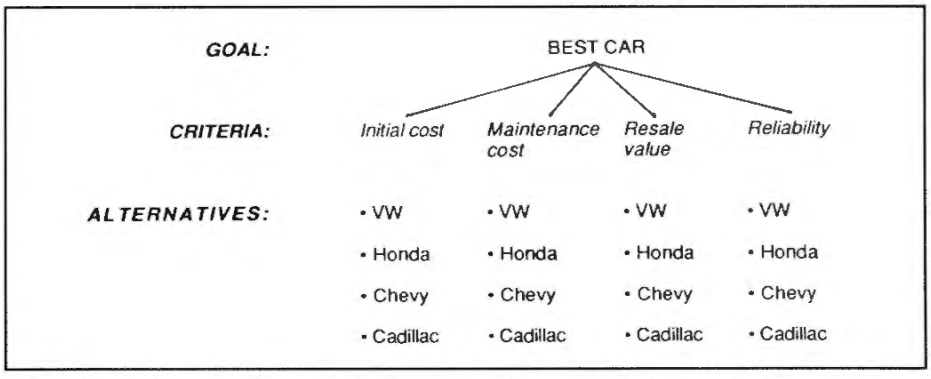

Figure 2. Choosing the Best Car: An illustration of the Analytical Hierarchy Process

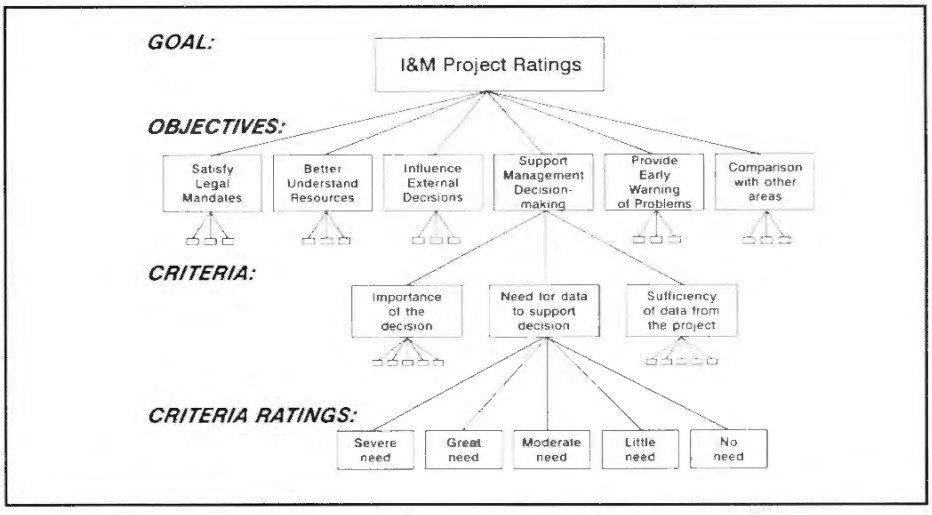

Figure 3 Rating I & M projects using the Analytical Hierarchy Process

Support Tools. . .
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allocation of resources. Similarly, a cost-benefit approach--wherein projects with the best economic payoff garner the highest rankings--falls short by not including other constraints, such as personnel time.

Schmoldt et al. (1992) have formulated an integer programming model which, by combining AHP and linear programming, maximizes total program value, subject to specified constraints. With technical support from the I&M team, resource managers would enter the minimum constraints (budget and personnel limitations) into the mathematical formulation. Other constraints, such as restrictions on project timing, could be factored in as well. For example, if a particular project to analyze snow chemistry should not be performed until a geographic survey of snow has been completed, then those constraints would be added to the formulation.

As the final step in the resource allocation process, priority values estimated from the AHP exercise would be used as coefficients in the integer programming model.

As in any optimization procedure, the results of this "constrained optimization" approach will be only as realistic as the parameter values used in the calculations. More accurate budget or personnel estimates, or revised value judgments, can alter the emerging I&M program. Repeated use of this process will insure that results are acceptable and stable.

[1] **Tradenames are used for information purposes only. No endorsement by the U.S. Department of the Interior is implied.**

Rugh is a technical writer and Peterson is a Research Biologist at the U/WA CPSU, Seattle. Schmoldt is a Research Forest Products Technologist with the USDA Forest Service at Blacksburg, VA.

The following publications are available from the NPS CPSU, AR-10, U/WA, Seattle, WA 98195:

Peterson, D.L., D.G. Silsbee, and D.L. Schmoldt. 1992. Guidelines for developing inventory and monitoring plans in national parks. Manuscript submitted for publication.

Schmoldt, D.L. D.L. Peterson, and D.G. Silsbee. 1992. Strategic inventory and monitoring programs: prioritizing projects and allocating expenditures. Manuscript submitted for publication.

Silsbee, D.G., and D.L. Peterson. 1992. Planning and implementation of long-term resource monitoring programs. Environmental Monitoring and Assessment (in press).

Silsbee, D.G., and D.L. Peterson. 1991. Designing and implementing comprehensive long-term inventory and monitoring programs for NP System lands. Natural Resources. Rep. NRR-91/04. National Park Service, Denver, CO.

meetings of interest

1993

Feb. 2-5, **EXXON VALDEZ OIL SPILL SYMPOSIUM**, in Anchorage, AK. Sponsored by members of the Exxon Valdez Oil Spill Trustee Council,representing USDA, USDI, NOAA, the Alaska attorney general, and the AK Depts. of Fish and Game and of Environmental Conservation. Contact: Brenda Baxter, Symposium coordinator, U/AK, Fairbanks; 907-474-7086; FAX 907-474-6285.

Mar. 6-7. **PUBLIC INTEREST SCIENCE CONFERENCE in Eugene, OR, to address** issues relating to the interaction of science and the public policy process. Panel topics will include new paradigms for science and policy making, science and the law, and ethics. Workshops will deal with communicating to the non-scientist. Contact: Len Broberg, Dept. of Biology, U of OR, Eugene, 97403.

Mar. 24-27 **EIGHTH ANNUAL U.S. LANDSCAPE ECOLOGY SYMPOSIUM,** "Pattern and Process in Landscape Ecology" at Oak Ridge National Lab in Oak Ridge, TN. Contact: Dr. Monica G. Turner, Envir. Sciences Div., Oak Ridge Nat'l Lab, PO Box 2008, Oak Ridge, TN 337831-6038; (615)574-8282.

April 18-23 **WESTERN REGIONAL INTEGRATED CULTURAL & NATURAL RESOURCES WORKSHOP**, at Furnace Creek Ranch, Death Valley National Monument. WRO Contacts: Jonathan Bayless, (415)744-3968, and Gene Wehunt, (415)744-3957.

May 17-21 **NATIONAL INTERAGENCY WILDERNESS CONFERENCE**, Tucson, AZ. Focus on 3 stewardship themes: (1) Wilderness Restoration--minimum tool use in alien plant species control and reveg; (2) Complementary Management of wilderness and archaeological, historical, and cultural resources, and (3) Emerging Challenges: cultural diversity, demographic trends, adjacent land uses, day use, outfitter policies, and access for the disabled. Contact: Alan Schmierer, WRO (415)744-3959.

June 22-25 **CONSERVATION IN THE WORKING LANDSCAPES,** the 1993 Natural Areas Conference, at Univ. of Maine, Orono, ME. Symposia topics: Biological diversity in working landscapes (total perspective and institutional perspective), conservation in marine ecosystems, inventory and monitoring natural landscapes in working landscapes, conserving endangered species and natural communities in working landscapes, and managing natural areas in working landscapes. Deadline for papers, Jan. 15, 1993. Contact: Hank Tyler, ME State Planning Office, Station 38,. Augusta, ME 04333; (207)624-6041.

Aug. 24-26 **12th WILLIAM T. PECORA REMOTE SENSING SYMPOSIUM,** "Land Information from Space-Based Systems," Sioux Falls, SD. Sponsored by the USGS in cooperation with other federal agencies. Abstracts are due by Feb. 15, 1993. Contact: Dr. Robert Haas, Symposium chair, 605-594-6007 or Dr. James W. Merchant, Program chair, 402-472-7531, FAX 402-472-2410.

Ecological Society Meeting

Six members of the U/WA CPSU research team attended the 1992 meeting of the Ecological Society of America in Honolulu in August. Four papers presented in a session entitled "Effects of Global Climate Change on Forests," were:

Regina M. Rochefort and David L. Peterson: Effects of climate and other environmental factors on tree establishment in subalpine meadows of Mount Rainier NP;

Gregory J. Ettl and David L. Peterson: The effects of climate on growth of subalpine fir *(Abies lasiocarpa)* across elevation gradients;

David W. Peterson and David L. Peterson: Subalpine forests and climate change: a dendroecological study; and

Ronda L. Little and David L. Peterson: Effects of climate on regeneration of subalpine forests following wildfire in the Cascade Range of Washington.

An additional paper, presented in the session on Paleoecology, was by Michael J. Arbaugh and David L. Peterson: A dendroecological analysis of drought sensitivity for ponderosa pine along the Front Range of Colorado, USA.

Research Assoc. David G. Silsbee presented the results of previous air quality studies in Great Smoky Mountains NP in a poster paper, "Effects of canopy position and topographic sheltering on exposure of plants to ozone."

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Ecology of High Mountain Black Bear Population In Relation to Land Use at Rocky Mountain NP

By Henry E. McCutchen

Rocky Mountain NP in Colorado is one of the most heavily used parks in the west. It receives more visitation than Yellowstone yet is only 1/8 the size. In addition, unlike other large western parks sucb as Glacier and Yellowstone, which were carved out of near wilderness, ROMO was established in an area that had been heavily homesteaded, hunted, logged, farmed and grazed for over 50 years.

By 1915 when the park was established, the large mammalian fauna populations had already collapsed (Newmark, 1987) from the impact of European settlement, and they have yet to recover. The elk, once numbering in the thousands, had become extinct by the 1900s. Transplants from Yellowstone were made just before the park was established, and under park protection the herds are now flourishing. Mule deer and bighorn persisted; however bighorn numbers declined in the 1930s and required transplants to supplement lost herds (Stevens and Hansen, 1986). The wolf became extinct before 1900; the grizzly was present until the early 1920s, then it also disappeared. The two other large carnivores, the mountain lion and the black bear, were present when the park was established but occurred in low numbers.

According to historical reports (Superintendents annual reports ROMO) after the park was established, black bears were extremely scarce. By the 1930s bears were observed fairly regularly yet were still believed to be low in numbers. From the 1930s to the 1980s the bear population was thought to be stable and occurring in low densities throughout the park.

Rocky Mountain, unlike other parks with black bear populations, has not experienced large numbers of bear depredations. For example, records of bear incidents from 1959 to 1983 totaled 133 with an average of about 5 per year compared to Sequoia and Kings Canyon NP which, between 1959 and 1976, had a total of 3,968 bear incidents for an average of 220 per year (McCutchen, 1987).

In 1984 bear depredations at ROMO unexpectedly became a problem in the backcountry, reaching a record of 90. Park management found there was no information on the population, and without an idea of the population and its dynamics there was no way to predict the impacts of a management or control program. In 1985 the park began a research program on the bear's population dynamics and ecology.

The southern 2/3 of the 265,000 acre park (about 190,000 acres)--the overall study area--was dissected by the Continental Divide, forming convenient east and west study areas. The area east of the Continental Divide (90,000 acres), where most of the bear depredations occurred in 1984, receives the highest front and backcountry use. Outside the park boundary to the east is a region of intensive urban and suburban development and human use, including the gateway town of Estes Park. The study area west of the continental divide (100,000 acres) provided a good "control." It receives less visitor use and most of the area outside and adjacent to the park is undeveloped USFS land.

Rocky Mountain NP, in north-central Colorado about 50 miles northwest of Denver, preserves the most rugged section of the Colorado Front range. Elevations are among the highest in the contiguous U.S., (8,000' to 14,000'+). Vegetation zonation is apparent. About 1/3 of the high study area is alpine tundra. Mid-slopes contain spruce/fir vegetation; lodgepole pine occurs on old burns and south facing slopes. At the lower elevations, north facing slopes contain Douglas fir and aspen; glacial moraines with Ponderosa pine intermixed with meadows occur in the dryer sites. The winter climate is cold with low precipitation; summers are cool, with moderate precipitation; the alpine tundra can demonstrate arctic conditions year round.

Because black bears are difficult to count, the study aimed at a total capture census. The bears were captured with foot snares, marked with ear tags and radiocollared. The east area census took two years. Low bear densities meant that a lot of country had to be covered to capture one bear and almost all the field work had to be done in the backcountry. Baiting and capture equipment was carried by backpack.

The west side study area was censused in 1987, 1988, and 1989. Following this, radiotracking and monitoring were performed until the study was terminated in the winter of 1992.

The study was hindered throughout by funding, manpower and logistics problems. Volunteers in the Parks (VIPs) were increasingly utilized for lower risk tasks (radiotelemetry and assistance in bear capture). The park put out a call for volunteers and eventually a cadre of about 25 VIPs was available to meet project needs.

Most of the volunteers became highly skilled in radiotelemetry and bear handling assistance. The project could not have been done without them. The park staff, particularly the West Unit staff, also provided assistance and logistics support. Because of the rugged terrain the bears inhabited, it was not uncommon for a radiotracking team to spend an entire day hiking in order to get a single radiolocation on a bear. It was necessary to go to the bear dens in the winter to replace radiocollars, to obtain data for denning ecology and to check for reproduction and physical condition, which posed special logistic and safety problems. The bears tended to select cave dens near timberline, a little over 2 miles above sea level--from 10,000 to 11,000 feet, on steep north facing slopes, among cliffs, remote from human use and trails. The winter team had to snowshoe or ski, with heavy packs, coping with cold weather, high altitudes, blizzards, temperamental snow packs, steep slopes, snow covered cliffs and avalanche hazard.

Hazardous Work

Although the work was hazardous, as the winter crew gained experience with safety foremost in mind, the risk was reduced. There were minor mishaps on almost every trip - frost bite, tumbles down steep slopes, bruises and sprains,

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Author with 25 pound yearling black bear at its den in Rocky Mountain NP. The bears in the park were found to he among the smallest in North America

The bears in Rocky Mountain NP denned in caves on steep slopes, in remote areas far from roads and trails at 10,000' elevations. Radiolocating and snowshoeing to the dens was a dificult task. Research technician, BillMcEwen, clears den entrance as VIPs Damon Lamothe, Holly McCutchen and Jana McCutchen observe.

altitude sickness, and forced overnight bivouacs, but no serious injury occurred on any winter trip.

After all the census effort on the east side, only 6 adult and subadult bears were captured. Of these only 2 were adult females; 3 were subadult males, 1 was a subadult female, and 3 were cubs of the year. The study team believed that all resident bears in the area had been captured, as each was snared several times before the bears became trap wary.

Since the area had been well covered with capture sites, the study team concluded that the low capture rate was because of their low numbers. Because it had seemed logical that there should be more bears in the area, capture effort was maintained long after all the residents had been captured.

The research revealed the extremely low density of bears in this area. If 3 cubs were counted for a total of 9 bears, the density was only 1 per 16 square miles compared to 1 bear per 2.2 square miles found in the black bear research program conducted by the Colorado State Division of Wildlife in southern Colorado (Beck, 1991). About 40 percent of the east side study area was alpine habitat, which the bears did not utilize. If this area was not included and only forested habitat was calculated in relation to bear numbers, the density was 1 bear per 9.7 square miles--still a low density.

(The bear depredation problem was solved in 1985 by the capture and radiocollaring of the first subadult male, a 3-year- old. After his release his activities resulted in his recapture and transplant to a remote section of the park. He was killed by a hunter outside the park, and after his demise bear incidents in the backcountry dropped to previous low levels.)

West Area Results

The bear census on the west side study area (from 1987 to 1989), revealed a slightly better situation than the east side. Of 12 bears accounted for by 1989, 3 were adult females and 4 were adult males. Two subadult females, a subadult male, and two cubs completed the count. The bear density for the west side was one bear per 13 square miles of study area or one hear per 8.7 square miles of forested habitat below timberline.

A comparison of the east vs. the west side subpopulations showed no mortality of adult females on either side of the park during the study, but the male bear population on the east side of the park showed exploitation and considerable turnover. No adult resident males were captured here, only subadults. Males did not live long enough to become mature.

The study provided insight into the causes of this male mortality. Three of the 5 subadults eventually captured here were killed, 2 by legal hunting outside the park and 1 by unknown causes. In addition a fourth mysteriously disappeared from the population. The subadult males, apparently because of their less wary nature and needs for more space, wandered in and out of the park, subjecting them to human predation outside.

Boundary Effect

The project researchers noted a "boundary effect" of human use and development outside the park in relation to bear land use inside the park. Much of the area outside and adjacent to the eastern park boundary was occupied by the town of Estes Park and mountained subdivisions. Bears could not occupy these areas. The females inside the park on the east side survived in home ranges far within the park boundaries. On the east side we found areas within the park that we called vacant bear habitat. These were areas extending inside the park for 1 to 2 miles where bear habitat was suitable but rarely used because of high human use outside the park.

The land tenure system and population structure of bears on the west side of the park was considerably different from the east. Here much of the area outside and adjacent to the park was USFS land. Mature males were found on this side in addition to subadults. There was no mortality of these bears while they were being radiotelemetered. Most of them had large home ranges that were partly in the park but extended for many miles to the west outside the park. Several females had home ranges straddling the boundary here, and they would move in and out of the park freely. One area outside and adjacent to the western park boundary did not contain park bear home ranges. This was the township of Grand Lake; park bears avoided this area.

Radiotelemetry showed the adult females had exclusive home ranges averaging about 20 square miles. Home ranges of the large males were not obtained; however 2 smaller males had ranges from 16 to 26 square miles in size.

Secretive Behavior

We found black bears at ROMO were unique in behavior compared to those in other parks. In many national parks black bears are highly visible and frequent human use areas. In contrast, the ROMO bears secretive and avoided human use areas. The park has about 600,000 visitor days of hiking use on the trails, but bears and bear sign are seldom observed. Intensive radiotracking of two east side female bears, which had home ranges in the areas of heaviest human use, indicated they were almost never found in human use areas. On average they were radiolocated about 1 km from trails, 2 km from trailheads, 2 km from dirt roads, 1 1/2 km from paved roads, 2 km from picnic areas, 3 km from human residences, 5 1/2 km from the major campgrounds, and stayed about 6 km from the park boundary (McCutchen, 1990). As we interpreted it, the bears partitioned the space, with humans using the network of roads and trails and the bears using the interstitial areas.

Because bears and other large carnivores reproduce so slowly, it requires several years of study to obtain some idea of their population dynamics. The research on the bears in the park was extended into 1990, 1991 and 1992 to gain this information.

Low Reproductive Rates

We found that reproductive rate and success among black bears at ROMO were among the lowest on record for any study of black bears in North America. Females in the park did not successfully reproduce and bear their first litters until they were about 7 years old. Generally black bears in the western U.S. have cubs at about 4 to 5 years of age (Beck, 1991), and the bears in the eastern U.S. reproduce at about 3 years (Alt, 1989). Litter size at ROMO varied from one to 3 cubs but overall was quite low, averaging 1.7 as compared to Beck's (1991)

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High Mtn Black Bears. . . Cont'd from p. 26

Summer capture crew members Steve King (left) and Jeff Gould measure immobilized black bear snared in Rocky Mountain NP.

findings in southern Colorado of 2.0, and Alt's (1989) 3.0 for Pennsylvania. To put this in perspective, assuming a 2 year litter interval, a 10 year old female black bear in Pennsylvania would have produced 12 cubs in her lifetime whereas a 10 year old female at Rocky Mountain National Park would have produced 3 or 4.

The sex ratio of cubs at ROMO was about 1:1 males to females, similar to other studies. Cub survival, e.g. the percent surviving from birth to 1 year of age, however, was extremely low, averaging about 43 percent as compared to 56 percent found by Beck (1991), who considered his cub survival low as compared to other studies. The causes for cub mortality at ROMO need further study. Two sources of cub mortality identified were starvation in the den and cannibalism by other bears.

The black bears at Rocky Mountain NP also were found to be among the smallest on record. Mature females weighed from 80 to 165 pounds as compared to weights of 130 to 235 pounds (Beck, 1991) for female black bears in southern Colorado. Mature males weighed from 140 to 240 pounds as compared to males in the southern Colorado study (Beck, 1991) which weighed from 176 to 350 pounds. Yearlings at ROMO were consistently small. Both females and males averaged about 26 pounds as compared to averages of 48 pounds for females and 50 pounds for males in southern Colorado (Beck). We surmised that one of the causes of yearling mortality was low body weight going into hibernation.

The small body sizes, late maturation and low rates of reproduction of the bears in Rocky Mountain NP appear to be functions of the habitat. Beck (1991) considered the park area marginal for bears and judged that his study area in southern Colorado was above average. In Beck's area, where the bear habitat was somewhat lower in average elevation, the bears had two major feeding economies to draw from; beginning in early summer and into the fall berry crops provided food; in late fall acorns (hard mast) from abundant oak stands were utilized. In this area also there is greater habitat diversity with many patches of vegetation in various seral stages.

At Rocky Mountain NP the growing season in the bear habitat is very short, and the climate is essentially subarctic (subalpine). The extremely high elevations and dry cold result in low productivity of food bearing plants. Further, the bears have only one major feeding economy - berry crops - from mid summer to early fall. There is no oak in the park. One important, but infrequently produced, hard mast crop which the bears did utilize was the tiny seeds from limber pine in late fall. Bear habitat diversity in the park is limited. Much of the park's forest is mature; there is not a good mosaic of various seral or age stands. This is due to the park's vigorous protection from wildfire for the 77 years since its establishment.

Multiple Pressures

The research indicates that low densities and numbers of black bears in Rocky Mountain NP result from a combination of factors. First, along the eastern park boundary the town of Estes Park, subdivisions, summer homes, resorts and other forms of urbanization have usurped and fragmented bear habitat and constricted travel corridors. These areas also act as "population sinks" where emigrating bears come into conflict with man and are removed from the population.

Second, hunting pressure along the eastern boundary appears to have been so great as to nearly eliminate the older male age classes. The Colorado State Division of Wildlife is aware of this hunting pressure and since 1986 has formulated more restrictive regulations for bear hunting in areas surrounding the park.

Third, visitor use on the east side is extremely heavy on roads and trails. Many human use areas are in highly productive bear habitat (riparian areas and aspen stands). Because of their unique human avoidance behavior, the bears do not use this habitat, which reduces the area's carrying capacity for the species.

Fourth, historic fire suppression has degraded the bear habitat causing further reduction of the black bear carrying capacity. The park is developing a fire management plan that will include prescribed burning. Restoring the park's fire regime eventually will create the needed vegetative mosaics and increase herbaceous and shrub primary productivity needed by the bears. Fifth, this high mountain area is marginal habitat for the bears, and their reproductive rate is correspondingly low.

Summary of Results

In summary, this 7 year study of black bears in Rocky Mountain NP reveals that the species is being heavily impacted by humans. The population is very low. The census of the study area on the lower 2/3 of the park indicated a population of 21 bears. Extrapolating for the entire park there is probably a population of about 30 to 35 bears. Recruitment of 2 subadult females to the breeding population set the trend slowly upward. Male age classes on the east side of the park show exploitation, however radiotelemetry revealed no evidence of poaching of bears inside the park.

The bears are of small body size and exhibit late maturation and low rates of reproduction. Their high avoidance behavior to humans explains why park areas of suitable habitat are not being fully utilized. The four factors of impact, coupled with the species very low reproductive capacity, have made this a subpopulation at risk. The population is so small in the park that the loss of 2 or 3 adult females would put it on a downward trend.

Although the habitat is marginal, research indicates that the bear population would be significantly larger (by perhaps as much as an estimated 30 percent) if human impacts were eliminated or mitigated. Periodic monitoring of the black bear population in the park is essential. The species is an indicator of the impacts of human use on the area as well as an indicator of ecosystem (forest) health.

From an ecosystem viewpoint the black bear population at Rocky Mountain NP provides a useful model of what can happen to large carnivores in a preserve when the area is too small to maintain a viable population and begins to suffer from the "island effect," being encroached upon by adverse human land uses.

The information obtained by this research project was incorporated into the bear management section of the park's Natural Resources Management Plan.

McCutcheon is a Research Wildlife Biologist with the NPS Rocky Mountain Region, stationed at the CPSU at Northern AZ State University, Flagstaff.

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Data Base Mapping and Management at Colonial NHP

By Janet L. Johnson, John Fels, Chuck Rafkind, and Hugh Devine

Since its modest beginnings in 1987, GIS use at Colonial has experienced rapid growth in both the range of resource management issues it addresses and the corresponding physical size of its database. Both natural and cultural resource information is being added to the system at an increasing rate, forcing the park to institute a more formal system of organization, management, and output of its GIS data.

In the summer of 1991, the park enlisted the GIS Research Program at North Carolina State University (NCSU) to design a Database Management System (DBMS). The objective was a system design that would facilitate expanded use of Colonial's GIS and provide better management and control of the database. Four major factors were considered: accessibility, usability, reliability, and adaptability.,

The main accessibility concern was that the GIS be available at multiple locations throughout the park. There is little value in data that is not on-hand or accessible when needed. The second factor--usability--requires that the database be usable hy personnel with limited GIS training and experience. A GIS DBMS that is too difficult will frustrate first-time or casual users and will tend to discourage all but the most experienced database users. The third factor--reliability--is contingent on at least three criteria: (1) the database must be secure from unauthorized access; (2) it must be properly stored so that a catastrophic event such as fire or hurricane does not destroy it; and (3) it must he updated, documented, and distributed to users in a timely manner. Adaptability--the final critical design factor--is about insuring that the DBMS design be flexible enough to allow for reconfiguration as GIS experience grows. It is unlikely that any one design will serve indefinitely as GIS use continues to expand and change.

DBMS Design

The GIS program at Colonial is managed by the park's Natural Resource Management Specialist and use of the system is distributed among four work areas. Two of these are within the park's Natural Resource Management and Protection division; the other two are located within the Interpretaive and Cultural Resource Management division. Expansion to the Maintenance division is planned. The computers are DOS systems and are not networked. The park uses the ATLAS*GIS software program and exchanges data routinely with local and state governmental users of ARC/INFO. Currently, there are 148 layers of themes in the park GIS database.

The study developed and evaluated two basic DBMS designs: the first would combine all the GIS layers into one large file, eliminating the need for a user to keep track of multiple subdirectories or files of data within the system; the second would divide the database into a number of files that would reduce the database size for an application and facilitate development of new layers and map products by linking multiple themes *logically*, not physically.

The first file design maximizes user accessibility, as any part of the GIS database could be retrieved without the difficulty of invoking separate files or subdirectories. Reliability is achieved in that the database is backed up, edited, and restored in its entirety. This means new versions of the database could be installed with very few commands, and back-ups could easily be performed and catalogued. Flexibility is a mixed result with this design, as the addition of new layers is simple, but the manipulation and cataloging of the numerous layers is complex. For example, just remembering the name of the layer for utility rights-of-way, let alone what is in it, could be a problem. This design's major drawback is usability. Stepping through 148 layers, turning them on or off for a mapping application, is a tedious process; further, the time and commands required to effect a mapping change would be significant due to the large size of the database.

The second DBMS design, one that employs multiple files as a way of grouping themes into logical categories, was chosen for implementation. This design divided the 148 themes into 10 files. The subdivided design was significantly easier to operate, since development of a map, application, or analysis involves manipulation of very few layers. Although his was offset somewhat hy having to access several files, the net number of commands and time requirements for map production was greatly reduced. Accessibility and reliability are slightly compromised unless every file is maintained in every computer. Some infrequently used files may be temporarily unavailable from a given work area, but our experience has not sbown this to be a major problem.

Finally, adaptability is enhanced, as the addition or reconfiguration of the master files involves the use of a small subset of the total database, and tracking where information is stored is considerably simpler.

Ongoing Work and Recommendations

The design of the DBMS has definite implications for both the symbolization (i.e. map representation) of map analysis products with the GIS and the operational procedures for managing the system. At Colonial, the development of the DBMS has proceeded concurrently with the construction of guidelines and procedures for these other activities. The results have been formalized into the park's *GIS Database Management System and Map Presentation and Feature Taxonomy* standard operation procedure.[1]

The DBMS design and subsequent implementation has proven useful at Colonial. In addition to addressing the obvious need for data organization and control, it has produced the unexpected benefit of clarifying the role of GIS within the park and indicating the extent to which GIS can be utilized.

For the near future, the park is working to refine DBMS and Map Preparation and Feature Taxonomy operating procedures. During FY 93, a more complete data dictionary, detailed numerical classification system, and expanded input of attribute data will be undertaken. Also, as the ATLAS*GIS program is released in a Windows version, the park will explore linking it with digital photos from the resource management files. The park plans to embark eventually on digital orthophotoquad research with the USGS.

This design works well for Colonial, but we recognize it may not suit the needs of other parks. It is hoped however that this study will facilitate other GIS DBMS designs, and for those who elect this path, Colonial's construction processes can provide guidance.

[1] The GIS SOP is available from the park by sending a DOS formatted floppy diskette and self-addressed stamped diskette mailer to Colonial NHP, Natural Resource Mgt. Spec., PO Box 210, Yorktown, VA 23690.

Johnson is a research associate and Fels is a Ph.d candidate with NCSU's GIS Research Program; Rafkind is GIS Coordinate/Natural Resource Management Specialist at Colonial; Devine is Director of the NCSU GIS Research Program.

FILE NAME	CONTENTS OF GEOGRAPHIC FILE	DESCRIPTION OF GEOGRAPHIC FILE LAYERS	COLOR
HYDRO	1 HYDROGRAPHY	shorelines of rivers, ponds, lakes, rivers, streams, drainages, springs, floodplains, watersheds	blue
VEG	2 VEGETATION	forest, fields, wetlands	green, aqua, brown, cyan, yellow, sky blue
ACCESS	3 ACCESS	primary, local, public and park, administrative, fire roads; trails	black, red, orange
INFRAST	4 INFRASTRUCTURE	utilities (park, public-row's), structures - buildings, bridges, fences, man-made drainage, signs	black, red, blue, green orange, brown, yellow
BOUNDARY	5 BOUNDARIES	park, local, county, state, reserved row's, park scenic easements and fee simple	black
CULTURAL	6 CULTURAL	pre-contact, 17th, 18th, 19th, 20th century, archaeological excavation sites - sites, buildings, other structures, earthworks, historic roads	purple, violet, red, orange, yellow, brown
ADJACENT	7 ADJACENT LAND USE	residential, commercial/industrial, military, public lands, agriculture	orange, red, violet, yellow,green
ENVIRON	8 ENVIRONMENTAL	soils, topography, wildlife sightings, vegetation monitoring, erosion problems, RTE, critical habitats, fire NFFL, fire NFDRS	brown, red,
REG	9 REGULATORY	Ches. Bay RPA/RMA, floodplains, tax parcels, zoning, land status within park	violet, black, orange
GEOD	10 GEODETIC CONTROL	kilometer markers, UTM grid, Long/Lat grid, geodetic controls points	violet, yellow

Colonial GIS database is divided into 10 master files. These files represent groups of layers combined by common features.

Impact Monitoring and Restoration in Mount Rainier NP

By Regina M. Rochefort
and Stephen T. Gibbons

Each year about 2 million people come to Mount Rainier NP. Day hiking and camping are among the most popular activities; subalpine and alpine meadows are the most frequently visited destinations (Johnson et al, 1991). Almost 3/4 of all visitors go to Paradise, a beautiful subalpine meadow located on the main park road.

The Paradise area has been a popular attraction since 1915, when the road first was opened to automobiles (Martinson, 1966). Other subalpine areas, such as Spray Park, have been heavily used since the 1890s, when hundreds of tourists were guided in over mining roads (Martinson, 1966). This sustained level of heavy use has resulted in numerous bareground and/or severely eroded areas. To deal with this problem, Mount Rainier has developed a comprehensive system of impact monitoring and restoration. The program was developed first for the Paradise Meadows and now has been extended to the entire park.

Impact sites are stabilized with silt bars, ready for filling and revegetation.

Restoration crew is shown here installing stabilization bars or silt dams; the area in the foreground has been filled with gravel and will next be filled with soil.

Paradise Restoration

The Paradise meadows encompass approximately 389 ha (960 acres) and extend from 1,646 to 2,256 m (5,400' to 7,400') in elevation. Most of the meadow is within the subalpine parkland zone (Franklin and Dyrness, 1984), although a small portion is above treeline and is dominated by alpine vegetation. Park policy is to discourage off-trail hiking due to the fragility of the subalpine vegetation, but off-trail travel still persists, causing new impacts and perpetuating existing bare-ground impacts.

In 1986 the park began a large scale program to repair human-caused impacts in the meadow. The first step was to form an interdivisional committee to write a plan for protection and restoration of the meadow (Rochefort, 1989). Members of the committee were Doug Buehler (Interpretation), Mike Carneyu (Trails), Steve Gibbons, Rick Kirschner and Garry Olson (Ranger Division, Bob Elmore (Landscape Architect), and Regina Rochefort (Botanist, chairperson).

The plan was developed over a 3 year period; steps included field surveys of impacts, sociologic surveys regarding noncompliance and optimal control methods (Johnson and Swearingen, 1988), and development of a method to rate and rank impacts for restoration.

Impacts Documented

Field surveys in 1986 and 1987 documented 913 human-caused bareground impacts in the meadow. Approximately 89 percent were informal "social" trails. The remaining impacts (11%) were large bareground or trampled areas used as rest and/or view points. Impact dimensions are variable: lengths range from 0.5 to 1,500 m, widths from 0.1 to 25.6 m, and depths from 0.01 to 0.95 m.

The sociologic study, conducted by Darryll Johnson and Thomas Swearinger (U/WA CPSU), tested 7 sign texts, 2 types of barriers, and the influence of a uniformed NPS employee on off-trail hiking. The authors also developed a profile of non-compliers.

The study showed that the standard sign text in use at that time (Meadow Repairs, No Hiking) was the least effective text tested. Both barriers were effective, but the yellow polypropylene rope was more effective than split rail fencing, perhaps because many visitors came from urban areas and equated ropes to area closures. The sociological study also indicated that the mere presence of a uniformed NPS employee reduced non-compliance to a negligible level, showing that visitors did indeed know they were expected to walk on maintained trails.

The study results led to revised regulatory sign texts within the meadow, additional interpretive signs in the meadow and visitor center exhibits, and increased meadow roves by Interpretive Rangers.

Restoration Rating Criteria

Restoration rating criteria were developed by the Paradise Plan Committee, Dr. William Rippe (OR/State/U), and Susan Fritzke (now at Yosemite NP), to quantify relative damage of each site and the potential for continued damage, and to produce a ranked list of all impacts for restoration. The rating is the product of 2 numeric values: soil erosion potential, and aesthetic or visual quality (Rochefort, 1990).

Seven factors are used to estimate soil erosion potential: vegetation type, soil texture, length of impact, depth of impact, width of impact, slope, and percent bare ground. Three factors are evaluated to determine the visual quality of the impact: distance from a developed trail, visibility, and accessibility. In addition, notations are recorded on a number of qualitative factors: safety hazards; presence of rare, threatened, or endemic species; laws or regula-

Anastasia Island Beach Mouse 'At Home' at Fort Matanzas National Monument

By Philip A. Frank

Fort Matanzas National Monument (FMNM) is a small park on the southern tip of Anastasia Island, a slender 14 km long barrier island on the Atlantic coast of NE Florida. Its featured attraction is a beautifully preserved 16th century fortification built by the Spanish to control access from the south to the town of St. Augustine. Less well known is its status as a prime example of coastal strand--one of Florida's rarest and most imperiled natural communities. The dune communities there are home to a wide variety of wildlife, including several threatened and endangered species, most notable of which is the Anastasia Island beach mouse (AIBM, *Peromyscus polionotus phasma*), a small mammal endemic to the Island.

Beach mice are coastal forms of the more common and widespread oldfield mouse that occurs throughout the southeastern United States. These mice inhabit coastal dunes along the Atlantic coast of Florida and the Gulf coasts of Florida and Alabama. Beach mice are habitat specialists, preferring primary dunes and adjacent coastal strand and scrub. They are entirely nocturnal and pale in coloration, closely matching the light beach sands they inhabit.

Because of beachfront development throughout Florida, the loss of beach mouse habitat has been extensive, and much of the remaining habitat is fragmented, disturbed, and occupied by exotic cats and house mice. As a result, 6 of the 8 subspecies of beach mice are listed as either threatened or endangered, and one subspecies formerly found on the barrier island to the south of Anastasia Island is believed to be extinct (Humphrey and Barbour 1981).

The AIBM was listed as endangered in 1989, and I have been conducting field research stressing basic ecology in order to guide management for the beach mouse. Research has been funded by the Florida Game and Fresh Water Fish Commission's Nongame Program, with additional support from the University of Florida and the Florida Museum of Natural History.

Anastasia Island is developed over most of its length; only 2 parcels of land remain essentially undisturbed. Fortunately, both are publicly owned, and are managed with the needs of the beach mouse in mind. Anastasia State Recreation Area (ASRA), located at the island's northern end, is managed by the Florida Park Service and has approximately 6.5 km of linear dune habitat. FMNM at the southern end is considerably smaller, with about 1 km of linear dune habitat. Because of the protected status of FMNM and ASRA, these locations are critical to the long-term persistence of the AIBM.

The primary method used to study the beach mouse was live trapping--on a series of grids located at FMNM and ASRA, and on transects

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tions affecting the site; and potential impacts on aquatic or wildlife resources.

Impacted sites are ranked numerically, but if the impact affects one of the qualitative factors, it can be raised to the top of the prioritized list during annual, interdivisional reviews. All field data are entered into a computer data base (dBase program, which can be run on any IBM compatible computer), developed by Dr. Richard Frenzel. The computer data base calculates numeric rating values of each impact and prints reports of numeric values, qualitative factor notations, and the supplies required for restoration of individual sites (e.g. soil and gravel volumes, numbers of greenhouse plants). The program also contains modules for entering reports on restoration efforts (supplies used, hours spent, costs, materials, etc.) and monitoring results.

Restoration Methods

Restoration of individual impacts involves 6 steps: scarification, stabilization, filling, revegetation, site protection, and monitoring (Rochefort, 1990). Many sites have become compacted and must be scarified to enhance root penetration and water percolation. Impacts deeper than 3 cm require stabilization to impede downhill movement of soil. Wood or rock silt bars are installed as subsurface erosion control structures.

Following stabilization, the site is filled to the grade of the adjacent undisturbed area. Fill material consists of 3 components: rock, gravel, and topsoil. All topsoil is purchased from outside the park but specifications require it to be approximately the same soil texture, pH, and organic matter content as that of native soils. Soil is steam sterilized to prevent importation of exotic seeds.

Once the site has been filled to grade, it is revegetated, using 3 techniques: seeding, transplanting, and natural revegetation. Most sites in Paradise are seeded and planted rather than allowed to revegetate solely by natural means. All seeds are collected as close to the impacted site as possible, to maintain the genetic integrity of the site. Transplants are either salvaged from within the impacted site prior to filing, or grown in the park's greenhouse from seeds or plant stock collected in close proximity to the impacted site (Davis, 1991).

Mount Rainier NP has completed restoration of 35 social trails; an additional 24 sites have been partially completed. Restoration over the past 6 years has cost $810,000 and required 24,404 workhours. Approximately 30 percent of this cost has been personnel wages; the remainder has been for supplies, materials, and private helicopter use. The work has required 645 m^3 of soil, 260 m^3 of gravel, 137 m^3 of rock, and 29,150 greenhouse and/or salvaged plants.

Park-wide Applications

Impact surveys in Paradise began in 1986 and were completed in 1987. In the winter of 1987, it was decided to expand the impact monitoring program to Spray Park. Paradise methods were revised and further tested in Spray Park. These methods now are used systematically to survey management zones within the park's Wilderness as funding permits. Impact monitoring is carried out on alpine areas by Rochefort; subalpine and forested areas are monitored by Natural Resource Specialist Barbara Samora. Currently 11 of the park's 22 alpine zones and 5 of the 33 subalpine zones have been inventoried (1,591 total impacts). Impact data are used both to direct restoration efforts and to develop Limits for Acceptable Change (LAC) standards within the park's Wilderness. Currently LAC standards have been revised for 8 alpine zones, 1 alpine camp, and 2 subalpine zones based on impact surveys (e.g. revised limits on numbers of camping parties/night).

All impacts are entered into 1 data base and restoration efforts are directed at the highest priority impacts. Restoration plans are developed by a variety of personnel, depending on the size of the impact. Small projects are the responsibility of the area ranger; larger projects have been planned by the Botanist or an interdivisional committee.

Pam Griffin supervises restoration crews that work on large projects such as those now underway in Paradise, Spray Park, and Sunrise. Implementation of large projects also rely on substantial support from trail crew and roads personnel. Protection and monitoring of restored areas is a shared responsibility of Ranger, Interpretive, and the Planning and Design and Natural Resource divisions.

Rochefort, Botanist at Mount Rainier NP, is pursuing her Ph.D. at U/WA; Gibbons is a Natural Resource Specialist in the NPS Pacific Northwest Regional Office as well as National Natural Landmarks Coordinator.

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located over the entire length of the island. The grids were trapped quarterly from January 1989 to January 1991, and the transects were trapped during the summers of 1989 and 1990. Information from the grids was used primarily to estimate beach mouse density and predator (feral cats) abundance, while the transects provided data on island-wide distribution. The main study sites were FMNM and ASRA, although beach mice also were studied in a variety of conditions including severely degraded habitats adjacent to development.

Beach mice are distributed over nearly the entire island, with the exception of an area where the natural vegetation has been replaced with concrete reinforcement to deter erosion. The mice occupy sites with conditions ranging from relatively pristine (ASRA and FMNM) to severely degraded. Their population levels were found to be extremely variable, both in space and time. In high quality habitat, densities may range from 2 mice/ha to 90 mice/ha, with an average density of around 30 mice/ha. Over the 2 years of trapping, no seasonal pattern in abundance was obvious, although there was a tendency for populations to be at high levels in winter. Densities in the disturbed habitat adjacent to development were generally much less, compared to ASRA and FMNM. Habitat availability, habitat quality, and the presence of large numbers of domestic cats may have caused this difference.

Although separated only by a short distance and appearing superficially similar, population dynamics at FMNM and ASRA were quite different, suggesting different ecological factors are operating at these locations. One striking difference was the presence of large numbers of feral cats at ASRA, whereas cats were quite rare at FMNM. Data collected at ASRA over the 2 year study suggest a negative correlation between cat abundance and beach mouse density (Fig. 1). That cats are capable of depleting wildlife populations is common wisdom among field biologists (Churcher and Lawton 1989), but field documentation is usually lacking.

Recommendations for management of the AIBM include eliminating cats, both feral and free-ranging domestic types, from beach mouse habitat, preventing habitat damage from foot and vehicular traffic, educating the public on the plight of the beach mouse, and establishing a second population separate from Anastasia Island. This second population establishment is a high priority for the recovery of the AIBM, as it will reduce the potential for extinction caused by a catastrophic hurricane such as Hugo, which devastated the Carolina coast in 1989.

I am currently working on a reintroduction project in cooperation with the Florida Park Service, the National Park Service, and the U.S. Fish and Wildlife Service. The reintroduction would be to Guana River State Park, a prime site within the historic range of the subspecies located on a barrier island immediately north of Anastasia Island. Using methods like those used in a similar project (Holler et al. 1989), approximately 20 pairs of mice will be taken from several locations on Anastasia Island, including FMNM, so as to include the range of genetic variability into the founder population.

The reintroduction began in the fall of 1992, a time of maximum food availability and population densities, and the population will be monitored for 1 year, initially. Success of the reintroduction effort will be measured by growth and expansion of the population. If successful, this effort will significantly enhance the survival probability for this unique mammal.

I would like to acknowledge Wallace Hibbard, Brian Peters, and Rick Gushew of the NPS (FMNM) and Doug Carter, Paul Crawford, and Robin Huck of the Florida Park Service (ASRA), who provided valuable assistance, as well as Dr. Stephen Humphrey of U/FL who initiated this research and gave ongoing advice and assistance. Rebecca Henson was invaluable in the field.

The Anastasia Island Beach Mouse

Frank is a Ph.D. candidate at U/FL, Dept. of Wildlife and Range Services.

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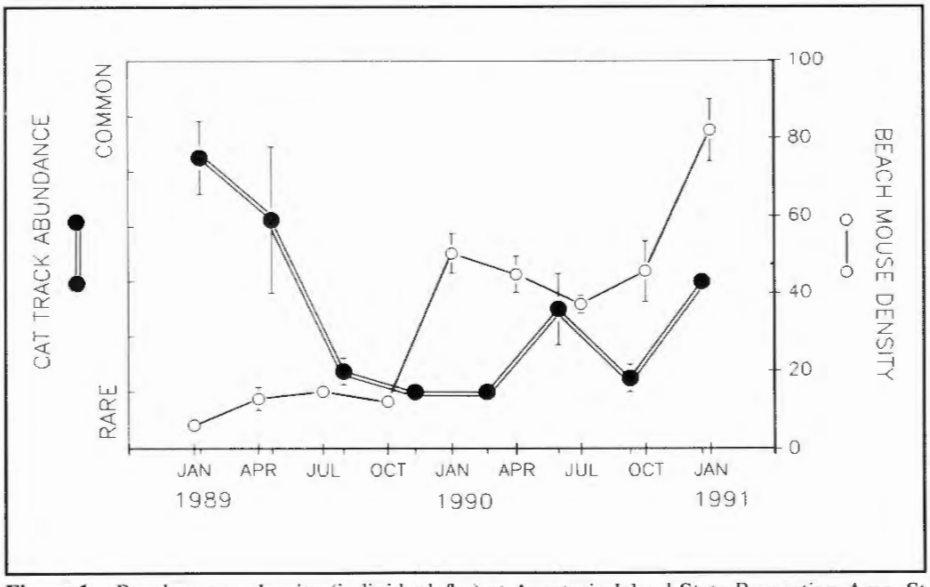

Figure 1. Beach mouse density (individuals/ha) at Anastasia Island State Recreation Area, St. Johns County, FL, compared to house cat abundance as determined through track counts indices. Cat numbers were reduced by park staff beginning in fall, 1989, followed by a significant increase in the beach mouse population.

IN THE NEXT ISSUE. . .

- Carol L. McIntyre's **Notes from Abroad**;
- **"Predation of Yellowstone Elk Calves"** by Frank Singer;
- **"Subalpine Meadows: Promising Indicator of Global Climate Change"** by Andrea Woodward and June Rugh;
- **"Biological Implications of Trophy Hunting of Dall Sheep in Alaska NPs and Preserves"** by Frank Singer;
- **"Geologic Mapping Program at Great Basin NP"** by Janet L. Brown;
- **"Window to the Past"** by Carol McNulty-Huffman;

plus some holdovers previously promised and some newly-promised articles on native plant protection, the Grand Canyon willow fly catcher, and an evaluation of Mammoth Cave NP's groundwater basin.

USGS and NPS: Science Partners. . .

cont'd from p. 1

The right answer, of course, is both. Both the wonder of the beauty and the wonder of the science combined to make the first parks possible. And that natural partnership has lasted and must continue. I cannot imagine doing earth science without our national parks. I cannot imagine national parks thriving without good science.

As USGS Director, I can think of no better way to celebrate the accomplishments of the first 75 years of the National Park Service than to re-dedicate our partnership. As part of that re-dedication, Doyle Frederick, Associate Director of the USGS, and I had the pleasure earlier this year of sitting down with NPS Director Jim Ridenour and NPS Associate Director for Research Gene Hester to discuss ways of renewing and expanding the various understandings that formally bind our 2 agencies.

In follow-up sessions between our senior staffs, it was evident that our work together really needs no formal bind. I think we all were extremely pleased with reports of many joint projects underway and being discussed. It also is evident that our partnership continues to include the original elements of scientific description, interpretation, and discovery. But more and more our modern partnership is and must be expanding into 2 key areas:

* We must work harder to help the NPS interpret and explain the earth, water, and geographic science of the parks. We scientists are good at telling one another about the magnificent science revealed in each park. We must learn to share that scientific story with the park visitor and thus help to enhance the visitor experience. In a way, we've been too selfish with our science. It's time to share better the wonders of park science by providing more assistance where needed to the NPS park interpretation program.

* Perhaps even more important, our geologists, hydrologists, and cartographers need to work harder to share their science with park management and to provide information needed by management to make the best-informed decisions about protection and enjoyment of the parks. For our part, that means focusing on the information needed by park management and meeting the deadlines for supplying that information. Not all science and not all scientists can meet these conditions, but we are moving in that direction.

USGS geologists, hydrologists, and cartographers are increasingly being asked to help park managers develop the data and knowledge that will repair or head off overuse and misuse of parks by the swelling number of visitors. Increasingly, the earth scientist is asked to provide the long-term perspective on the environmental conditions of the past and likely conditions and changes of the future.

The following articles provide a taste of the range of joint scientific efforts underway: modeling climate change, water temperature and biological productivity in Yellowstone Lake; sediment transport and beach erosion in Grand Canyon; natural resources and natural and manmade hazards in and around park borders; coastal geology and pollution; fossils on the public lands; and atmospheric emissions and biochemistry.

But these articles provide only a taste of the exciting science that USGS and NPS are conducting together in the national parks...only a taste of the expanding partnership between the managers and scientists of NPS and USGS. Looking to the future, I am particularly pleased that 3 of our newest major program initiatives--National Water Quality Assessment, National Geologic Mapping, and Accelerated Production of Digital Base Cartograpbic Data--are finding immediate appeal and application to NPS.

Like all good partners, we sometimes disagree on methods and answers. In fact, it is often hard for our own scientists to agree on a single answer. But that is the nature of science--to probe and challenge from different perspectives. As a bureau, we are working harder to develop a consensus response to tough questions in time to help park management do its job and make the necessary tough management decisions.

Few government agencies have accomplished as much in 75 years as the National Park Service. We at the USGS congratulate you. And we accept the challenge to work with you to help make the next 75 years equally productive. Our natural partnership is older than either of us. May it continue to prosper.

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