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Late Oligocene Biostratigraphy at Badlands National Park

By Vincent L. Santucci

Badlands NP in southwestern South Dakota preserves one of the most complete sequences of fossil mammals. Since Dr. Hiram Prout first described a fossilized titanothere jaw fragment (Prout, 1846), paleontologists have searched extensively the Oligocene sediments. Research in the White River Badlands continues to reveal new information related to the geology and paleontology.

Paleontologists working in Badlands' fossil rich sediments have established a comprehensive biochronology based upon fossil mammal assemblages. The stratigraphic sequence includes the basal Chadron Formation, overlain by the Brule Formation and then topped by the Sharps Formation. The Brule is subdivided into two members in South Dakota – the lower Scenic Member and the upper Poleslide Member. The Sharps Formation base is defined by the Rockyford Ash Member, which is widespread throughout southwestern South Dakota.

The lower portion of the Sharps Formation has yielded a significantly less diverse assemblage of fossil vertebrates by comparison to the other stratigraphic zones within the White River Group (MacDonald, 1963; MacDonald, 1970). An abundantly rich mammalian assemblage is known from the stratigraphic zones directly above and below the Lower Sharps. Furthermore, faunal assemblages from the strata above and below the Lower Sharps exhibit distinct taxonomic differences. Thus the rarity of described paleontological material from the Lower Sharps limits biostratgraphic zonation at the Whitneyan/Arikareean Land Mammal Age (LMA) boundary and warrants further investigation of this intermediate zone.

Extensive field surveys of the well exposed portions of the Lower Sharps throughout southwestern South Dakota during the 1985 and 1986 field seasons confirmed a poorly fossiliferous horizon.

A series of channel sandstone units in the Cedar Pass Area of Badlands NP was examined closely during an independent survey. The channel deposits contained an abundance of fossil vertebrate material. Detailed study of these sandstone deposits indicated that the channels had downcut through the Rockyford Ash Member of the Sharps Formation into the Poleslide Member of the Brule Formation. Therefore, the assemblage of fossils contained within the sandstones represent a Lower Sharps fauna.

A paleomagnetic study of the lower portion of the Sharps Formation and the upper portion of the Poleslide Member of the Brule Formation was undertaken in order to further demonstrate a post-Rockyford Ash age of the downcutting channels at Cedar Pass (Fig. 1). Previous Oligocene paleomagnetic studies performed by Donald Prothero have yielded consistent data, and a well defined magnetic polarity time scale has been established (Prothero, et al, 1983). The magnetostratigraphic patterns recorded can be utilized with other lithologic and paleontologic data to more precisely correlate geochronologically equivalent zones.

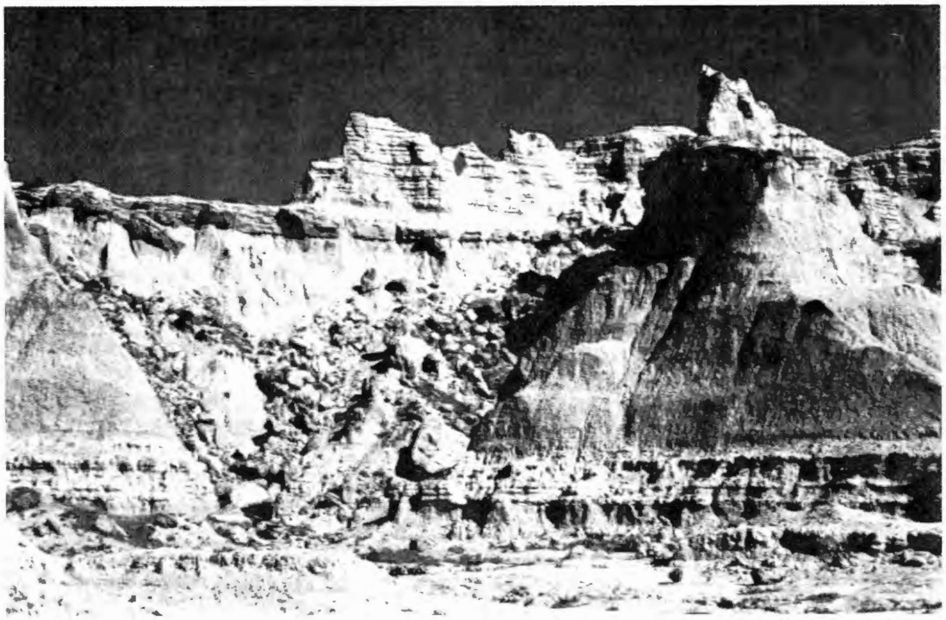

Figure 1. Lower Sharps channel sandstones downcut into the Poleslide Member of the Brule Formation in the Cedar Pass Area, Badlands NP.

Regional paleomagnetic sampling indicates that the upper portion of the Poleslide Member, to the base of the Rockyford Ash, is a zone of reversed polarity (reversed magnetozone); whereas, from the base of the Rockyford Ash through the lower half of the Sharps Formation is a zone of normal polarity (normal magnetozone). The magnetic polarity boundary at the base of the Rockyford Ash provided the opportunity to test whether the paleomagnetic character of the downcutting channel sandstones reflects a pre-(reversed) or post- (normal) Rockyford Ash correlation.

Paleomagnetic samples were collected within the Poleslide Member of the Brule Formation and the Sharps Formation at Cedar Pass. Samples were obtained from both the channel sequences downcutting through the Rockyford Ash and in adjacent areas where the Brule-Sharps sequence and contact still were preserved.

Natural Remnant Magnetization (NRM) was measured for each sample through the use of a large bore ScT cryogenic magnetometer at the University of Pittsburgh. Two orientations were measured on each sample. Thermal demagnetization treatment was performed at a range of temperatures and each sample measurement was recorded after each thermal treatment. Zijderveld vector demagnetization diagrams (Fig. 2) were plotted for each sample (Zijderveld, 1967).

All samples obtained from the upper portions of the Brule Formation, where channelling did not interrupt the sequence, exhibit a reverse polarity. The samples obtained from the sequence above the base of the Rockyford Ash in the Sharps Formation, where channelling did not interrupt the sequence, show a normal polarity. The last set of samples was obtained directly from the downcutting channel sequence in areas where the Rockyford Ash was cut through and no longer present. These samples all were collected at elevations that were

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PARK SCIENCE

NATIONAL PARK SERVICE

SUMMER 1992

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

ARTICLES

DEPARTMENTS

MISCELLANEOUS

editorial

It was one of those serendipitous coincidences that delight an editor's heart. Across our desk as we worked on the current issue devoted to paleontological research came a gem of a mini-essay by Stephen H. Lekson, Curator of Archaeology at the Museum of Indian Arts and Culture in Santa Fe, NM. It appeared in the Jan.-March 1992 issue of ***Contact***, the Southwest Region Interpreters Newsletter and was forwarded to ***Park Science*** by Glen Kaye of the SW Regional Office. Lekson's article goes beyond mere guidelines for interpretation of prehistoric findings. He offers, instead, that far rarer commodity, *wisdom*.

Lekson's subject deals with the reason that science and belief systems often clash. They are "simply too different in structure, strategy, and intent" to be reconciled. Moreover, he says, "there are good reasons not to make the attempt."

Science and belief systems, Lekson observes, are related to culture in very different ways. Belief systems are "integral to their cultures," whereas science attempts to minimize the ways that culture infringes on knowledge . . . "it consciously attempts to shed cultural biases." Therein lies the first difference.

Belief systems are internally coherent; they are *believed*. They may be challenged, but "at any one moment it must be believed that a belief system is correct for all time." Science, on the other hand, is open to correction. As Lekson points out, with science "it's OK to be wrong." Science *learns* through findings that disprove prior theories. Thus, the second fundamental difference between belief systems and science: "Belief systems are always right: science is always prepared to be wrong – and usually is."

The third major difference springs logically from the second: "Belief systems are inextricably bound up in their cultures: they are always right; they are constant. Science is explicitly trying to escape culture; it is always wrong; and it is always changing."

The wisdom lies in Lekson's admonition to interpreters:

"First, understand the differences between belief systems and science. Second, never try to judge belief systems against science, or science against belief systems. *They are not comparable.* Third, present both views – and the function of both views – as separate, equally valid *realities*.

In conclusion, Lekson writes:

"Science and belief systems are incompatible and incomparable. It is the interpreter's challenge to present them intelligently and intelligibly, without exacerbating the real (and potential) conflicts between the two. We cannot let one override the other. But at the same time, we are dishonest if we gloss over their differences or offer facile blendings of the two.

"The best approach is one that is honest and open, and that recognizes the validity of two very different ways of knowing."

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Thank You!

This issue, which is largely devoted to paleontological research and interpretation in the national parks, contains 8 more pages than usual. The extra costs involved have been picked up by the 3 NPS Regions in which the bulk of these articles originated, namely the Western, Southwestern, and Rocky Mountain Regions.

The previous (Spring 1992) issue of Park Science, featuring Caribbean area research, also contained extra pages, subsidized by the NPS Southeast Region. To all 4 of these Regions, a heartfelt vote of thanks for helping make these issues possible. (The Pacific Northwest Region also deserves recognition for consistently picking up the rising costs of publication.)

Late Oligocene Biostratigraphy at Badlands NP

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both above and below the level of the Rockyford Ash at Cedar Pass. Each of these samples exhibits a normal polarity, regardless of the elevation at which it was collected.

The paleomagnetic polarity pattern determined from the measurements obtained at Cedar Pass strongly supports that the downcutting channel sequences were developed during a post-Rockyford Ash event within the Lower Sharps Formation. Therefore, the fossil material collected from the channels provides a significant contribution to the previously scanty record.

The biostratigraphic range under investigation in this study lies at a stage overlapping two biochronological zones of North American Land Mammals. The Whitneyan/Arikareean Land Mammal Age boundary lacks an associated lithostratigraphic marker and has not been firmly established. The assemblage of fossil mammals collected from the channel deposits provides integral information that supports the establishment of the Whitneyan/Arikeean boundary in the Lower Sharps. The Lower Sharps can be characterized as a concurrent range zone for the last appearance of numerous representative Whitneyan fossils and the first appearance of many Arikareean mammals.

The fossils collected from the Cedar Pass channels provide a broader window into the poorly understood lower Sharps fauna. This enigmatic biozone clearly displays a pivotal assemblage of fossil mammals. Given 150 years of study in the White River Badlands, much work remains. Mammalian biochronology augmented with paleomagnetic data will prove instrumental to greater understanding of the depositional history of the continental Tertiary and the evolution of mammls.

Santucci is Paleontologist/Curator at Petrified Forest NP.

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NPS Staff and Consulting Paleontologists *meet in San Diego at the Society of Vertebrate Paleontology meetings: (l to r) Rachel Benton, Fossil Butte NM; Elizabeth Barnosky, Yellowstone NP; Neil King, Hagerman Fossil Beds NM; Mary Thompson, Idaho Museum of Natural History; Ted Fremd, John Day Fossil Beds NM; Dale Hanson, BLM, Montana; Laurie Bryant, BLM, Idaho; Ann Elder, Dinosaur NM; Vince Santucci, Petrified Forest NP; Dan Chure, Dinosaur NM, and William Akersten, Idaho Museum of Natural History.*

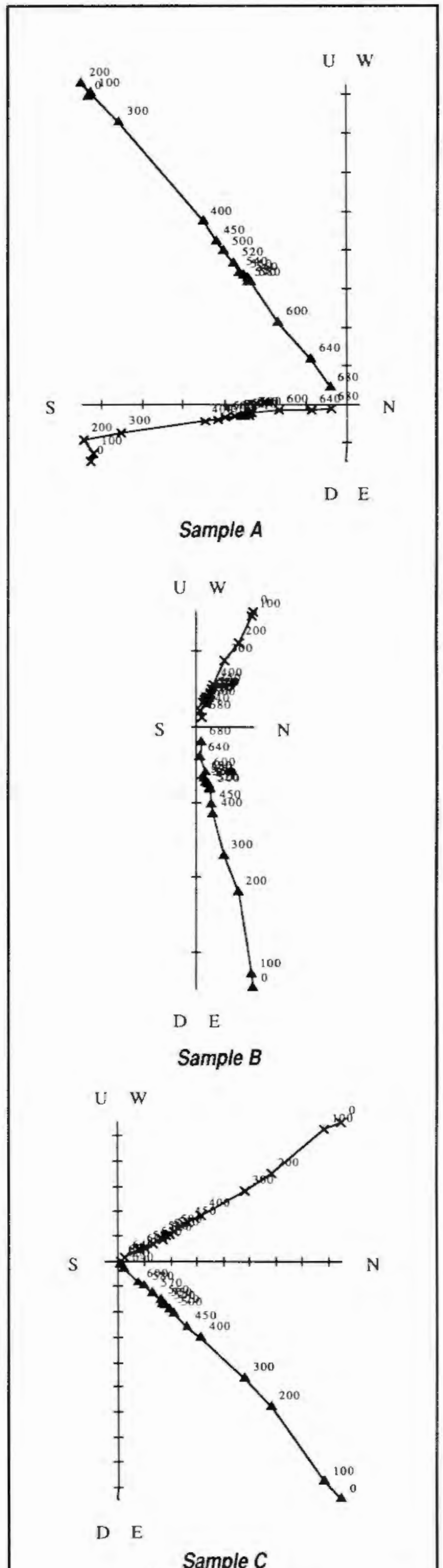

Figure 2. *Zijderveld vector demagnetization diagrams. (A) Sample obtained from below the Rockyford Ash in the Upper Brule, showing a reversed polarity; (B) sample collected abover the Rockyford Ash in the Sharps, indicating a normal polarity; and (C) sample taken from the channel sediments downcutting through the Rockyford Ash, displaying a normal polarity.*

New Discoveries of Fossil Footprints at Dinosaur National Monument

By Martin Lockley, Kelly Conrad and Marc Paquette

Dinosaur National Monument (DINO) is most famous for the spectacular dinosaur bone quarry in the Morrison Formation. Here visitors can see the remains of well known dinosaurs like *Stegosaurus*, "Brontosaurus" (correctly known as *Apatosaurus*), *Camarasaurus* and other extinct animals from the Late Jurassic epoch - or golden age of brontosaurs. As recent discoveries have shown however, it is not just the world famous Morrison beds that reveal evidence of dinosaurs and other Mesozoic vertebrates at DINO. During the last two years the park service has sponsored a fossil footprint research project that has so far resulted in the discovery of about 18 new tracksites.

Historically, dinosaur tracks and other fossil footprints were virtually unknown from DINO and the immediate vicinity. In fact only one fossil track had ever been collected in the large area that makes up the monument. This situation reflected a lack of research activity in the field of Ichnology (the study of trace fossils). All this has changed dramatically as the study of tracks and traces has rapidly developed into a mainstream geological science in recent years.

At Dinosaur National Monument there are at least 8 potentially track-bearing Mesozoic formations including 5 that pre-date the bone rich Morrison Formation and 2 that post date it. During the first two years of field work our research team (the U/CO at Denver, Dinosaur Trackers Research Group) has focused attention on pre-Morrison beds. Most of the tracksites so far discovered occur in the Late Triassic Chinle Formation (also referred to as the Popo Agie in this area). A few tracksites also have been discovered in the Glen Canyon sandstone (Late Triassic-Early Jurassic) and tracks have been reported from the Middle Jurassic Carmel Formation very near the monument boundaries.

The Chinle Formation tracksite discoveries are particularly interesting because of the variety of track types and the quality of preservation. Most people are familiar with the Chinle Formation in the type area of northeastern Arizona where it makes up the famous Painted Desert badlands and contains the logs that comprise the well-known Petrified Forest. In this region bones also are abundant but tracks are rare. At Dinosaur National Monument however the reverse is true; bones are very rare but tracks are quite abundant. In fact, as shown below, most well-known Late Triassic tetrapods are represented by their tracks, and it is possible to derive a census of the animal communities of that epoch just from the fossil footprint evidence (Fig.1).

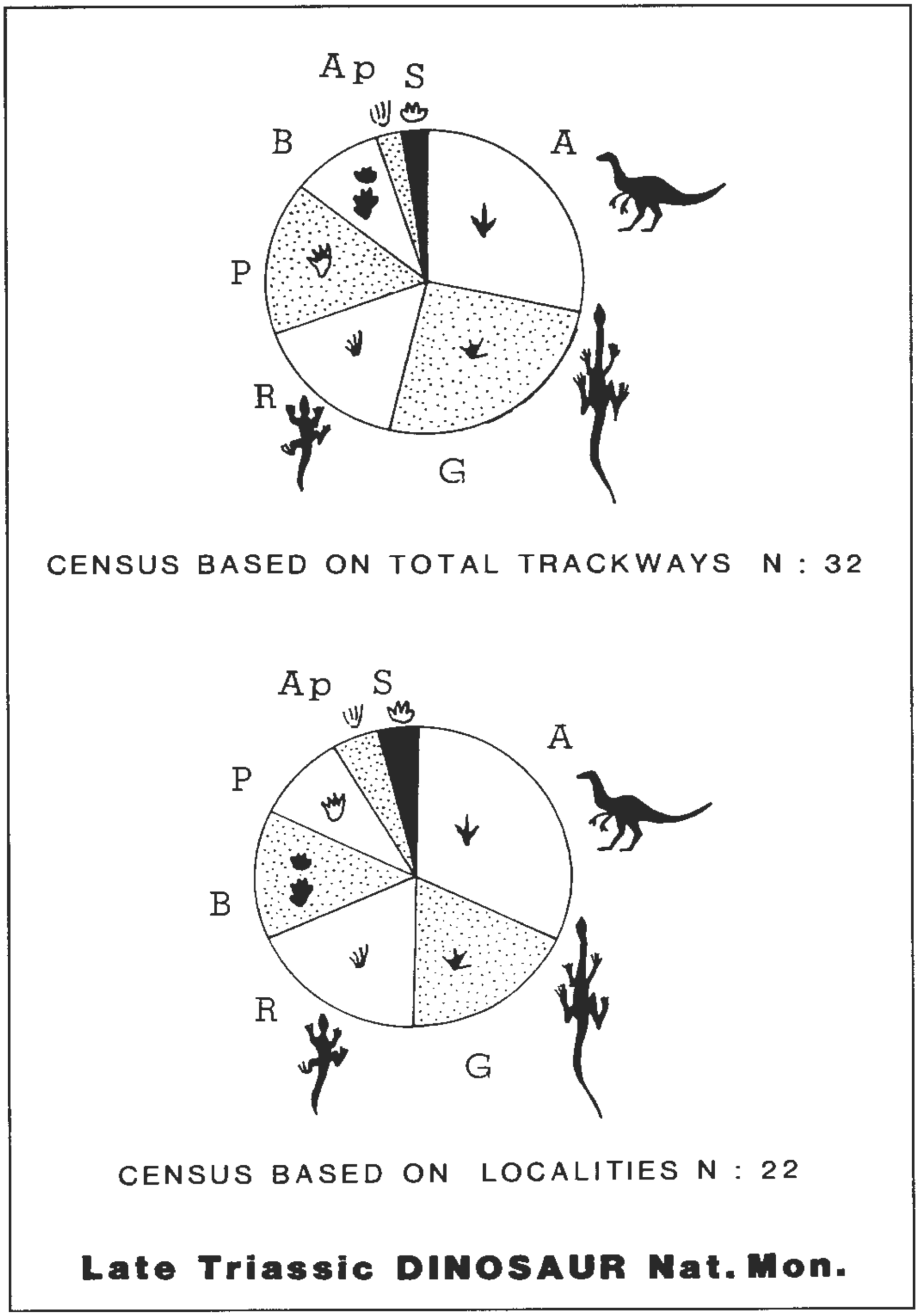

Figure 1. *Pie diagrams showing the proportion of different Late Triassic track types found at Dinosaur national Monument. Top diagram based on total number of trackways; bottom based on number of localities revealing various track types.*

The Late Triassic was the beginning of the Age of Dinosaurs - a time when many non-dinosaurian reptiles were undergoing rapid evolutionary radiation. The track record reflects this epoch of diversification by revealing an interesting menagerie of archosaurian reptiles. In approximate order of relative abundance the Chinle Formation at Dinosaur National Monument has so far yielded the following trackway types (Fig.2).

Agialopus: the three toed tracks of a small, bipedal, turkey sized dinosaur like *Coelophysis* [similar bird-like tracks are also referred to as *Grallator*].

Gwyneddidinium: the four toed tracks of a relatively rare aquatic reptile known as a tanystropheiid [possibly genus *Tonytrachelos*].

Rhychosauroides: the five toed tracks of a lizard, or lizard-like animal related to the modern "Tuatara" (genus *Sphenodon*) from New Zealand.

Brachychirotherium: the five toed tracks (hind feet) and four toed front footprints of a quadrupedal archosaur, probably an armored herbivorous aetosaur.

"Chirotherium": the five toed tracks (hind feet) of a quadrupedal archosaur, probably an aquatic, crocodile-like form known as a phytosaur.

Mammal-like reptile tracks: five toed footprints made by the only non-archosaurian vertebrate represented in this list.

Kouphichium: distinctive, complex trace made by

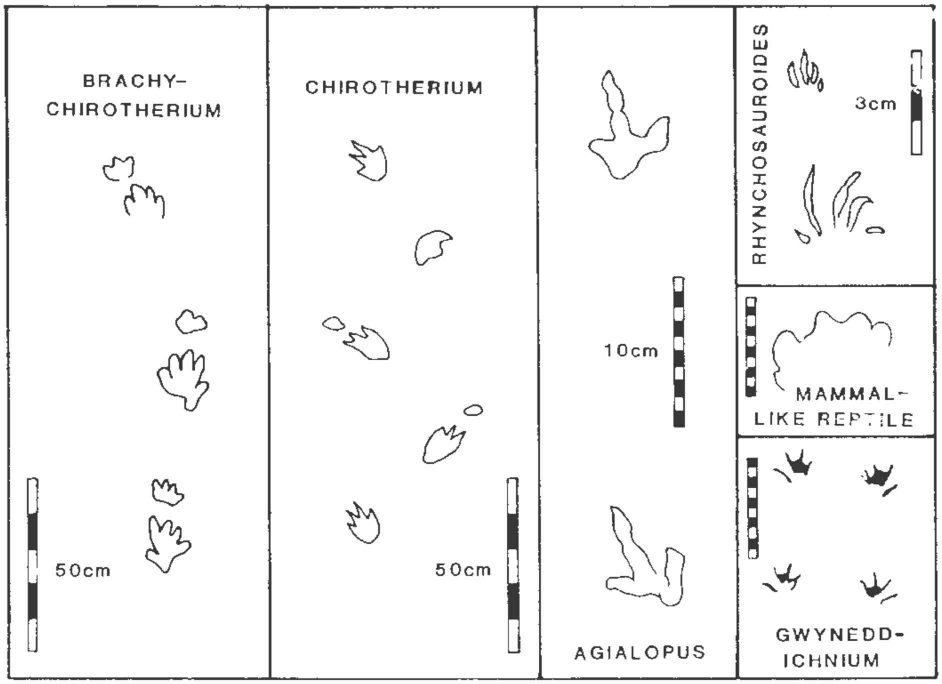

Figure 2. Detail of tracks and trackways of various Late Triassic trackmakers from Dinosaur National Monument

a horseshoe crab, or close relative (cf. modern genus *Limulus*).

Scoyenia and others: trails of various invertebrates including miscellaneous arthropods and worms.

All these vertebrate and invertebrate tracks and traces were found in the upper part of the Chinle Formation in deposits that represent ancient lake and floodplain settings. Recent work suggest that the Late Triassic was generally a wet epoch in the western United States and that intense monsoonal conditions prevailed (the so-called Megamonsoon). Such circumstances would have resulted in high water tables and good conditions for trackmaking as seen in many formations in the western USA at this time.

The presence of at least two mainly aquatic trackmakers (phytosaurs and tanystropheiids) also fits this picture. Trackways of the latter animal include examples with pairs of right and left hind foot impressions that reveal distinct web impressions and show that it swam with synchronous strokes of its hind feet (Fig. 3). These trackways are the first "swim tracks" ever reported for this animal and the first evidence that it had webbed hind feet. They are also a very rare example of swim tracks for an animal additionally known from walking tracks, thus allowing us to study two different modes of locomotion.

To date we have done little work on the Jurassic track-bearing beds that overlie the Chinle. However we can report that beds in both the upper part of the Glen Canyon Group (Navajo Formation) and the Carmel Formation are dominated by the three toed tracks of bipedal dinosaurs. This evidence shows that dinosaurs rose to a position of prominence between the Triassic and Jurassic and displaced a significant number of their formerly successfully archosaurian relatives. Ongoing research and the present high rate of discovery fossil footprint sites promises to reveal more trackway evidence at Dinosaur National Monument and elsewhere in the western USA.

Lockley, a paleoichnologist, is a professor at U/CO Denver; Conrad is a graduate student at U/CO Denver; Paquette is a geology student at U/CO Denver.

Further Reading

Tracking Dinosaurs by Martin Lockley
Cambridge University Press. 238 p.

Figure 3. Comparison of trackways of swimming and walking tanystropheiids. Note web impressions in swim tracks.

So What?

By David Whitman

Interpreting paleontological resources is a challenge. Most people have little if any personal experience with paleontological processes and practices so they have a limited frame of reference to draw upon. The terminology is foreign, the scatter of fossil parts they see is confusing, and sometimes the creature represented is bizarre in appearance.

Paleontology also is closely tied to geology – especially stratigraphy. Again, the average American finds geology hard to understand – perhaps even boring, and has little understanding of the basics of this and other sciences that use observation, mathematics, and logic. To the park visitor, the conclusions that paleontologists formulate often appear to be based on unrelated evidence.

I recall working at the information desk at Dinosaur National Monument headquarters, where we have a relief map of the monument on display. A mother, "interpreting" the place for her two children, told them, "Just think – dinosaurs used to roam around in those canyons." For her, the world has always looked as it does today – the Morrison ecosystem of 150 million years ago never existed and the Rocky Mountains never rose 65 million years ago.

Making the unfamiliar familiar, especially something from the incomprehensible past, is a real challenge . . . one with which we will not have much success until we learn to connect the unfamiliar with things the visitor can recognize . . . what the legendary park interpreter Freeman Tilden called "relevance."

To achieve relevance, the interpreter must be able to empathize creatively with the visitor. Since not everyone is endowed with empathy and creativity, this can present problems. For example, to compare Diplodocus or Apatosaurus with a giraffe is helpful, (it gives visitors an ecological equivalent with which they are familiar), but it can lead to a simplistic conclusion that Diplodocus WAS a giraffe. At the other end of the spectrum, to include the term "multituberculate" in a talk, without a graphic or model to explain it, is to take a step AWAY from interpretation.

Sometimes a concept can be experienced. Heat and pressure are the forces that transform unconsolidated material into rock. The words convey the idea, but a fuller and more lasting impression of their meaning can be transmitted by staging a participation game. Take a volunteer and describe him as an inland sea. Have him lie down. Take a second volunteer, describe him as a coastal marsh, and have him lie down on top of the "inland sea." Take a third volunteer, call him "an inland desert of sand dunes," and place him (uncomfortably, no doubt) on top of the "inland sea" and the "coastal marsh." Now ask the volunteer on the bottom of the pile if he feels heat and pressure. What the visitor audience sees will be the sweat on his brow, the way he labors to answer. They will **observe** the heat and pressure that is "turning him to stone." The concept of heat and pressure has now been observed, testified to, enjoyed (by all but the bottom volunteer), and *experienced*.

Even though the public's ignorance of paleontology and geology is profound, there still exists an inextinguishable curiosity about the past. This

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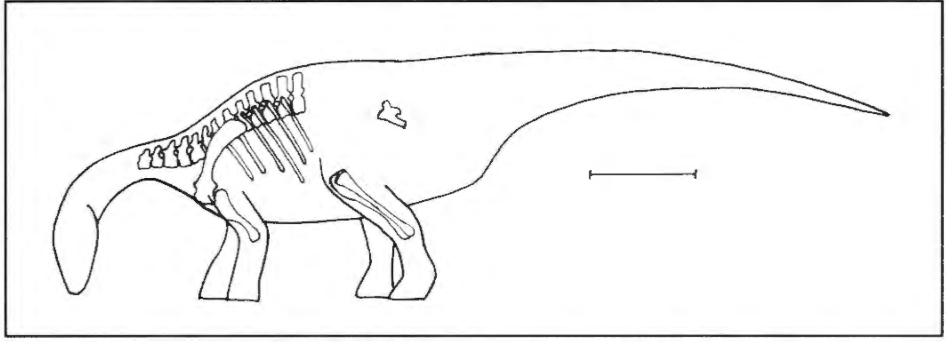
A Baby Dinosaur From the Land of the Giants

By Daniel J. Chure

The dinosaur quarry within the Visitor Center at Dinosaur National Monument (DINO) is well known for its spectacular dinosaur fossils – the remains of some of the largest animals ever to walk the Earth. However, not all dinosaurs were giants and even those that were began life as small hatchlings.

The main dinosaur producing layer at DINO is a sequence of terrestrial sediments known as the Morrison Formation. These rocks were deposited during the late Jurassic some 150 million years ago. Sandwiched in the Morrison in this area are over 30 separate volcanic ashes spewed from Jurassic volcanic highlands near the Utah - Nevada border. In late 1991 a small excavation in one of these ashes resulted in the discovery of a number of fossil vertebrates. Upon detailed preparation in laboratory one of these fossils turned out to be an unexpected treasure and one of the rarest of all dinosaur finds – the remains of a dinosaur that died quite soon after hatching from its egg.

The specimen is a partial skeleton consisting of a scapula and coracoid (shoulder blade) with an articulated humerus (upper arm bone), an articulated series of 13 vertebrae from the neck and trunk, half a dozen ribs, an articulated tibia-fibula (lower leg bones), and a part of the pelvis. The specimen is very small, with a scapula-coracoid length of 20mm, while each vertebrae measures a mere 3-4 mm in length. The estimated overall length for the hatchling is 240 mm (9 inches).



Outline of a *Camptosaurus* *hatchling showing the preserved bones of the new specimen from Dinosaur National Monument. Scale bar = 1 inch.*

Although the specimen is small, it shows several skeletal features very similar to those found in the bipedal herbivorous dinosaur *Camptosaurus* and it can be provisionally referred to that genus. *Camptosaurus* is known from a number of upper Jurassic localities in North America and England. Several species have been described, the largest has an adult length of some 8 meters! Thus, the small individual from Dinosaur is not only a hatchling, but was probably only a few days old at death. This is the only hatchling *Camptosaurus* known and one of the few dinosaur hatchlings found anywhere.

A formal description of this specimen is being prepared for publication. However, the significance of the hatchling transcends its mere description. Any depositional environment that preserves a fragile specimen such as the skeleton of a hatchling dinosaur may also contain skeletons of lizards, mammals, frogs, salamanders, and the other small, poorly known contemporaries of the dinosaurs. Remains of any of these groups would be an important addition to our knowledge of the Morrison community. More important, however, is the fact that an individual as small as this hatchling is not likely to have been capable of traveling long distances. Thus, it is possible that the level from which it was recovered contains fossilized nests and breeding grounds. Field work in the summer of 1992 will focus on additional excavation at the site and exploration of lateral continuations of the horizon in the hope of finding additional hatchling and/or nests. With a little luck, Dinosaur National Monument will become famous not only as a graveyard of the dinosaurs but as a nursery as well!

So What? *Continued from page 5*

curiosity is the open door, inviting us to satisfy the public's thirst to know. It provides an opportunity for us to do some real interpretation, beyond sharing facts and pictures of strange creatures.

Interpreters sometimes fall into what I think of as a subtle trap. The facts, the terminology, are seen as interpretation. It IS necessary to lay a factual framework from which an interpretive activity will advance, but sometimes the interpreter forgets to ask a simple but important question: *So what?*

Before we send that exhibit text to the contractor, before we stand up in front of the public and expound, we should ask *ourselves*, "So what?" *So what* that the Dinosaur Quarry offers the most complete picture of the Jurassic Period megafauna? So what that the Florissant fossil beds contain so many terrestrial species preserved from a single geologic period?

When we ask the same question about a national park, or wolves, or a mountain lake, the answer comes easily. So what? Well, there's biodiversity, there are predator/prey relationships and maintaining ecological balance, there is recreation and refreshment of spirit – these and many other responses. But fossils are long dead; some are greatly transformed by petrification. They're not going to put food on our tables; we aren't going to sell them; they no longer play any active role in the ecological health of the planet. They are, it seems, just natural curiosities, of no importance for our present or our future.

Even so, visitors are curious about fossils.

The answer to the "so what?" question is harder with fossils than most other resources with which we normally deal. One approach is to present examples of how fossils are a key to our past. As pieces of a greater puzzle, those fossils help form the whole and should be protected.

So what? Well, as the prehistoric past becomes better understood, it confirms what we already suspected – that the rules that governed the ecological workings of 150 million years ago still hold today. We learn too that extinction is natural, but the extinction rates we see today are unnatural and theatening to our well being.

In our interpretive programs on dinosaurs, we try to satisfy the visitors' questions about the Quarry and the creatures that lived here 150 million years ago. Having done that, we make a logical leap from dinosaurs to a general discussion of the extinction events we are witnessing today. This can lead to other kinds of discussions – threatened and endangered species, habitat loss, biological diversity, the legacy we are leaving for our children, and so forth. Tilden told us: Interpretation is revealing the truth behind the facts.

I feel strongly that fossil resource interpretation should provide facts and make the point that fossils should be protected. But pleading for that protection presupposes an answer to "So what?" The message can go farther if it is powered by thought on our part. Fossils are more than petrified natural freaks whose freakiness captures the public's interest. They are a resource – like all our park resources – that can and should be used to suggest a greater truth and to sharpen the visitor's sense of values.

Whitman is Chief of Interpretation at Dinosaur National Monument.

> *"Paleontologists have learned much about the timing, magnitude, selectivity, and recovery patterns of the major extinction events, but the implications for present biodiversity is still not well understood. The fossil record is, however, our only direct source of information on how biological systems respond to large-scale perturbations and thus can provide important insights into potential outcomes if habitat destruction or climate change proceeds unchecked."*
>
> **Dr. David Jablonski** *(Univ. of Chicago)*

Leaping Lizards, Frolicking Frogs, Swimming Salamanders, and Minute Mammals: The Non-Dinosaurs of Dinosaur National Monument

By Daniel J. Chure

Although dinosaurs are the most spectacular terrestrial animals during the Age of Reptiles, they were not the only component of the vertebrate community at that time. Secreted amongst rocks, up in trees, along the forest floor, and in ponds, rivers, and lakes there lived a diverse community of small vertebrates – a community which until recently has been very poorly known in upper Jurassic rocks such as those in Dinosaur National Monument. Many of these non-dinosaurian members of the fauna were relatively small and their fragile bones were easily destroyed before they could be fossilized. Nevertheless, under the right conditions they could be preserved. It is these "windows" which are yielding paleontological treasures and providing a fuller understanding of the Morrison ecosystem.

Frogs, salamanders, and fish are all closely tied to aquatic habitats and are found in Morrison pond deposits in Dinosaur. At least three new genera of salamanders have been identified, one of which is the first record of the family Karauridae outside of Asia. Frog discoveries of equal importance also have been made (see article by Amy Henrici elsewhere in this issue). Fish remains include species related to *Amia*, the living bowfin, lungfish of the genus *Ceratodus*, and a possible fresh-water shark.

Lizards and their relatives, the sphenodontids, are common small reptiles in the Morrison. A skull of *Paramacellodus*, measuring only 1.5 cm in length, is the first complete skull ever found of that lizard. An isolated jaw of *Dorsetisaurus* is only the third specimens of that genus known from North America. Other partial skeletons and isolated lizard bones belong to several genera and species that are new to science. Two skulls of the sphenodontid *Opisthias* are only the second and third skulls ever found for that animal. Both juvenile and adult sphendontid specimens have been collected and fragmentary material indicate that sphenodontids other than *Opisthias* are present.

While less diverse than lizards, turtles and crocodiles were not uncommon. All of the turtles are referrable to *Glyptops*, although fossils include large adults and very small individuals (hatchlings?). At least one large crocodilian is present (*Goniopholis*), while a partial skeleton and skull indicate the presence of a smaller species, one which may be new to science.

Morrison mammals were shrew to rat sized and were abundant and diverse within Dinosaur. Nineteen species in 7 families have been identified to date including 5 new genera and 10 new species. Among these mammal fossils are several complete or partial skulls, one of which is the best multituberculate mammal skull known anywhere in the world during the Jurassic.

These fossils are important in themselves for what they can tell us about the morphology and evolution of their particular groups. However, they are also part of a larger research project at Dinosaur aimed at providing a more detailed understanding of the extinct ecosystem which is buried in the sediments of the Morrison Formation. Over the last several years a multi-disciplinary approach has been taken to unraveling the secrets of the Morrison. This approach involves stratigraphers, sedimentologists, radiometric dating, paleobotanists, palynologists, and vertebrate and invertebrate paleontologists (see articles by Englemann, and Turner and Peterson elsewhere in this issue). The geologists have developed a detailed framework for the Morrison Formation within Dinosaur and have correlated the beds with major fossil localities in the formation beyond the monument boundaries. In addition, they have identified the major environments present during Morrison times and how these environments changed through time.

Using this framework, paleontologists have examined fossil vertebrates, plants, pollen, trackways, ostracods, conchostracans, and charophytes to help refine the faunal, floral, and paleoenvironmental analyses developed through geological studies.

This project will not only allow for an inventory and evaluation of the fossil resources within the monument, but will aid in developing management actions, future research programs, and in selecting localities for further excavation and study. Finally, all of the major dinosaur localities within the Morrison Formation will be correlated with each other and with the Carnegie Quarry within the monument, and for the first time paleontologists will have a clear understanding of how these quarries are related in space and time.

Literally thousands of fossils have been collected from the Morrison Formation within Dinosaur over the last 7 years. More than half of the fauna and nearly all of the flora known from the Morrison within the monument has been found during that same time period and similar rates of discovery are expected to continue at least into the near future. Although gone and buried, the Morrison ecosystem is not forgotten and in Dinosaur it is beginning once again to see the light of day.

Chure is Park Paleontologist at Dinosaur National Monument.

Biodiversity – It's More Than Biological!

By Daniel J. Chure

There is great concern in the life sciences about the biological holocaust currently under way around the globe. While estimates vary, it is clear that a very large number of species may well go extinct in the next few decades. Thus it is not surprising that preserving biodiversity is a major effort, one in which the National Park Service is playing a significant role. NPS-77 (Natural Resources Managament Guideline) identifies four components to biological diversity: 1) species, 2) genetic, 3) community/ecosystem, and 4) process. Clearly, these categories are directed toward maintaining the diversity of the living biotic world. Admirable as this is, it is needlessly restrictive in that it ignores the important temporal component to all biotic resources. The current world is the result of billions of years of evolution, adaptation and extinction on a planet where climate, environments, and the very physical surface upon which organisms live are changing due to the drift of the continents. To a paleontologist the pageant of life preserved in the rock record is as important a part of the biodiversity of the planet as the living world.

To exclude the fossil record from the concept of biodiversity is to ignore much of the diversity of our planet. There is no way to know how many specimens of any given fossil species are preserved in the earth's crust, but the loss of a single specimen to erosion, theft, or vandalism may result in a species never being completely known or perhaps never known at all to science. Fossil species are extinct and are not breeding new individuals. Whatever specimens of a given taxa have been fossilized are all there ever will be. Some are buried deep in the earth's crust while others were exposed and are being, or have been, destroyed by erosion. Thus, specimens that are now exposed or endangered must be evaluated for their scientific significance and collected if they are important. Inventorying, monitoring, and collection programs for fossil resources must be implemented in order to avoid the loss of the fossil biodiversity within the NPS.

On a larger scale, the fossil record may well provide an important evolutionary basis for conservation strategies. The NPS needs to look at how paleontological studies can help in conservation and what the record tells us about the immediate origins of our present communities and ecosystems. Few if any modern communities existed in their present form 10,000 years ago. Pliocene-Holocene climate changes (especially post-glacial global warming) have had a profound effect on the evolution of our modern biota. An understanding of these effects has obvious implications for developing conservation strategies in light of predicted future global warming trends. Furthermore, the Pliocene-Holocene record of species responses to environmental changes also provides data that will be important in developing and designing nature reserves.

Even this brief discussion shows that the fossil record provides temporal data for three of the four components listed by NPS-77 as components of biodiversity; species, community/ecosystem, and process. Clearly the NPS needs to bring fossils into its overall planning for preserving biodiversity. This should include not only preserving the fossil record of species diversity but also supporting studies that help us understand the processes that affect community evolution and community response to climate change. Coordinated research of fossil and extant biotas should yield real benefits for understanding, anticipating, and managing the biological changes resulting from development, habitat destruction, and climate change.

Paleontological Survey of the Jurassic Morrison Formation In Dinosaur National Monument

By George F. Engelmann

Many NPS units contain important paleontological resources. In some cases, as at Dinosaur National Monument (DINO) they are a major feature of the park. Yet these resources have been little utilized; their extent and scientific significance often is unknown and even more often, undocumented. With paleontological materials, a hands-off approach to protection of fossils results in destruction of the resource. The information that is contained in fossils and the context of their occurrence is a scientific resource that can only be conserved by active investigation.

The Carnegie Quarry at DINO has been a site of great paleontological importance since its discovery in 1909. It is well studied and accessible for continuing study. But the reason Earl Douglass came to the Uintah basin looking for a dinosaur in the first place was the extensive exposures of the Jurassic Morrison Formation (Fm) in which the Quarry is located. The Morrison was known, even then, to contain a remarkable sample of fossil vertebrates. Important localities had been found in this formation in the years before, and continue to be discovered.

Although the Morrison is exposed beyond the Carnegie Quarry within DINO, throughout most of the monument's history no systematic survey of these exposures had been undertaken to determine if they might produce additional sites of scientific importance. In 1984, a preliminary survey of the Morrison Fm. within the monument was conducted. Although most of the field party consisted of volunteers with little experience, more than 100 localities were recorded. Two of these sites have been quarried since then; hand quarrying and screen washing have revealed a diverse fauna of microvertebrates previously unknown from this area (Chure and Engelmann, 1989).

Beginning in 1989, we have undertaken a more thorough survey of the Morrison to clarify the picture of the nature and extent of the paleontological resources at DINO. The survey objectives were to examine all Morrison Fm. exposures within DINO for all fossil occurrences, to document any localities found in such a way that they could be relocated, and to evaluate the resource as we found it and make recommendations for its management.

Methods

The methods we used are standard paleontological practice. Geological mappings in DINO have delineated the areas where the Morrison occurs at the surface. Discussion with field geologists Christine Turner and Fred Peterson of the USGS, who are conducting a stratigraphic and sedimentologic study of the Morrison at DINO (Turner and Peterson, 1990), have helped develop recognition criteria whereby we can locate ourselves stratigraphically in the field.

With this information as a guide, we (a student assistant and I) identify and walk over the Morrison Fm. exposures. We cover areas systematically in a pattern determined by the terrain, but typically as a series of closely-spaced traverses. In this way, we are able to inspect the surface visually from a distance of no more than several feet. Occasionally, exposures deemed promising by virtue of sediment type or association are examined more closely. Shallow excavations may even be made.

When fossil material is found, we first attempt to determine whether it represents a specimen (or specimens) in place. This is done by tracing the fossil material to its source in the bedrock and making shallow, localized excavations if necessary, to reveal the source and discover the nature and extent of the deposit. If possible, a tentative identification of the fossil(s) is made. As a rule, fossils are not completely exposed or collected, but when a scientifically useful specimen is in imminent danger of loss or destruction, it may be collected where feasible.

Whether a specimen is collected or not, the occurrence is documented in the field. Field notes of all work are kept. They include verbal description of the location, nature of the occurrence, nature of the material present (including a taxonomic and anatomical description), stratigraphic position, and other information judged useful. Sketches may supplement any of these items. Photographs including the site are taken and referenced by a field number in the notes as are any specimens or samples collected. Each locality is assigned a field number in the notes and is plotted on a topographic map where it is identified by the same number.

In the lab, all this information is transferred to the DINO archival locality files, where a unique locality number is assigned and specimens are catalogued into the collections. Field data are entered into a computerized locality data base that cross references all the various types of materials. Samples have been collected by this project and the stratigraphic project in DINO for radiometric dating and for analysis for palynomorphs.

Results

Two seasons of field work have allowed us to survey about 75 percent of the exposures of the Morrison Fm. within DINO. Within this area we have identified more than 260 distinct localities. The majority of these sites (well over half) are occurrences of dinosaur bone. Dinosaur bone could be said to be virtually ubiquitous within the Morrison. In most cases, the occurrence consists of little more than bone scraps, but as a rule I only recognized a "locality" at an occurrence when there was some reason to conclude that the specimen(s) was in place or close to the horizon of its origin. Such indications might be: a specimen still partly imbedded in the unweathered rock of the outcrop, a concentration of related fragments in a small area, discovery of additional fragments on digging into the weathered sediment around a fragment found loose at the surface, or other such information. A surface occurrence was not regarded as a locality if it was reasonable to suppose it had been transported from its source.

In many cases, bone specimens were poorly preserved. Some of those in place in unweathered rock had been abraded to little more than bone pebbles prior to burial; however, a few were well preserved. One site revealed articulated tail and foot bones at the surface and further excavation has exposed more of the skeleton. Most sites fall into a category that could be described as of unproven potential. It may be that a significant fraction of these sites contain incomplete but identifiable specimens that could be useful in a comprehensive study of dinosaurs or paleoecology, and some may yield much more complete material.

After dinosaur bone, the next most common fossil is silicifed wood, which occurs as specimens ranging from small fragments to logs a meter or more in diameter. Preservation type and quality is variable but is excellent in some cases. One specimen preserves what appears to be insect borings. Others preserve clearly the structure of the woody tissues and could provide taxonomic identifications. A specimen that appears to be a cone from one of the trees was collected by this survey. None of the logs is upright or rooted, but some are quite large; one unusual specimen appears to be more tha 20 m long as preserved.

A small fraction of the localities preserve other elements of the biota. Freshwater gastropods and bivalves occur at a few sites, as do charophytes. Invertebrate trace fossils have been found. There are the two microvertebrate sites noted above and a handful of sites that have produced a few microvertebrates, suggesting a potential for further development.

All the fossil localities found so far have been within the Salt Wash Member and the Brushy Basin Member of the Morrison Fm. The Salt Wash is dominated by thick sandstone bodies and the fossils seem to be confined to the sandstones within this member; surprisingly, they are quite fossiliferous for dinosaur bone and silicifed wood. The sandstones in the middle and upper part of the Salt Wash seem most consistently fossiliferous.

The Brushy Basin, on the other hand, is dominated by fine sediments with occasional prominent sandstones. Both lithologies contain fossil localities. Dinosaur bone and silicified wood are abundant in this member, as they are in the Salt Wash, but virtually all the fossils other than dinosaur bone or wood occur within the Brushy Basin.

Discussion

This survey is not yet complete, but based on results to this point I expect that by its conclusion we will have documented well over 300 Morrison Fm. fossil localities at DINO. This record may be used in various ways. Some of the sites reported should be excavated as opportunity permits; indeed, some already are being developed. I think a majority of the sites might be worth examining more thoroughly. Some may yield useful identifications or even good specimens. This would be especially important for the Salt Wash localities, as fossils from that part of the section are not well known.

It also appears possible to get a good sample of the biotic diversity of the Morrison from these localities if some of the less studied groups of organisms, such as plants, are examined. The locality records should make it easier to recover such a sample.

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Digging For the Best Bones

An Application of the Delphi Process At Hagerman Fossil Beds

By Ron West

The Delphi process is a procedure of written commentary and expanding feedback designed to gather information and ideas that otherwise would be impossible to amass without a common discussion group. It can be an inexpensive way to generate a great deal of valuable discussion on a wide range of topics.

The process works like this:

1. Determine what aspect of an issue needs looking into:
2. Compose a short list of open-ended questions to be presented to the participating group;
3. Determine who should be involved in the first iteration:
4. Solicit written answers to the first questionnaire. including a request for names of other colleagues who should be involved in the process;
5. Compile all comments anonymously, ask follow-up questions. and return to all participants for a second iteration. again requesting more participants:
6. Compile these new comments and return for a third and fourth iteration if necessary.

Participants need to understand that this is an open. subjective process. the only goals being to exhaust the possibilities of ideas and perhaps to reach a consensus on the issues represented by the questionnaire. The iterative process allows participants *anonymously* to evaluate and prioritize all suggestions generated by the group. The anonymity also helps to focus debate on content rather than source. Based on our Hagerman experience, it works.

Application at Hagerman Fossil Beds

Newly-designated Hagerman Fossil Beds National Monument in southern Idaho is possibly the first park unit to have a clear, legislated mandate for research that equals its mandates for preservation and visitor use. In fact, the legislation calls for construction of a "center for continuing paleontological research," and for "orderly and regulated use of and research in the monument by qualified scientists." Since NPS expertise in paleontology is limited and the geologic time frames of the science are vast, we decided at the outset of the general management planning process that we needed professional help. We began by using the Delphi process.

A letter of introduction and a list of 5 questions was developed. Questions included those on a research facility. curatorial storage of specimens. protection of the deposits. interpretive ideas. and significance of the site. Most questions had a short lead-in statement for background, but the questions themselves were stated in an open. even naive, manner to generate a wide-ranging response. Participants were asked to reply with whatever level of detail they saw fit. Of the 19 participants originally sought. 10 were from universities. 5 from the NPS. and 4 from other federal or state agencies. We received responses from 12 of the 19: these respondents recommended 10 additional participants.

The only time-consuming part of the process proved to be compilation of the responses into a rational package for redistribution. For each question asked. we compiled the responses in a slightly different manner. attempting to summarize and organize the responses so as to elicit further questioning while not losing pertinent information.

For some questions, such as the one for interpretive ideas. we simply organized and listed all ideas and asked that they be ranked in priority order. For other questions we reiterated the responses verbatim, then posed a summarizing question asking for the participant's level of agreement with it. We used a sliding response of "strongly disagree, disagree. neutral, agree, and strongly agree." In this way we could more easily compile the next set of responses.

For one question—the type of research facility needed—the issue appeared to be so complex that the Delphi approach was inadequate to address it. This realization spawned a workshop at the park, involving 5 of the professionals. When such a workshop grows out of the Delphi process, it becomes a broad avenue rather than the blind alley it might otherwise be.

The 12-page second questionnaire was sent to 29 participants; we received responses and/or workshop participation from 18. (Copies of all Delphi documents are available on request.) Of these, 13 indicated they would be interested in serving on a long-term advisory group for the monument.

Recommendations Emerge

The third (and in our case the last) iteration compiled the new responses into an 18-page document which was returned to the now 34 participants as information only. At this point, through a combination of meeting our primary objectives and losing GMP funding. we decided not to pursue further refinement of the discussions. This last document presented the consensus of the professionals involved and, for the first time. recorded in writing the planning team's recommendations on the various issues. It also summarized for the entire group the conclusions of the earlier workshop.

We believe the process was very useful. particularly given the modest outlay of time and money required. We were successful in getting the attention and involvement of many of the paleontologists who specialize in Hagerman's Pliocene environment, establishing an open dialogue with the professional community, eliciting a great deal of specific information and concerns. and in some cases diffusing inherent mistrust of the NPS in such a research endeavor.

The Possibilities of the Delphi

I highly recommend this process. Its potential applications are limited only by our imaginations. The idea of using a Delphi surfaced in one of our first team meetings, and within a couple of hours we had typed out the first questionnaire. The process snowballed easily from there. Large quantities of information suddenly were ours for the asking. Except for the compilation of responses, all of the "effort" was generated by motivated. professional volunteers who wanted to have input and were interested in seeing us manage the monument well. From the outset, it is a captured audience. but the choice to be involved is theirs.

Conceivably, the process could be used anytime the NPS doesn't have enough information on an issue. a problem. an interpretive approach. a methodology. or whatever we're looking for. All that is necessary is that we admit we want some help and that we be open to input. Workloads being what they are. we probably should seek such assistance whenever it is in keeping with our processes and values. There are no strings attached that require us to follow suggestions or Delphi consensus if we have rational reasons for pursuing other approaches. The process also can work well with participants who are antagonistic toward one another and who thus might not work well face to face.

Some possible Delphi examples: resource specialists could be asked about management techniques for a given resource; superintendents of a given type of park (say, national seashores) could be asked how to approach a management concern in a similar unit; local professors could be asked if a certain resource is or is not significant, based on their own or our criteria; conservation biologists could be asked how to manage an area from an ecosystem perspective; or certain publics or user groups could be asked how best to meet their needs while meeting our mandates.

Extensive possibilities are there if we acknowledge them. So with this example of a successful Hagerman Fossil Beds exercise. I'll leave these bones in your backyard. Good luck with your digging.

West is a Natural Resource Specialist with the Denver Service Center.

Jurassic Morrison

Continued from page 8

Finally, the record of distribution of localities within the Morrison is itself data that may be useful in interpreting Morrison environments.

Engelmann, a vertebrate paleontologist. is a professor at U/NE. Omaha; he is under contract to DINO for baseline inventorying of fossils from the Morrison Formation.

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Systematic and Biomechanical Studies On Fossil Vertebrates in Badlands NP

By William P. Wall

Beginning in 1982, students from Georgia College, a branch of the University System of Georgia, have engaged in summer field expeditions to the rich Eocene/Oligocene rocks of southwestern South Dakota – Badlands NP and the surrounding public and private lands. Since 1987, a park collecting permit has provided access to the richest deposits in the area. Georgia College's collection of Eocene/Oligocene fossil vertebrates now is approximately 8,000 specimens, representing more than 40 genera. This collection has made Georgia College a center for study on mammalian evolution approximately 37 to 25 million years ago.

Paleontologic research at Georgia College is concentrated into two major areas, systematics and biomechanical analyses. Preliminary results of several of these projects are presented here by Dr. Wall, a Georgia College professor of biology.

The Oligocene was a time of transition in North America, both climatically and faunally. The Chadronian beds at the base of the fossil bearing sequence indicate this region was an open forest environment at the end of the Eocene. Throughout the Oligocene the region became drier; the habitat probably was similar to modern African savannas. The mammalian fauna is a mixture of archaic and advanced taxa. Artiodactyls, for example, exhibit a broad spectrum from primitive leptochoerids to advanced protoceratids.

Perissodactyls, including rhinoceroses, horses, and titanotheres, make up the other major group of Badlands fauna herbivores. I chose the South Dakota Oligocene for our fossil expeditions because of one rhino in particular that comes from there. *Metamynodon* (Fig. 1) can be found in the Orellan (early Oligocene) channel sandstones of South Dakota, but is rare or absent in equivalent age deposits of adjacent states.

Metamynodon is a member of the extinct rhinoceros family Amynodontidae, the group on which I based my own doctoral dissertation. Amynodontids in general were regarded as semi-aquatic animals reminiscent of hippopotami. I have shown (Wall 1980, 1982, 1989) that an aquatic lifestyle probably is valid only for *Metamynodon* and its close relatives, not for the entire family. My continuing studies on amynodontid biomechanics center on locomotor mechanics and feeding and are aimed at better interpretation of this group's life habits. Post-cranial material of *Metamynodon* is rare in museums, so the Georgia College expeditions were begun with the intent of providing adequate research material. These specimens have proved useful in systematic and biostratigraphic work (Wall 1989, in press) and form the nucleus for my biomechanical studies.

Walker Hickerson undertook a project of direct interest to my work for his master's thesis. *Hyracodon* is a small rhinoceros (extinct family Hyracodontidae), common in the Badlands. This animal is typically reconstructed as a gracile animal and colloquiallly referred to as "the running rhino." No one before Hickerson had ever tested the biomechanical feasibility of this mode of life. Hickerson compared *Hydracodon* to modern cursorial (running), subcursorial, and mediportal (weight bearing) mammals in the following areas: Limb bone indices, relative development of locomotor muscles, and in force/out force ratios for these muscles. Hickerson concluded that *Hyracodon* was no cursorial. This rhino exhibited locomotor adaptations more reminiscent of a feral pig or peccary than a pronghorn.

Although rhinoceroses were the initial reason for working in the Badlands, it soon became apparent that we were collecting many other fossils of potential research value. One group of artiodactyls in particular – the oreodonts – is associated with the Badlands deposits. *Merycoidodon* is the most common fossil found in this region, strongly implying that this animal was a major component of the Oligocene fauna. Agriochoeres are close relatives of oreodonts, but for some reason are much rarer in the fossil record. The two animals are similar in many ways, yet the difference in their abundance suggests they were fundamentally different in a significant way.

Many paleontologists believed agriochoeres were arboreal (Colbert and Morales 1991); however, except for claws these animals exhibit none of the anatomical traits typical of large tree climbers (Coombs 1983). If these animals were terrestrial, how did they minimize competition with oreodonts? Since feeding behavior is a major ecological factor, one of my graduate students, Michael Shikany, undertook a comparative analysis of dentition and jaw mechanics in *Agriochoerus* and *Merycoidodon*.

Dental wear facets are distinctly different in the two animals; *Agrichoerus* facets indicate primarily a tooth/food contact characteristic of a shearing mastication, while *Merycoidodon* teeth exhibit a tooth/tooth pattern characteristic of grinding. Comparison of premolar to molar surface area ratios corroborates the wear facet data in that the oreodont has relatively more posterior molar surface – the area where grinding takes place. Conversely, the well developed sagittal crest (site of origin for the temporalis muscle) of *Agriochoerus* points to the importance of shear in this herbivore.

Shikany concluded that agriochoeres probably occupied a woodland habitat, feeding on shrubbery (a declining niche during the Oligocene) and that oreodonts were adapted for feeding on the savanna grasslands. This dietary difference probably accounts for the demise of the agriochoeres and the success of the oreodonts during the Miocene.

The Badlands strata also contain important evidence of the initial radiation of rodents, including the first representatives of several modern families. Sherri Ray, for her graduate work, examined the jaw mechanics of *Ischyromys*, a common protrogomorphous rodent. Protrogomorphy (all branches of the masseter muscle originate in the zygomatic arch) is the primive jaw muscle pattern for rodents; only one animal, *Aplodontia*, the mountain beaver, retains this masseter arrangement. Ray was particularly interested in learning what advantage the sciuromorphous muscle pattern provided to animals like squirrels.

Sciuromorphy, one of the three jaw muscle patterns in advanced rodents, is characterized by having the lateral branch of the masseter expand its origin onto the rostrum of the skull via a zygomatic plate. *Protosciurus*, the first true squirrel, is a rare component of Badlands fauna. Since this animal was protrogomorphous, substitution of the more common *Ischyromys* in a jaw mechanics comparison with modern squirrels is valid. Ray dissected recent squirrels to produce a vector analysis for the temporalis and the three heads of the masseter (lateralis, medialis, and superficialis). The relative size and orientation for the same muscles were determined from study of several fine *Ischyromys* skulls in our collection.

Results show that modern squirrels have exag-

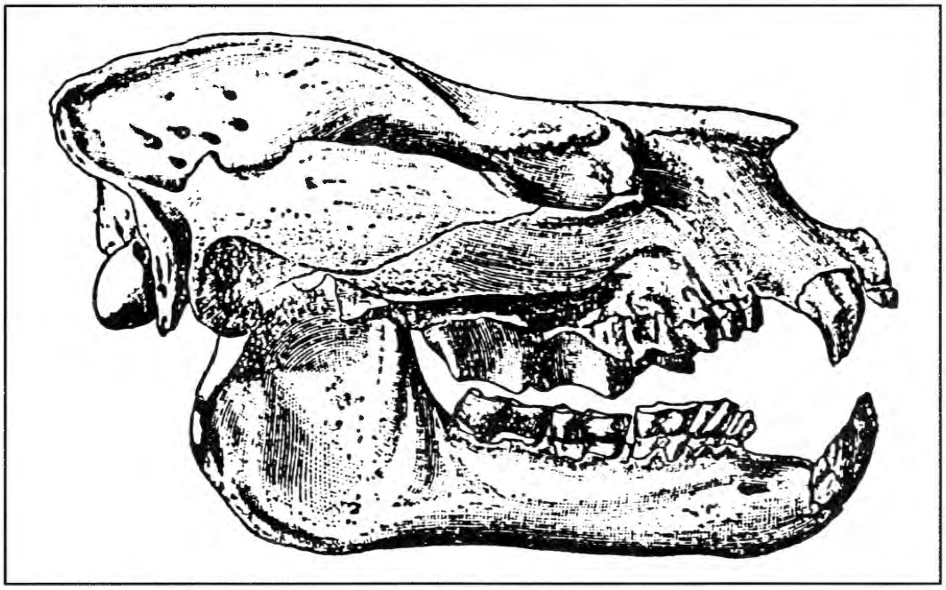

Figure 1. *Lateral view of a skull and jaws of Metamynodon, a semi-aquatic rhinocerotoid from the Oligocene of North America (from Osborn, 1898).*

Fossil Frogs: Dinosaur NM

By Amy Henrici

The name Dinosaur National Monument (DINO) brings to mind images of the enormous sauropod dinosaurs that roamed the earth some 144 to 160 million years ago. Within the past decade paleontologists have been striving to enrich this picture of the late Jurassic time epoch by searching for new localities at the monument in which non-dinosaurian remains are preserved. One such locality, the Rainbow Park Microsite, contains fossils that represent all the major groups of vertebrates except birds (Chure and Engelmann, 1989). Several tiny frog skeletons as well as many isolated frog bones have been found here. The isolated bones were collected by washing "dirt" through screens and sieves and picking out pieces of bone from the trapped debris with the use of a microscope. The frog skeletons, on the other hand, were collected intact on slabs of rock from a quarry.

Even though the isolated frog bones in the screen wash material are mostly broken pieces of limb bones, vertebrae, and a few skull bones, study of these fragments has revealed the presence of at least four different frog types. Two of these frogs, *Comobatrachus* and *Eobatrachus*, were previously known only from another site, the Quarry Nine locality at Como Bluff, Wyoming, which has an age approximately equivalent to that of Dinosaur National Monument. Unfortunately, the affinities of these fossils to other frogs remains obscure in part because they are known only by fragments of the humerus, or upper arm bone (Hecht and Estes, 1960). Fragments of other humeri are distinct enough to indicate that at least two other frog types were present. It will take many hours of comparison of these humeri to those of recent and fossil frog specimens to determine if they are new taxa and also their relationship to known frogs, both living and extinct.

The tiny frog skeletons collected from the quarry may represent yet another taxa new to science. Preserved on one slab of rock are the remains of at least 7 individuals bunched together in an area measuring roughly 5 x 2 inches. One of the skeletons has a head body length of only 3/4 on an inch. The small size of these frogs skeletons coupled with incompletely ossified vertebrae suggest that these specimens are tadpoles. However, the level of development found in the limb and hip bones is reminiscent of frogs that have completed metamorphosis. In order to determine whether or not these frogs are indeed tadpoles careful comparison with tadpole growth series of living frogs and the few known tadpoles of prehistoric frogs will be undertaken.

The frogs and dinosaurs at DINO were collected from a widespread unit of rock known as the Morrison Formation, which is in the Jurassic Period in the geologic time scale. The Jurassic is one of three time periods in the Mesozoic Era, and it is preceded by the Triassic Period and followed by the Cretaceous Period. Generally, these periods are subdivided into epochs which are designated by prefixing the period name with early, middle, or late, in which early is the oldest and late the youngest.

This late Jurassic frog fauna from DINO should add to knowledge concerning the early evolution and distribution of frogs. It is generally believed that frogs evolved sometime during the Triassic, the evidence for which is a fossil that shows some similarities to frogs, and may be ancestral to frogs, from the early Triassic of Madagascar. The first unequivocal frog dates back to the early Jurassic of Argentina and frogs are known from North and South America and Europe by the late Jurassic. However, frogs were not very diverse by the late Jurassic. Of the 22 currently recognized families of frogs, both extinct and living, only 3 of these families are represented in the fossil record by the late Jurassic.

There also are four other late Jurassic frogs which cannot be placed into any known families due to the poor preservation or incompleteness of these fossils. This sparse record of frogs in the late Jurassic is due in part to frogs not having diversified much at this point in time, and also because frogs are generally very rare in the fossil record. Thus, study of these new frogs from DINO will add considerably to knowledge on the early evolution and distribution of frogs and also helps to round out the picture of vertebrates that co-existed with dinosaurs during the late Jurassic. Perhaps mention of Dinosaur National Monument now will evoke an image of tadpoles frantically swimming away from a drinking dinosaur, or frogs leaping into the water to avoid a dinosaur approaching the lakeshore.

Henrici is with the Section of Vertebrate Fossils, Carnegie Museum of Natural History, Pittsburgh, PA.

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Fossil Vertebrates *Continued from page 10*

gerated the anterior and posterior components of these muscles when compared to *Ischyromys* (Fig. 2). The vector directions for *Ischyromys* indicate this animal, and probably most protrogomorphs, could not have split the masticatory cycle into separate incisor and cheek teeth phases as efficiently as modern rodents. Evergrowing, chisel-like incisors are the hallmark of rodent success; hence it is not surprising that rodents that could not take optimal advantage of this tool lost out to rodents that could.

Through concerted effort we have built an impressive Oligocene microvertebrate collection. Our four skulls of the burrowing lizard, *Rhineura*, give us one of the largest samples of this intriguing animal. Our collection also contains complete or nearly complete skulls of *Protosciurus, Agnotocastor, Paleocastor, Eumys*, eomyids, several as yet unidentified genera of rodents, the insectivore *Centetodon*, and the marsupial *Peratherium*. These, along with several hundred jaws and maxillae, will form the nucleus of a graduate thesis project by Murali Thirumal, our best microvertebrate collector.

A separate but related thesis project involves a microvertebrate accumulation from a stream channel deposit from the Chadronian in the Badlands NP's Southern Unit. This isolated riparian sandstone is important for its early age and rarity of fossils from a river environment (most of the beds in the badlands preferentially preserve members of the terrestrial ecosystem). Due to the nature of the soil however, it will take several more years of collecting to obtain sufficient specimens to characterize this fauna adequately.

These projects provide an indication of the abundance of paleontologic work still to be done on Badlands fossils. Fieldwork and research by faculty and students at Georgia College should continue to contribute to our knowledge of vertebrate evolution in North America during the Oligocene.

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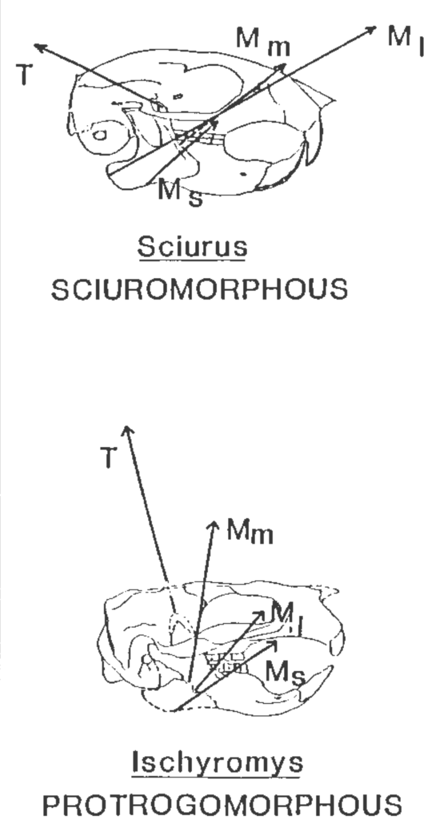

Figure 2. *Vector analysis of the major jaw muscles in a modern squirrel, Sciurus, and the Oligocene rodent, Ischyromys. Abbreviations: Ml, lateral masseter; Mm, medial masseter; Ms, superficial masseter; T, temporalis.*

"I've Seen the Miocene" in Central Oregon

By Ted Fremd

Within what is now the beautiful John Day River Basin in central Eastern Oregon, thousands of feet of sediments were deposited over hundreds of square miles during tens of millions of years. These strata represent a bewildering variety of processes and events that left practically every category of sedimentary and volcanic rock type, from tremendously violent pyroclastic surges to the gentle accumulation of fine-grained ash in lake environments.

Presently, fossiliferous exposures of these rocks total tens of thousands of acres; much more was either eroded away during subsequent tectonic episodes or is currently buried under thousands of feet of basaltic lava. In a few areas, such as within the John Day Fossil Beds National Monument (JODA) boundaries, significant segments of the stratigraphic column are exposed, revealing some of the finest Tertiary plant and vertebrate assemblages in the world.

The world renowned significance of the John Day Basin is due to a fortuitous combination of five factors:

1. Because of continual volcaniclastic deposition, large numbers of very well to excellently preserved paleontological specimens are available, both in the field and in repositories.
2. The taxonomic diversity of these faunal and floral assemblages is high, sampling a broad spectrum of the ancient ecosystems.
3. The fossiliferous strata span a long time interval with few temporal unconformities.
4. This sequence of entombed biotas was accumulated during significant time intervals in earth history, including periods of major climatic changes, adaptive radiations, and mass extinctions.
5. A variety of dateable marker beds (crystal-rich "tuffs") conveniently permit ready correlation of the strata, both within the depositional reservoir and with those documented from elsewhere on the planet.

The temporal range of strata exposed in the John Day Basin is impressive (Table 1). Although there are many hiatuses of varying lengths, it is remarkable to have such abundant, varied, and well-preserved fossil populations enduring in one geographic area. In most areas on the continent, geologists are required to "cut and paste" stratigraphic sections that may be quite remote from one another – a process that considerably lessens the accuracy of results. Comparison of the JODA fossil populations with those recovered from sediments of similar age throughout the world is yielding important models of terrestrial floral adaptation and mammalian evolution.

A Little Research History

The analysis of fossils from the John Day Basin began roughly 120 years ago and continues with gusto today. The history of fossil retrieval before establishment of the national monument reflects a small-scale and temporally compressed version of the larger history of western North American paleontology. For example, early activity (ca. 1870s) consisted predominately of "trophy hunting," often by hired collectors. Crates of specimens were shipped to the sponsoring eastern institutions, with locality data that can be designated generously as "vague." If the fossils differed substantially from previously described specimens, they were tagged as new taxa (the differing views of "substantial" contributing in large measure to the development of modern paleontological systematics). The majority of type specimens were collected sloppily early in this purely descriptive (and sometimes pugnaciously argumentative) phase of paleontologic research, resulting in a plethora of taxonomic synonyms and vaporous localities that still plague the researcher.

In the following decades, workers began to look more thoroughly at the encapsulating rocks and stratigraphic units themselves, subdividing the formations into recognizable members and horizons. Comparisons of these were made with previously described localities of similar geologic age, and work began constructing stratigraphic and biotic correlations of dozens of beds in the John Day area with those from elsewhere.

Most recently, the monument has been supporting studies in absolute age determinations, using single crystal laser fusion technology and magnetostratigraphy. Other investigators, collaborating with the monument's museum staff, are focused on paleoecological syntheses of paleosols and fossil units, gradual evolutionary change, biostratigraphy, taphonomy, and other projects.

Research Benefits

Interpretation and public enjoyment is enhanced as a result of this research *process* as well as its results. The pursuit of this knowledge can itself be interpreted in the parks, perhaps better than anywhere, because the parks are the actual *places of discovery* – the laboratories of geologic inquiry. Accurate interpretation of the science of paleontology in the midst of active exploration and excavation is important. It beats merely explaining how this process might have been done, or describing how this is happening somewhere else.

It also reflects on the credibility of the Service that the most accurate, up-to-date information possible is presented to the public and that erroneous or outdated theories are promptly removed from exhibits and programs. This bolsters the public perception of the Service as an active manager, not a passive caretaker. Nearly all scientific research is justifiable on interpretive grounds alone.

Curation and administration of the museum mission benefit from scholarly study. For example, the ability of NPS curators precisely to identify specimens in their care is critical. However, taxonomic studies do not merely identify material for cataloging purposes; they are essential in determining the relative significance of specimens. The ability of curators to determine the scientific value of specimens, both in the field and in the collections, is indispensable. And this value can only be ascertained through scholarly analysis of the literature, reference collections, and time-stratigraphic relationships revealed through research.

Natural Resource Management at the monument is facultatively divided between recent (neontological) and fossil (paleontological) resources, with most emphasis given to the latter. In many "fossil parks," neontologists have held sway. Indeed, it is only within the last two decades that Servicewide paleontological resources have been viewed as threatened objects, or even as a resource to be actively managed at all. Perhaps this is because "rocks" appear not to demand the relatively constant surveillance modern ecosystems need; or because of confused priorities between preservation of weathering processes and preservation of significant specimens; or simply because of a lack of strong advocacy such as that enjoyed by cultural resources.

Complacency may be appropriate in some strata, where fossils are so abundant or durable that there is, in fact, little threat. In most localities, however, deterioration of the resource is measurable. The reader can consult the sections within NPS-77, Paleontological Resources Management, for an overview of the programs currently employed at JODA and other developed sites. The cornerstone of this activity is a program of cyclic prospecting, where scientifically significant specimens are collected with abundant field data, including precise locality records, and placed in dedicated museum storage where they can be preserved and are avail-

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Table 1. *Key fossil assemblages of the John Day Basin represented within or proximal to management boundaries of the National Park System. Presented in temporal order, with the oldest strata at the bottom.*

FORMATION	ASSEMBLAGE NAME	AGE
RATTLESNAKE	Rattlesnake flora	Pliocene
RATTLESNAKE	Type Rattlesnake fauna	Pliocene
MASCALL	Mascall Flora	Miocene
MASCALL	Type Mascall Fauna	Miocene
PICTURE GORGE	Palynomorphs	Miocene
JOHN DAY	Haystack Mbr. Fauna	Miocene
JOHN DAY	Kimberly Mbr. Fauna	Miocene
JOHN DAY	Turtle Cove Fauna	early Miocene
JOHN DAY	Bridge Creek Flora	late Oligocene
JOHN DAY	Big Basin Fauna	Oligocene
UPPER CLARNO	Fern Leaf, others	Oligocene
UPPER CLARNO	Slanted Leaf Beds	Oligocene
UPPER CLARNO	White Cliffs	Oligocene
UPPER CLARNO	Hancock Mammal Quarry	late Eocene
LOWER CLARNO?	Lahar deposits	Eocene
LOWER CLARNO	Nutbeds Flora	Eocene
LOWER CLARNO	Nutbeds Fauna	Eocene

Quaternary Paleontology and Paleoenvironmental Research In National Parks on the Colorado Plateau

By Larry Agenbroad and Jim Mead

National parks on the Colorado Plateau have unique resources and data sets for Quaternary research (Pleistocene and Holocene) of the last 1.8 million years of earth history. The Rocky Mountain Regional (RMR) office initiated a limited contract in the mid 1980s to conduct preliminary resource inventory and research of Quaternary deposits in Canyonlands NP (CANY) and Glen Canyon National Recreation Area (GLCA). This initial contract was a companion study to archaeological studies, by several archaeological contractors. Results of this contract and the increasing awareness of the quantity and quality of Quaternary resources in the national parks led to a second contract, beginning Sept. 1, 1991, for all the RMR parks on the Colorado Plateau.

Quaternary research is interdisciplinary in nature, involving biological, geological, geographical, climatological, and anthropological sciences. Quaternary resources recognized in the Plateau parks to date include: Pleistocene paleontological specimens (osteological and scatological) of a variety of extinct fauna (Fig. 1); vertebrate megafauna and microfauna) and invertebrate (mollusks and insects), as well as fossil pollen and macrobotanical remains. Many of these data sets are included in stratified deposits allowing geochronologic control [C14(radiocarbon) (Fig. 2), TL (thermoluminescence) and U-Th (uranium-Thorium) dating techniques]. Hyperarid conditions characteristic of the Colorado Plateau have preserved material such as dung, hair, horn sheaths, hooves, etc., that usually are considered perishable in more mesic conditions and environments.

Absolute chronologies of stratigraphic sequences allow paleohydrologic reconstructions of past environments, tied to a temporal framework. As such data are gathered and synthesized, we can begin to unravel the formation (and destruction) of soils, geomorphology, etc. Combination of data sets allows a multifaceted reconstruction of local and regional environments at varied temporal intervals throughout the Quaternary.

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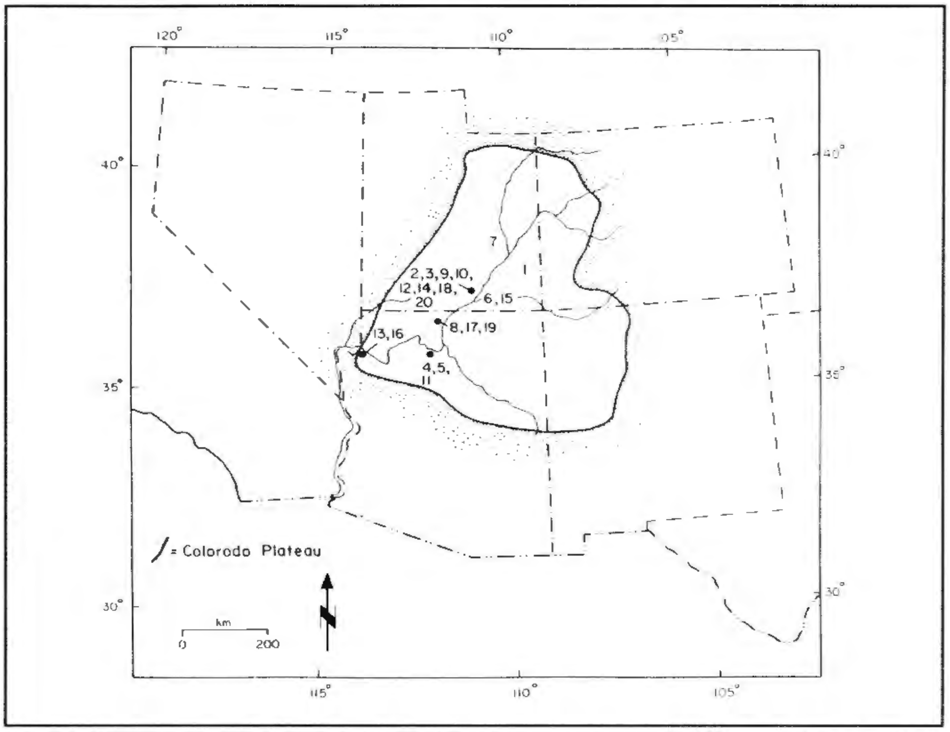
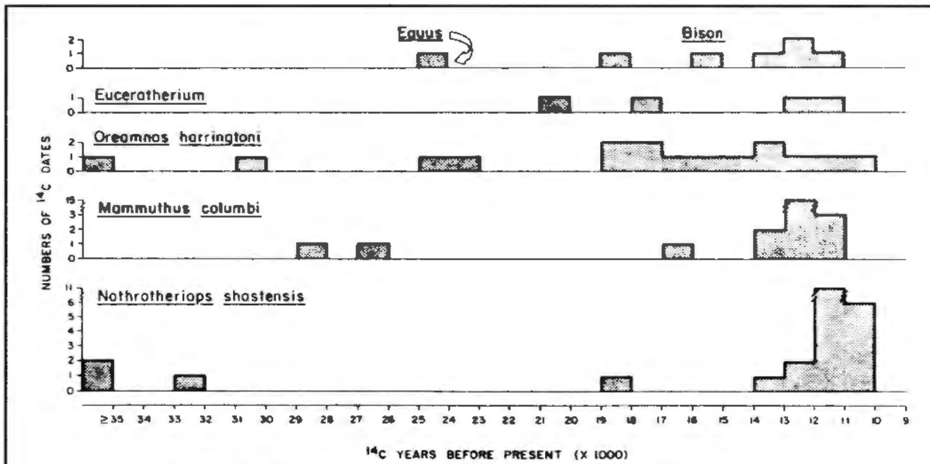


Figure 1. A generalized map of some of the localities of field research covered in this report. (Figure provided by Mead)



1	Bare Ladder Shelter	11	Kaetan Cave
2	Bechan Cave	12	Mammoth Alcove
3	BF Alcove	13	Muav Caves
4	Bida Cave	14	Oak Haven
5	Chuar Cave	15	Oakleaf Alcove
6	Cottonwood Alcove	16	Rampart Cave
7	Cowboy Cave	17	Sandblast Cave
8	Disappearing Cave	18	Shrubox Alcove
9	Grobot Grotto	19	Stanton's Cave
10	Hooper's Hollow	20	Wither'fs Wallow

Figure 2. Radiocarbon age plot from dated dung samples of late Pleistocene fauna from the Colorado Plateau. (Figure provided by Mead.)

Miocene *Continued from page 12*

able for study.

Positive steps have been taken at several monuments, including JODA, to quantify threats and diminish harm to scientifically significant fossils. Obviously, the process of planning and design of park facilities is enhanced by accurate baseline data. Research also improves the ability of the manager to control public use patterns, identifying park areas warranting greater protective measures that range from simple surveillance to formal closures of sensitive areas. A productive cooperative agreement for paleontological resource protection with the Bureau of Land Management in the monument's vicinity was made possible only as a result of detailed research groundwork.

In contrast to the covetous approach that typified early work in the area, JODA and other NPS sites are entering an exhilerating new phase of helping to share research with society. A new visitor center with a major series of exhibits, dedicated museum storage, and lab facilities is being planned with cooperation and enthusiastic input from the research community. The position of NPS as a leader in the management of fossil resources looks brighter than ever before.

Fremd is Paleontologist at John Day Fossil Beds National Monument.

The Dynamics of Fossil Lake

By H. Paul Buchheim and Rachel Benton

Fossil Butte National Monument is contained within the ancient boundaries of Fossil Lake, one of three Eocene freshwater lakes located in present day southwestern Wyoming, Utah, and Colorado. The monument encompasses only a small fraction of the ancient lake, which extended 40 miles at its longest point. During 2 million years of deposition, great numbers of fossil fish, reptiles, birds, and plants representing a subtropical environment were preserved in the lake sediments. The present day Fossil Butte and Angelo members of the Green River Formation (Oriel and Tracey 1970) are the depositional product.

Because of the excellent preservation of both the fossils and the lake deposits, Fossil Lake has been studied extensively. The fossil fish fauna were described in detail toward the end of the 19th Century (Cope 1884). Other workers have followed with further systematic descriptions, including the most recent monographs of Grande (1982, 1984, 1985, and 1991). McGrew and Casilliano (1975) and McGrew (1975) dealt with some taphonomic aspects of fossil fishes in Fossil Basin.

One of the first attempts to develop a depositional model for Fossil Lake was completed by Bradley (1948), providing an explanation for the burial and preservation mechanism of fishes at Fossil Lake. Further depositional models of these units were put forth by Buchheim and Eugester (1986) and Buchheim (1990).

Present day research at Fossil Butte involves studies of lake depth, turbidity, salinity, alkalinity, temperature, and faunal elements. These features in turn provide clues to paleoclimatic interpretation. Many of these conclusions are based on changes in thickness and lithology of individual rock units. Also, the interaction of deltas and fluvial inlets with the main lake body provide information on lake evolution and dynamics.

Researchers in the past have interpreted thin laminae found in the Green River shales as "varves" or records of seasonal deposition. Recent studies within Fossil Basin have included laminae

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Quaternary Paleontology *Continued from page 13*

What types of questions can be addressed by these Quaternary data sets? One line of research receiving considerable attention is paleoclimatic reconstruction. The data sets we have begun to discover and interpret from the Plateau parks promises "fine-tuned" information unavailable from other regions. One example is the fecal remains of extinct Pleistocene fauna including mammoths, shrub oxen, sloths (3 species), horses, camels, bison, Harrington's mountain goat (to name some large animals), plus rabbits marmots, packrats, porcupines, and other small fauna.

All these animals are grazers, browsers, or both. A paleobotanical reconstruction based on multiple species with differing ecological adaptation/exploitation provides a more complete paleobotanical reconstruction model than any single line of evidence. Pollen data added to the macrobotanical and histological data from dung further completes the reconstruction. Knowing the variety of plants in a region at a given time period allows estimates of moisture and temperature conditions necessary for such a plant community. Repetition of such analyses at varied temporal intervals can reveal climatic changes tied to a temporal framework.

Added to the data sets described above, a second set of botanical information is preserved in multiple repositories across the Colorado Plateau. These repositories are packrat middens . . . indurated piles of nest material, "collectibles," feces, and packrat urine (amberrat). We have collected and analyzed packrat middens dating from greater than 40,000 B.P. to modern. Midden analysis can generate independent paleoclimatic change models, and added to the reconstruction from fecal remains, as described above, it enhances the overall model and reconstruction.

Paleontological research within the Quaternary temporal interval documents a variety of extinct Pleistocene fauna, in relative abundance across the Plateau. A map by Harris (1985) depicts the Plateau, north of the northern borders of Arizona and New Mexico, as devoid of Pleistocene paleontological localities. That void has largely been filled in the past 7 years of research, most of which was concentrated in national parks. We have shown the relative abundance of mammoth remains (Agenbroad and Mead, 1989). Similarly, we have documented the distribution of shrub oxen, musk oxen, bison, horses, camels, sloths, tapirs, giant short-faced bears, mountain goats, and bighorn sheep.

Questions to be resolved are:

1. Precisely when did the various species of megafauna (>100 lb. live-body weight) become extinct on the Plateau?

2. Why did at least some of Pleistocene fauna become extinct at ±11,000 B.P.?

3. When did bighorn sheep, deer, elk populations become established on the Plateau? Was it contemporary with terminal Pleistocene fauna, or did it happen in response to niche vacancies caused by Pleistocene extinction?

4. Was human influence responsible, or partially so, for the extinction of Pleistocene megafauna?

5. What was the late Pleistocene environment on the Colorado Plateau and how has it changed?

To help us begin to answer some of these questions we have enlisted Dr. J. Theis at U.CA Davis; he has developed a preliminary method of animal identification from chemical bile "signatures." This technique is especially applicable to the pellet-forming animals such as deer, elk, mountain goats, bighorn sheep, camel, and shrub oxen, among others. Theis has used the NMR (nuclear magnetic resonance) techniques to provide bile signatures of various genera. The hyperarid Plateau environment has preserved fossil dung in conditions that make it possible to apply this technique to extinct fauna. This, combined with microhistology, macrobotanical analyses, pellet morphology, absolute dating, and pollen analyses, provides unparalleled information as to extinction, or replacement, of Pleistocene species; as to the competition, replacement of niche-filling of modern species, and when such changes took place.

Microfauna (<100 lb.) analyses provide added data sets – usually on a local basis, to be integrated into the data generated by the methods enumerated above.

Was there climate change stress? Was there nutrient depletion? Or did the arrival of Eurasian megafauna numbers at approximately 11,500 B.P. cause the extinction of large Pleistocene forms? Until recently, the presence of human cultures predating the Archaic cultures (±8,000 - 2,000 B.P.) was not accepted for the Colorado Plateau, with the general rationale in the category of "there was not a megafaunal game base for Paleoindian hunters on the Colorado Plateau." Dot map compilations of mammoth and bison and the artifact scatter of mammoth and bison hunters for the Colorado Plateau nullifies that reasoning. To date we have not found primary association of humans and Pleistocene megafauna on the Pleateau, but we feel this is due to the lack of serious search for such localities. (The dot maps indicate relatively high populations of both the hunters and the hunted for late Pleistocene and early Holocene time periods.)

We have begun to realize that each national park on the Plateau has its own unique set, or sets, of data. Yet as an integrated whole, they provide information that is unretrievable in other parks in other regions of the country. By completion of the current NPS contract, we feel that collectively we will be able to provide syntheses of the Quaternary environments, fauna, human history, and climate changes that previously have never been envisioned – all this for a unique physiographic province encompassing more than 300,000 square miles and for a temporal period (Quaternary) that has virtually be ignored in this region until the last decade.

Agenbroad and Mead are professors with the Quaternary Studies Program, Dept. of Geology, Northern Arizona University, Flagstaff.

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15 Years of Research at Fossil Lake

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counts between two time-synchronous units (tuff deposition occurs during one "instant" in geologic time) (Buchheim and Biaggi 1988). Because the same amount of time is represented, the laminae counts between the two tuff beds should be consistent throughout the lake deposit. However, a 32 percent increase in laminae number and thickness occurs toward the basin margin. Sedimentation rates appear to be greater toward the shoreline (Fig. 1) due to an influx of calcium rich waters delivered from intermittent storm runoff, river inflow, and possibly calcium rich springs. As the calcium rich waters come in contact with the alkaline lake waters, calcium carbonate precipitates. A model based on seasonal deposition, as stated by the varve theory, does not appear to pertain to the Fossil Lake sediments.

Fossil Lake has classically been considered a freshwater lake. However, recent studies have indicated that periods of increased salinity occurred at various times in the lake's depositional history. Saline content is based on variations in calcite-dolomite ratio, tuff bed minerologies, oxygen isotopes, and paleontology.

The lower two-thirds of the lake sequence is dominated by finely laminated micrites that are interbedded by a number of massive dolomicrites. The data indicate that Fossil Lake fluctuated from fresh to hypersaline, probably due to sudden fresh water expansions followed by more gradual regressions. The upper third of the sequence is composed of massive dolomicrites containing salt casts, indicating that Fossil Lake was dominated by hypersalinity near the end of its existence.

Many questions pertaining to the dynamics of Fossil Lake remain. Reseach plans for this summer require further collection of rock samples, to be analyzed in the lab by x-ray defraction, total organic carbon, thin sectioning, and isotope analysis. The goal is to produce 7 time slice maps, revealing lake changes through time and space. These maps will test the hypothesis that Fossil Lake was dynamic and underwent dramatic changes in chemistry, size, and shape through time. The goal is to determine the interaction between this ancient environment and its inhabitants.

Much of the knowledge gained in the last 15 years will be used to address a resource management project proposed for this summer. An extensive inventory on the fossil bearing units of the Green River Formation both within and outside the monument needs to be done. Baseline information such as this is crucial for addressing future land management issue between NPS and the Bureau of Land Management.

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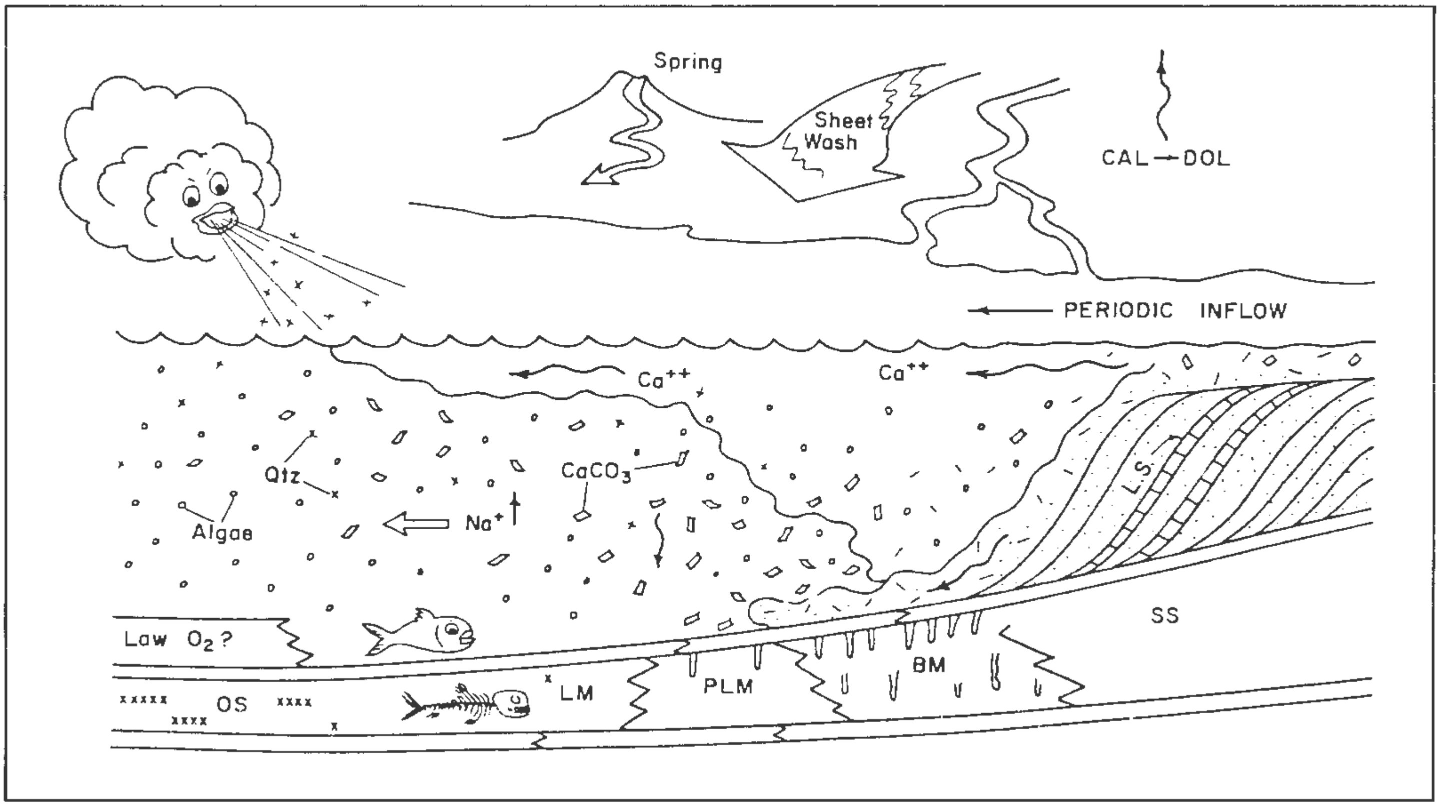

Figure 1. *Depicted here are several lateral facies patterns found at Fossil Lake. Increased sediment deposition and a greater number of laminae characterize the lake margins, due to seasonal inflow and the precipitation of calcium carbonate. Highly reducing and organic rich sediments as well as an increase in salinity toward the lake's center enhanced the preservation of laminated sediments and fishes and discouraged bioturbators.*

Abbreviations: Na+ = salinity; qtz = quartz; Ca++ = dissolved calcium; BM = bioturbated micrite; SS = siliciclastics; LM = laminated micrite; PLM = poorly laminated micrite.

Tracking Dinosaurs and Other Extinct Animals at Lake Powell

By Martin Lockley, Adrian Hunt, Kelly Conrad, and John Robinson

The Glen Canyon National Recreation Area (GCNRA) is one of the largest preserves in the National Park System and one of the most spectacular in terms of geological exposures. It is therefore not surprising to discover that, like other national parks and public lands in the Colorado Plateau region, it is rich in fossil resources - particularly fossil footprints. A recent exploratory survey of known tracksites in this area reveals a wealth of interesting sites and suggests considerable potential for future discovery and research.

Fossil footprint sites in GCNRA fall into several categories including those that were known before dam construction and the filling of Lake Powell, those that were studied, collected or rescued as Lake Powell filled up, and those that have been discovered since. Tracksites in this region can also be classified according to age ranging from Early Permian (about 280 million years) before the Age of Dinosaurs, through the Late Jurassic Epoch (about 140 million years) by which time dinosaurs were well-established. Our preliminary surveys suggest that there are at least a dozen tracksites known in GCNRA and that several are of considerable scientific significance.

It is convenient to follow the geological convention of a trail through time and describe selected sites in chronological order. It is also appropriate to distinguish between sites that are still accessible and available for future study, and those that are now submerged or in danger of damage or destruction by rising water levels and erosion. For purposes of this report we have focused attention on sites that have been documented as the result of rescue missions.

Permian Footprints

To date we know of only one Permian Age tracksite from the Cedar Mesa sandstone in the Dirty Devil River. In 1973 former Utah State Paleontologist Jim Madsen made a rubber mold of a track-bearing slab in order to preserve a record before it was inundated by the lake. The trackways are remarkable because they show what Madsen suggests is a "Permian Murder: (Fig.1) - where a large animal snapped up or swallowed a smaller victim. Such direct evidence for predator-prey interaction is rare in the fossil-footprint record.

Triassic Tracks

So far we know of only one indisputably Triassic Age tracksite in GCNRA. This is a Late Triassic, Chinle Formation site in the vicinity of Four Mile Canyon. Here several specimens of distinctive track *Atreipus* (Fig.2) were recently discovered and moved from a vulnerable location to preserve them in the Park collections. These are the first *Atreipus* tracks ever reported from the western United States. They are also a controversial trackway type because they have hind footprints that are similar to those of bipedal theropod dinosaurs but also display unique tulip-shaped front footprints. *Atreipus* tracks also are known from Late Triassic beds in Europe and eastern North America. They probably were made by slender, long limbed dinosaurs or

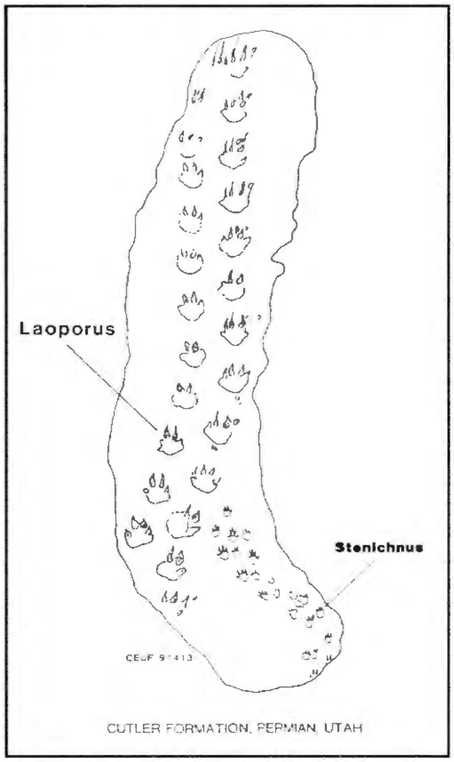

Figure 1. *Trackways from the Permian Cedar Mesa Sandstone provide evidence of predator prey interactions.*

dinosaur-like archosaurs, but authorities have reached no firm consensus on the trackmaker's identity.

Jurassic Tracks

Tracksites have been reported from three Early Jurassic Formations in the GCNRA. These are, in ascending order, the Wingate, Kayenta and Navajo Formations that collectively comprise the greater part of the Glen Canyon Group.

Tracks are known from three sites in the Wingate Formation in the vicinities of Lee's Ferry, North Wash and the Rincon. The former site was the first ever documented from the area that is now GCNRA, and a specimen of a three toed theropod track known as *Grallator* was described in 1904 by Elmer Riggs and curated in the Chicago Field Museum collections (Riggs, 1904). The other two sites also yield typical *Grallator* tracks, made by turkey- to Emu-sized theropod dinosaurs. The Rincon site is easily accessible and is referred to in Kelsey's Boaters Guide to Lake Powell.

Two tracksites are known from the Kayenta Formation including a large site in Explorer's Canyon that was featured in National Geographic (Edwards, 1967). Several large slabs were collected from this site including the specimen that is on display at the Wahweap Visitors Center. The tracks are known as *Eubrontes* (meaning "true thunder") and represent some of the first of the large theropod dinosaurs (Fig. 3). Based on foot lengths of up to 18 inches these animals were about 7 feet at the hips and measured between 20 and 25 feet from snout to tail. Several paleontologists have suggested that the carnivore *Dilophosaurus* was a probable candidate for the trackmaker.

At least three tracksites are known from the Navajo Formation including one, now lost, that was discovered during blasting in the early phases of dam construction. The other two sites, at the west end of Lake Powell include one that has been underwater for most of the last 10 years (Fig. 4). Both the latter sites are associated with the upper part of the Navajo Formation, and both reveal a large four-toed trackmaker *Otozoum* (means "giant animal") along with diminutive three-toed *Grallator*-like tracks. Although there is some debate about *Otozoum* tracks, many paleontologists interpret them as the footprints of prosauropods, forerunners of the well-known sauropods or brontosaurs.

It is interesting to note that *Grallator, Eubrontes*, and *Otozoum* tracks were all described from early Jurassic deposits in the eastern United States early in the 19th Century when the science of ichnology (the study of tracks and traces) was in its infancy. Although there has been little serious study of Early Jurassic tracks in the western United States until recently, it is now becoming clear that the same trackmakers were present, and relatively abundant at that time (Lockley, 1991). This means the tracks are useful for biostratigraphic correlation (age determination) of strata on a regional and global scale. This is particularly important in the Glen Canyon Group which consists largely of desert sandstone

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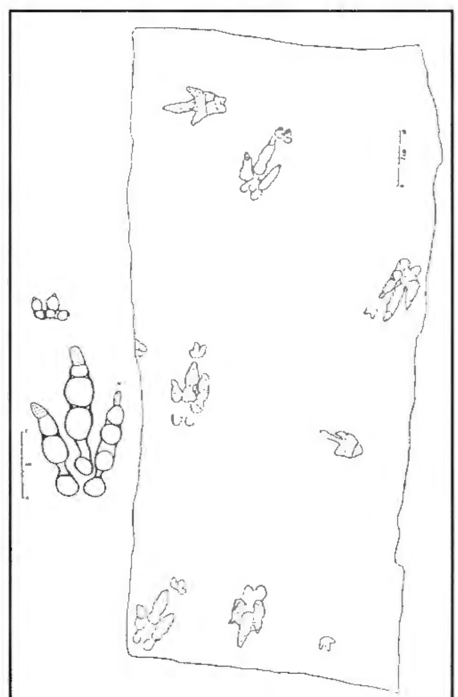

Figure 2. Atreipus *tracks from the Chinle Formation are the first reported from the western USA.*

Tracking Dinosaurs at Lake Powell

Continued from page 16

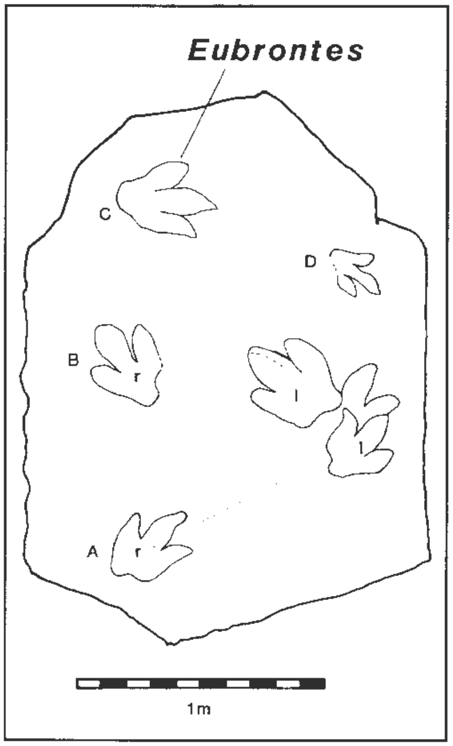

Figure 3. Eubrontes *tracks were rescued from Explorer's Canyon in the 1960-s.*

deposits that are mainly devoid of fossils. Tracks help show that these early Jurassic desert environments did support animal communities.

Last, but by no means least, we report on a very interesting discovery of a brontosaur front footprint that is so well-preserved that it reveals skin impressions (Fig. 5). The track was discovered in the Morrison Formation near Bullfrog and is the first example of skin impressions ever reported from a brontosaur track.

Our preliminary survey at Lake Powell indicates that tracksites are distributed throughout the GCNRA and occur in most of the exposed formations. We therefore anticipate that a systematic search is likely to reveal many more fossil footprint sites in future.

Lockley, a paleoichnologist, is a professor at U/CO Denver; Hunt, a vertebrate paleontologist, is with the New Mexico Museum of Natural History; Conrad is a graduate student at U/CO Denver; Robinson is a geologist consultant out of Littleton, CO.

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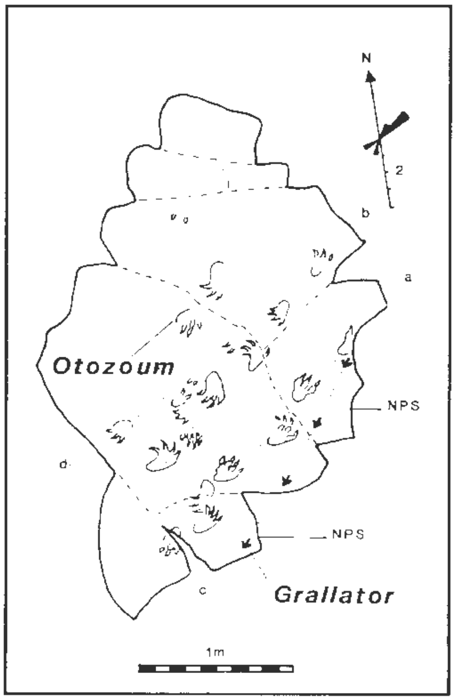

Figure 4. Otozoum *and* Grallator *tracks were rescued from West Canyon in 1992. NPS = specimens in Park Service collections.*

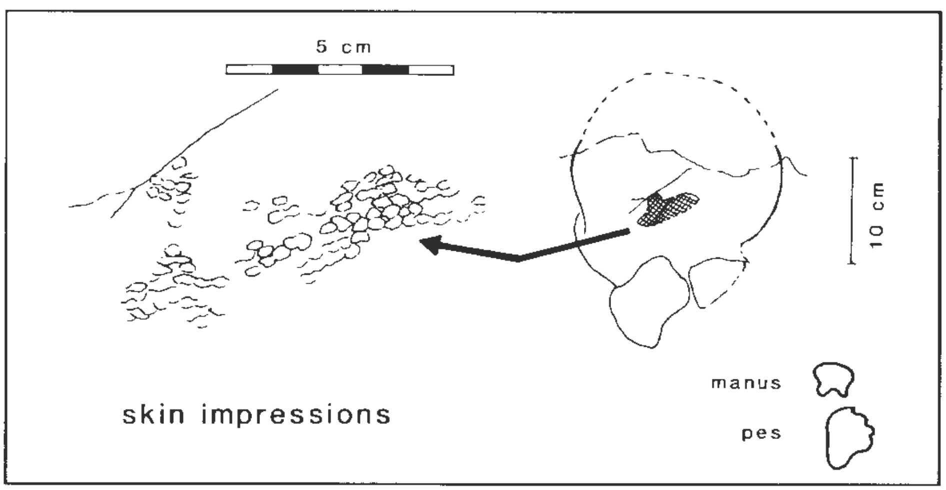

Figure 5. *A brontosaur front foot cast with skin impressions.*

information crossfile

A letter from Paul Goriup of 36 Kingfisher Court, Hambridge Road, Newbury, Berkshire RG14 5SJ, UK, in response to Kathy Jope's article on professionalism in resource management (***Park Science***, Winter 1992), describes the recent formation of the Institute of Ecology and Environmental Management. Mr. Goriup, who is Executive Director of the Institute, describes its objectives as "the encouragement of high quality and responsible work in the environment and to raise the profile of the profession and give ecologists and environmental managers equal status with other professionals."

Membership is open to ecologists and environmental managers with appropriate qualifications and at least three years' experience in professional practice. The Institute's inaugural meeting was held in London on September 26, 1991, and more than 300 applied for membership in the first 6 months. Four major organizations were the Institute's founders: The British Ecological Society, the British Assn. of Nature Conservationists, The Institute of Biology, and the Royal Geographical Society.

* * *

Michigan may have issued the wake-up call when it informed the world recently that it had a 38-acre armillaria bulbosa fungus and touted it as the world's largest living thing. But for a really humongous fungus, the Pacific Northwest is now staking its claim. Ken Russell, a forest pathologist with the Washington State Department of Natural Resources has informed the world that near Mount Adams in sothwestern Washington there exists a growth of armillaria ostoyae covering 1,500 acres—2 1/2 square miles—and boasting somewhere between 400 and 1,000 years of age.

Johann N. Bruhn, the Michigan Tech University research who reported the Michigan fungus in an article in ***Nature***, said he and his coauthors had used a 16-point genetic test to prove beyond doubt that the Michigan fungus was one organism, and he admitted that Russell is most likely correct in saying the 1,500-acre fungus is one organism. The fungus kills trees through direct root contact or through the roots of old stumps that it uses as a food base. The ring-like zones of infection can double in size about every 20 years. The Michigan fungus was estimated at 100 tons.

* * *

As a follow-up to the Spring 1992 issue of ***Park Science***, highly recommended reading is the 6-page section of the May 1992 (Vol. 42 No. 5:330-335) issue of BioScience, entitled "Increased dangers to Caribbean marine ecosystems." The article, by William Allen and subtitled "Cruise ship anchors and intensified tourism threaten reefs," describes in sickening detail the coral reef devastation wrought by cruise ships, whose numbers jumped from 35 in 1982 to 82 in 1987. Allen assesses the threat from increased recreational use, the NPS-funded baseline studies in search of data, and the outlook for solutions.

Managers must have reliable, objective information about public use and ecosystem abuse, and decisions will have to be made before all the information is in, says Allen. But, adds Caroline S. Rogers, research director at Virgin Islands NP, "if any errors are made they should be on the side of resource protection. Restrictions on visitation or use can always be relaxed if warranted. It is difficult to revive a dead reef."

A *Nonmarine* Standard for Part of Late Triassic Time

By Spencer G. Lucas

A local sequence of layered rocks (strata) and the geologic events it documents as well as the fossils it contains can represent an interval of geologic time: this concept is an old one in the science of geology. Indeed, well exposed and fossil laden rock sequences provide standards by which geologists order and interpret the major events of Earth history. Most such standards are in rocks that were deposited originally in the sea, since these rocks readily document geological and biological events that can be traced across the broad expanses of ocean basins and their shallow embayments and supra-continental seaways.

However, during the Triassic Period, 250 to 208 million years ago, all Earth's continents existed as one supercontinent (Pangaea) surrounded by a single "superocean" (Panthalassa). On that world map, not just rock sequences deposited in the ocean but also those deposited on land (*nonmarine* rock sequences) have a high potential for recording widespread events.

One such high potential nonmarine sequence of rocks is exposed in the badlands of the Petrified Forest National Park in Arizona. Here, an approximately 382 m (1,164 ft) thick sequence of Upper Triassic rocks is exposed over most the 37,864 ha (93,492 acres) of the park (Billingsley 1985). These rocks (Fig. 1) were deposited by rivers – in their channels and on their floodplains – and by lakes. Geologists term them the Chinle Group (or Formation), a sequence of nonmarine strata of Late Triassic age that was deposited in a vast basin extending from at least Wyoming to Texas, north-south, and from western Oklahoma to southeastern Nevada, east-west – an area of about 2.3 million km2 (0.9 million square miles) (Lucas 1992).

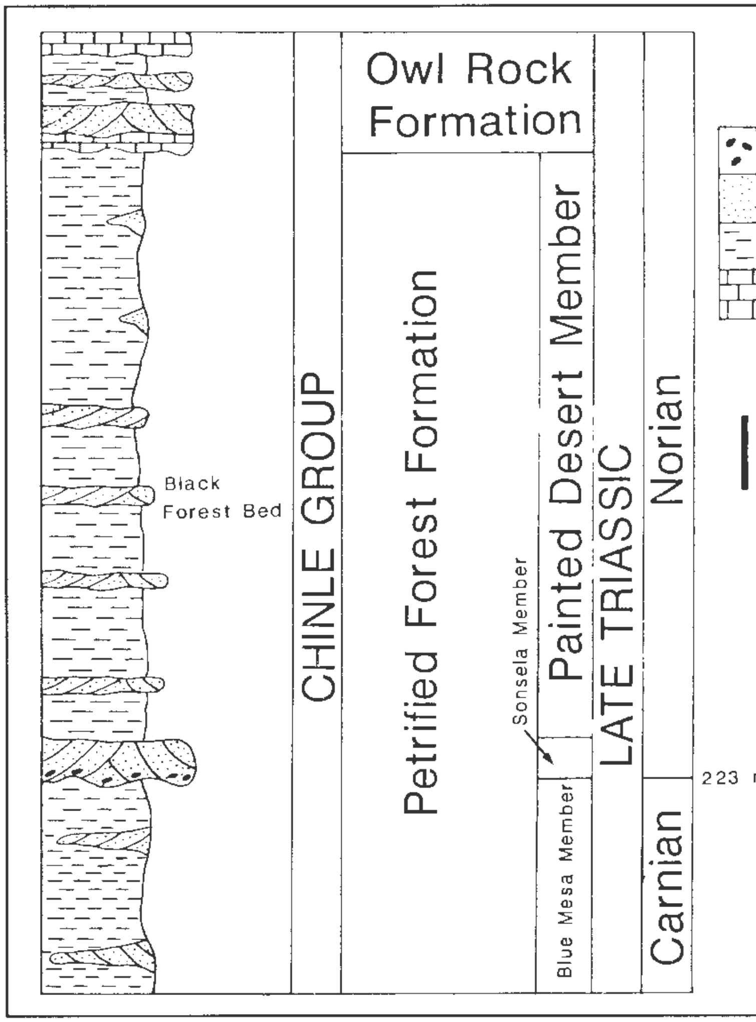

Figure 1. Upper Triassic rock types, stratigraphic units and their age in the Petrified Forest National Park.

Geological Events

The approximately 382 m (1,164 ft) of Upper Triassic strata exposed in Petrified Forest NP record a complex history of changing environments over a period of about 9 million years. Although the broad outlines of this history are understood, much detail remains to be elucidated.

Sediments accumulated in this area under a monsoonal climate of marked wet-dry seasonality at a latitude of about 5 degrees north of the equator (Dubiel et al. 1991). The oldest sediments exposed in the park, those of the Blue Mesa Member of the Petrified Forest Formation, are river-floodplain sediments riddled with ancient soil profiles. A break in the sedimentary record (unconformity) separates the Blue Mesa Member from the overlying Sonsela Member.

Sonsela river channels were larger and carried heavier bedloads than either earlier or later Late Triassic river channels preserved in the park. The Sonsela Member rivers flowed to the north and the northeast during a time of increased stream gradients in highlands well to the south of the park. This also was a time of lower gradients in the park and that facilitiated the deposition of a laterally extensive sheet of sandstone and conglomerate that is about 9 to 13 m (30-40 ft) thick (Deacon 1990).

Overlying sediments of the Painted Desert Member represent river floodplain, channel and pond deposits. One highly distinctive river-channel complex – the Black Forest Bed – consists of reworked volcanic ash much older than the sediments that encase it. The source of this ash still is uncertain (Ash 1992). Large channel and sheetflood sandstones of the Painted Desert Member imply lower subsidence rates than during deposition of the Blue Mesa Member.

The youngest Upper Triassic strata exposed in the park is the Owl Rock Formation. Its limestones have been interpreted as lacustrine, but many are actually pedogenic calcretes (soil caliches). The Owl Rock Formation reflects a period of greater landscape stability and lower sedimentation rates than prevailed during deposition of the underlying Upper Triassic strata exposed in the park.

Biological Events

Fossils found in Petrified Forest NP are of plants and of invertebrate and vertebrate animals. The most famous plant fossils are *Araucarioxylon*, a type of fossil conifer wood, the state fossil of Arizona. It and the wood of two other extinct conifers, *Woodworthia* and *Schilderia*, form the extensive fields of petrified logs and stumps from which the park takes its name. Fossil leaves found in the park are principally of ferns, conifers, and cycadeoids. They indicate moist, humid climates in the vicinity of the river channels and the pond margins where most of these fossils were preserved. Fossil pollen and spores (palynomorphs) are common in Upper Triassic strata in the park and are an important means by which their age is established (Litwin et al. 1991).

The most common invertebrate fossils in the park are of freshwater clams, the unionids, a group still extant. Their shells form extensive beds, some of which are well preserved, others of which are fragmented, having been transported prior to burial, and still others of which are oncholitic (algal encrusted). Growth bands preserved in the unionids' shells and in the shells of associated freshwater gastropods support the idea of a markedly seasonal climate. Other invertebrate fossils include ostracodes (seed shrimp) and charophytes (calcareous egg cases of algae) in some layers in the Upper Triassic rock sequence that were deposited by permanent lakes 6 to 8 m (18-24 ft) deep. Still other Late Triassic

Continued on page 19

Strategic Ecological Research Workshop

By Jane Lubchenco and John Dennis

The continuing growth of human populations and of human demands for natural resources has direct and indirect effects on the abilities of parks to sustain natural biological systems. Park research traditionally has emphasized short term projects to detect, understand, and predict some of the direct effects of human acitivites, including exotic species, overharvesting of species, and alteration of habitats to meet human needs.

Park scientists presently have little support for conducting longer term, strategic research on ecological effects caused by pervasive or difficult-to-detect, indirect influences. Such influences result from human acitivites outside the parks that lead to fragmentation of habitat patterns over broad landscapes and changes in ecological relationships in response to changes in such factors as climate, availability of seasonally used habitats, natural fire dynamics, long distance transport of pesticides and other pollutants, loss of genetic diversity from wild populations of plants and animals, or inter-species relationships in complex food webs.

In the absence of management intervention, the continued interaction of these indirect influences eventually may lead to irreversible declines of park resources as we know them today.

In an effort to develop the longer term research needed to support management of these indirect influences, 127 NPS and academic participants met at a workshop convened by Drs. Paul G. Risser, Michael Ruggiero, Jane Lubchenco, and Milford Fletcher in Albuquerque on Feb. 24-26, to define an NPS ecological research agenda structured in the context of the Sustainable Biosphere Initiative proposed by the Ecological Society of America (Lubchenco et al. 1991, Risser et al. 1991).

The report of this workshop recommends a long term, strategic, ecological research program designed to support current and future policy formulation by characterizing resource conditions and trends and the ecological processes that create them. The report also recommends that the strategic program be designed to encourage incorporation of parks and the NPS research program into the broader national research agenda dealing with global change, biodiversity, and sustainability.

To achieve this dual purpose of supporting park management needs and using parks as components of a national research agenda, the report recommends that the program build on existing and new Service research acitivities, link with strategic programs of other organizations, and include elements on anticipating and recognizing threats to park resources. The report recommends that these elements focus on:

- developing linked inventory, monitoring, and research programs that will detect and track change;
- identifying the status and trends of biodiversity at landscape, species, and genetic levels of diversity;
- merging complex social, economic, and environmental research into broad scale analyses and predictive models dealing with differing levels of uncertainty through a range of spatial scales (from larger-than-park landscapes through biological regions to global) and time scales (from decades to millenia) and,
- constructing a high quality NPS science program empowered to address both short-term and long-term research, focus on both park and national research agendas, act collectively, work cooperatively outside park boundaries, maintain rigorous information management systems, and develop and apply conceptual models as integral parts of research and resource management activities.

The intended product of this recommended program is information at genetic, ecosystem, landscape, biogeographic region, and global scales that will be useful for policy formulation, natural resource monitoring and management application, and public education on major resource issues.

For more information on the workshop report, contact Michael Ruggiero, Chief, Wildlife and Vegetation Division, NPS, Washington, DC, (202)343-8121.

Lubchenco is Professor of Zoology at Oregon State Univ., Corvallis, OR; Dennis is Chief, Science Branch, Wildlife and Vegetation Div., WASO.

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Triassic Time *continued from page 18*

invertebrates preserved in the park – conchostracans (clam shrimp), insects, and crayfish – either are not common enough or not well enough studied to permit many conclusions at present.

The most extensive fossil record from the park is of vertebrates. The fishes are mostly lungfishes, best known from their isolated toothplates, but small freshwater sharks and primitive bony fishes also are well represented as fossils.

The park's commonest vertebrate fossils are of phytosaurs, aetosaurs, and metoposaurs. The metosposaurs were a Late Triassic group of large (up to 2 m long) amphibians. The Blue Mesa Member metoposaurs are mostly large (*Beuttneria*), whereas the Painted Desert metoposaurs are mostly small (*Apachesaurus*). The phytosaurs, a group of crocodile-like reptiles of the Late Triassic, show a similar disjunct distribution, with phytosaurs below the Sonsela Member (*Rutiodon*) different from those above it (*Pseudopalatus*). Aetosaurs, large armored plant-eating reptiles, show a similar distribution – *Stagonolepis* and *Desmatosuchus* the dominant aetosaurs below the Sonsela, *Typothorax* the dominant aetosaur above it (Hunt and Lucas 1990). Other vertebrates known from fossils found in or just outside the park include the cow-sized mammal-like reptile *Placerias*, lizard-like trilophosaurs, and the rauisuchians, which include the ferocious meat-eater, *Postosuchus*. Some of North America's oldest dinosaurs are found in the park: they are only a million or so years younger than the oldest North American dinosaurs, which are from the Chinle Group near St. Johns, Arizona and near Big Springs in West Texas (Lucas et al. 1992).

The fossil vertebrates found in the park can be segregated into two "faunas," a lower fauna in the Blue Mesa Member and an upper fauna in the Painted Desert Member (Lucas 1990, 1992; Murry 1990). The fact that few vertebrates cross from one fauna to the other represents a reorganization (evolutionary turnover) of the vertebrates that suggests some time is missing between the two faunas, but causes of the reorganization remain unknown.

A Nonmarine Standard

For Late Triassic nonmarine environments, the 100 percent rock exposure over a large area, the extent and duration of collecting and research, and the prolific fossil record of the Petrified Forest NP are unparalelled. Therefore, as a key to ordering and interpreting an interval of Late Triassic geological and biological events on land, the sequence in the park should provide a global standard for geologists and paleontologists. This standard, for example, documents a complex evolutionary turnover of terrestrial vertebrates about 223 million years ago, at about the junction of the Carnian and Norian stages of the geologic timescale. This turnover is not the mass extinction identified by some authors (e.g. Benton 1991) but a more subtle replacement that took place over the course of millions of years.

We are fortunate that so excellent a standard for part of Late Triassic time is preserved in one of our national parks. Management of the park's rocks and fossils has not only conserved these resources but for many years has provided vigorous support, both logistically and materially, to the scientific study of park geology and paleontology. This management and the scientific study it promotes have established the Petrified Forest NP as a vital geological and paleontological standard that for years to come will continue to enhance understanding of the Late Triassic world.

Lucas is Curator of Vertebrate Paleontology at New Mexico's Museum of Natural History.

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regional highlights

Alaska Region

Wildlife Biologist Carol McIntyre presented a paper, "Territory occupancy, productivity, and breeding success of golden eagles in Central Interior Alaska," at the Fourth World Conference on Birds of Prey and Owls in Berlin, Germany, May 10-17. She was invited by the conference organizers to give this paper on her research at Denali NP/P, which has the largest reported breeding population of golden eagles in northern North America. Carol then traveled to Scotland, at the invitation of the Royal Society for the Protection of Birds, to visit and provide advice for a study of golden eagles there.

* * *

Concerns surrounding potential overharvest of and range overuse by the little known and previously unstudied moose population in Noatak National Preserve prompted the NPS and the Alaska Dept. of Fish and Game to begin a cooperative research project this spring. Working with a helicopter from April 1-9, crews darted 83 moose, radio-collared 50, and ear-tagged all of them. One moose was killed. Moose are relative newcomers to the area and their immigration is seen as a possible indication of global warming.

* * *

The Alaska Region welcomes some new additions to our staff. Two resource management specialists, Hubert Chakuchin (Denali) and Mike Tetreau (Kenai Fjords) have been selected for the '92-'93 Natural Resource Trainee program. Aquatic Ecologist Lyman Thorsteinson was hired recently to coordinate inventory and monitoring activities in selected park watersheds. Formerly a fishery scientist with NOAA, Lyman has been studying offshore features of the biology and ecology of Arctic fishes through the Outer Continental Shelf Environmental Assessment program. Since joining the staff on February 24, he has been working with Denali staff to implement a pilot monitoring program in Rock Creek this summer.

The GIS Regional Technical Support Center has three new members. Nancy Nicholaisen, the new Systems Analyst, formerly was with NOAA's National Ocean Service in Anchorage. She is a regular contributor to Dr. Dobb's Journal. Brian Mattos, a graduate of the Resource Management Training program, is our GIS Cartographic Technician. Before coming to Alaska, he was a Supervisory Forestry Technician at Rocky Mountain NP. Joni Peircy is a GIS Cartographer and comes to the group from the Alaska State Dept. of Environmental Conservation's Exxon Valdez Oil Spill Response Center in Anchorage.

North Atlantic Region

The NAR is pleased to announce two new CPSUs. Dr. Allan O'Connell, formerly of Acadia NP, has become Unit Leader at the University of Maine CPSU. Dr. Brian Underwood, formerly of NAR Office of Scientific Studies, has become Unit Leader at the State University of New York at Syracuse CPSU. Charles Norman Farris will join the University of Rhode Island CPSU as the new benthic biologist. Janice Minushkin, who was conducting field research at Cape Cod National Seashore, has joined the staff at the Office of Scientific Studies as Asst. Regional Coordinator of the National Natural Landmarks Program.

Midwest Region

The Regional Office and park staff have received numerous recent calls for information on the regulated lake level studies at Voyageurs NP. Many of our parks suffer the effects of regulated lake levels and may be interested in the following list of papers published within the last year:

Smith, D., and R.O. Peterson. 1991. Behavior of beaver in lakes with varying water levels in northern Minnesota. Env. Mgt. 15:395-401.

Smith, D., R.O. Peterson, T.D. Drummer, and D.S. Sheputis. 1991. Over-winter activity and body temperature patterns in northern beavers. Canad. Jrnl. of Zoology 69:2178-2182.

Thurber, J., R.O. Peterson and T.D. Drummer. 1991. The effect of regulated lake levels on muskrats, *Ondtra zibethicus*, in Voyageurs NP, Minn. Canadian Field-Naturalist 105:34-40.

Wilcox, D.A., and J.E. Meeker. 1991. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minn. Canadian Jrnl. of Botany 69:1542-1551.

Payne, G.A. 1991. Water quality of lakes and streams in Voyageurs NP, northern Minn., 1977-84. U.S.G.S. Water Resources Investigators Report 88-4016. 95pp.

For more information about research of this type, contact Larry Kallemeyn at (218)283-9821.

* * *

Six students at U/WI-Madison have agreed to participate in a summer interneship program through the Great Lakes CPSU. Their projects will be located at Ozark National Scenic Riverway, Pictured Rocks National Lakeshore, St. Croix National Scenic Riverway, Apostle Islands National Lakeshore, Lewis and Clark National Historic Trail, and Ice Age National Scenic Trail. For information on this program, contact Dr. James Bennett at (608) 262-5489.

* * *

Keely Goff, a student at Haskell Indian Junior College, Lawrence, Kan., has been selected to begin a cooperative education program with the Region's natural resources division. She will start on June 1 at Effigy Mounds National Monument, Iowa.

* * *

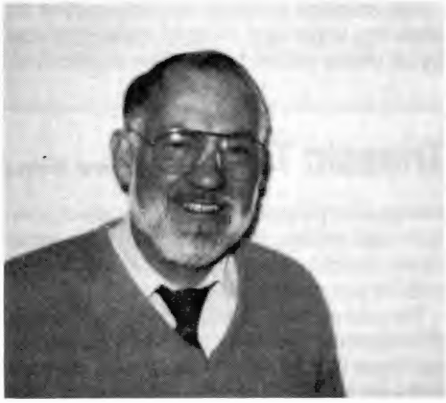
Regional Chief Scientist Ron Hiebert is coordinating preparation of a proposal to include cultural resource management classes in the Haskell Indian Junior College natural resources program. Future short courses also are planned on management of American Indian cultural landscapes and objects for NPS and other agency employees.

Southwest Region

Sam Kunkle, who formerly served as a research hydrologist with the NPS Water Resources Division in Fort Collins, has left the U.S. Forest Service to become Chief Scientist for the NPS Southwest Region.

For the past four and one half years he has developed and managed an overseas program in tropical forestry for the USFS – a program that promotes cooperation in training and technical assistance abroad with international and non-governmental organizations such as the World Wildlife Fund.

Kunkle completed his graduate studies and Ph.D. at Colorado State University in water resources, and undergraduate studies in California and Goettingen, Germany. He also served as research hydrologist for the Agricultural Research Service and as watershed specialist with the FAO in Rome, Italy.



Sam Kunkle

The Region's Technical Center at U/NM conducted a Geographic Information Systems (GIS) workshop on a DOS-based GIS in late April. The EPPL7 (Environmental Planning and Programming Language) software uses both vector and raster files and is in use at several USFS and NPS areas in New Mexico. The course was taught by a representative of the vender—the State of Minnesota.

Enough personal computers were rented or scrounged to assure each student her/his own workstation. The 24-hour course was a good beginning for field personnel and another is being planned for August or September.

* * *

Mike Hayden, the USDI Asst. Sec. for Fish, Wildlife, and Parks, was a keynote speaker at the 57th North American Wildlife and Natural Resources Conference in Charlotte, NC March 30-April 1. In his talk, "New Times, Old Questions, Tough Answers," Hayden emphasized the need for scientists and managers to get their message to the public; to fail is to forfeit public support for their programs.

Further stressing education, he suggested that our planet is abused more through ignorance than malice. He also highlighted economics, noting that annual expenditures by hunters ($10 billion), anglers ($28 billion), and non-consumptive natural resource users ($14 billion) total 1.5 percent of our entire GNP.

* * *

The annual meeting of the NPS's threatened and endangered (T&E) species coordinators followed the above meeting on April 1. The group discussed programmatic goals, Servicewide T&E publications, and training. Margaret Osborne presented the completed interagency Section 7 consultation handbook.

* * *

On May 20 in Albuquerque, NM, the USFWS conducted the first of two public meetings on the

Mexican wolf. The second meeting was held May 27 in Tucson, AZ. This is part of the preparation toward writing an environmental impact statement for the proposed experimental reintroduction of captive-reared Mexican wolves. Five sites are being considered—four in Arizona, one in New Mexico. Two of the sites are close to NPS units.

Of the 94 in attendance, a majority favored reintroduction. Milford Fletcher, Unit Leader of the CPSU at U/NM; Rob Arnberger, Big Bend NP Superintendent; and Jerry McCrea, SW Regional Biologist, were the NPS attendees. Written comments on the subject were accepted by the USFWS station in Albuquerque only until June 19.

* * *

The Regional Office's Natural Resource Management and Science (NRMS) staff held a training session in Austin, TX in April, covering resource management plans, program funding, and a wide range of technical topics. The 44 participants included resource management specialists, superintendents, scientists, and others from most of the Region's parks.

The NRMS Division will cooperate with the Denver Service Center in FYs 1993-95 on a study of natural vegetation for erosion control. They continue to advise Amistad NRA technically on the toxic landfill question, and met in the Regional Office with park personnel on May 21. The staff also is working closely with Big Bend on developing a River Use study.

* * *

Regional Chief Scientist Sam Kunkle met in late May with Howard Ness, Mexico Program Coordinator for the Region, and representatives of various parks in Las Cruces, NM, to consider possibilities for cooperation with Mexico on various projects.

Pacific Northwest

The National Park Service (especially Olympic NP) is a cooperator, with other land management agencies and scientific programs, in the newly established Olympic Natural Resources Center (ONRC). ONRC is conceived as the University of Washington's center for research and educational activities associated with development of natural resource management systems that integrate production of commodities with protection of ecological values.

The 1991 Washington State Legislature committed $5.675 million for construction of the facility, which already is producing information of help in resolving conflicts that arise in both forest and marine resource management. More on this later.

* * *

Every 3 months or so, PNR Regional Resource Management Specialist Kathy Jope compiles from a variety of sources a list of recent publications relevant to natural resource issues in PNR parks. To obtain a copy of the listing, contact the PNRO Library, 83 S. King St., Suite 212, Seattle, WA 98104.

* * *

At last! Dr. Gerald Wright's magnum opus, *Wildlife Research and Management in the National Parks*, has appeared. Published by the University of Illinois Press (1992, 224pp), the book represents the culmination of many years of independent work. It covers the evolution of science in the NPS as well as such issues as animal control, exotic species management, bear management, wolf reintroduction, and visitor interactions with animal life.

A review of the book will appear in a future issue. Meanwhile, congratulations to Gerry!

* * *

Bob Lee, U/WA sociologist in the College of Forest Resources, presented for the Regional staff his ongoing research on the Olympic Peninsula. He is attempting to develop an integrated computer model that could address relationships between the economy and environment on the Peninsula. His research is part of the MAB project and is being done in cooperation with U/WA, the USFS, NPS, and the Washington Dept. of Natural Resources.

Southeast Region

The Kentucky Division of Water has joined forces with the NPS and several other agencies in a project to reduce water pollution in and around Mammoth Cave NP. The Mammoth Cave Area Water Quality Special Project includes a 240,000 acre drainage basin. Instead of flowing into surface streams, rain falling in the basin flows into some 15,000 active sinkholes and through underground streams and caves, including Mammoth, before emerging as spring water in the Green River.

The project goal is to apply Best Management Practices (BMPs) on farms in the project area. BMPs are land use management practices designed to control pollution generated by storm water runoff. Other project activities includ monitoring water quality on demonstration farms, producing educational materials, and conducting project-related research.

Western Region

Dave Parsons, Research Scientist at Sequoia and Kings Canyon NPs, has three new publications:

Planning for climate change in national parks and other natural areas, in The Northwest Environmental Journal, 7:255-269, 1991, U/WA, Seattle 98195; Restoring natural fire to the Sequoia-mixed conifer forest: should intense fire play a role?, with Nathan L. Stephenson and Thomas W. Swetnam, in Proceedings of the 17th Tall Timbers Fire Ecology Conference at Tallahassee, FL, 1991, pp 321-337; and Preparing the Sierran Parks for global issues of the 21st century, in Yosemite Centennial Symposium Proceedings; Yosemite Assn., El Portal, CA, pp. 150-155.

* * *

The CPSU at U/AZ has published the following two reports, copies of which may be had from the CPSU in Tucson or by calling (602)670-6886:

Technical Report No. 43, Vegetation and flora of Fort Bowie National Historic Site, AZ, by P.L. Warren, M.S. Hoy, and W.E. Hoy, 78pp; and

Technical Report No. 44, Historical review of water flow and riparian vegetation at Walnut Canyon National Monument, AZ, by N.J. Brian, 39pp.

Water Resources Division

The Division's Annual Report for 1991 is now available. It describes Division activities in planning and regulatory assessment, water rights, water quality, floodplains, wetlands, watershed protection, information resource management, and research. Day-to-day support to parks, Regions, and the Washington Office also is described. The report may be had from NPS, Water Resources Division, 301 S. Howes St., Rm 353, Fort Collins, CO 80521. Ask for Report NPS/NRWRD/NRR-92/07, or call Jerry Walsh at (303) 491-1708.

Coyote Related Problems Studied

A 3-year study was started in fall, 1991, to assess the extent of coyote related problems in the NP System and study the ecology and human interactions of coyotes in and along the boundary of Saguaro National Monument (SAGU). The research is being directed by William Shaw, School of Renewable Natural Resources, U/AZ, and Norman Smith, AZ Cooperative Fisheries and Wildlife Research Unit, USFWS, in cooperation with the CPSU at U/AZ.

Graduate student Dixie Bounds completed a preliminary NPS-wide survey of coyote presence, human/coyote interactions and problems, movements, and population trends, to which 86 percent of the NPS units responded. A more extensive survey now is being developed and will be sent those areas having coyotes in order further to query the management, exploitation, habitats, disease, human interactions, and other wildlife interactions, and benefits/costs related to having coyotes in those units.

At SAGU, a geograpic information system (GIS) will be used for analysis of relocation data related to this study. Grad student Mark McClure is studying population numbers and diets of coyotes living near the SAGU boundary. The mark-recapture method is being employed to determine population density in the urban site. Scat analysis and small mammal surveys will help determine coyote diets there.

Biological technician Kathy Hiett (CPSU/UA) assisted in the trapping and radio-collaring phased and will continue to provide field support. The research areas comprise a control area south of the monument and a study area located within the monument along the western boundary. Trapping and radio-collaring of individuals was completed in October and November 1991. A total of 10 coyotes, 5 males, 5 females (7 adults, 3 juveniles) either were radio-collared or fitted with ear tags in the urban site. In the control site, a total of 4 individuals, 2 males, 2 females, (4 adults) also were radio-collared. Radio-tracking and mark-recapture data will be collected through 1993.

The study will provide management guidelines and recommendations for addressing coyote-related issues in NPs.

regional highlights

Rocky Mountain Region

A Cooperative Park Studies Unit has been established at CO/State/U, led by interim leader Dr. Dave Swift (303/491-1981). Researchers associated with the unit, as NPS or university employees, are Therese Johnson, Frank Singer, and Drs. Tom Stohlgren and Ed Redente. Current work includes bighorn sheep, global climate change, and reclamation studies.

* * *

The May 30-April 1 Rocky Mountain Region's 1992 Science and Resource Management Conference was attended by more than 150, and many stayed another 2 days for regional workshops (Colorado Plateau parks, Prairie parks, and Rocky Mountain parks.)

* * *

The Region has embarked on a multi-year project to gather ambient sound data for the Colorado Plateau parks (at least). Mary Ann Grasser (303/969-2945), formerly of the WASO Mining and Minerals Branch, is coordinating the program as an employee of the Resource Management Branch. Grasser also is reviewing proposals/plans from other agencies to assess impacts on natural quiet.

Vail Final Report Sets Six Goals

The Steering Committee's final report to Director James Ridenour on "National Parks for the 21st Century: The Vail Agenda," proposes six strategic objectives for correcting what it acknowledges as current flaws in the state of the National Park Service. (In spite of general recognition of the National Park System as the finest in the world, enjoying broad-based public support, the effectiveness of the National Park Service is weakened by decreasing employee morale caused by eroding professionalism, limited resources for resource management, and a sense of isolation from decisions that count.)

The proposed objectives aimed at creating and fulfilling a vision for the next century are: **resource stewardship and protection** (NPS's primary responsibility is protection of park resources); **public access and enjoyment; education and interpretation; proactive leadership; science and research** (the NPS must engage in a sustained and integrated program of natural, cultural, and social science resource management and research aimed at acquiring and using the information needed to manage and protect park resources); and **professionalism** (the NPS must create and maintain a highly professional organization and workforce.)

The Report, which deals in detail with all six areas and specific recommendations, was presented to Director Ridenour by William J. Briggle, steering committee chair, and Henry L. Diamond, symposium general chair. It has been distributed to all Regions and is available for study and review.

mab notes

The big question for biosphere reserves has always been: How do we expand our outlook beyond our unit boundaries and establish regional cooperation to address regional resource issues? In other words, how do we truly become a biosphere reserve?

A good model exists in the Southern Appalachian MAB Cooperative, but development of similar MAB regional structures elsewhere has been slow. There is hope that such development can be speeded up soon. In spring 1992 the U.S. MAB National Committee established a **special committee to develop a national MAB program plan** for U.S. biosphere reserves. The committee is composed of policy officials, BR managers, and scientists. Gene Hester, Associate Director, Natural Resources, and Rob Arnberger, Superintendent of Big Bend NP, represent NPS on this committee, which will pay special attention to finding ways U.S. MAB can improve the benefits of biosphere reserves to managers.

* * *

In 1991 **Big Thicket National Preserve** took the innovative step of producing a separate Statement for Management regarding its biosphere reserve status. The SFM lists 13 objectives, including research and education related to regional issues and steps to set up formal structures for communication among local groups on regional resource issues. A state park, state forests, Indian reservation, university research area, and a Nature Conservancy sanctuary in the area are potential partners.

The park recently has drafted a Partnerships in Preservation Plan to conduct outreach on regional issues with local groups and private landowners. Big Thicket thus joins a number of other biosphere reserves that are attempting to function like a BR and could do much more if given adequate support.

* * *

At the Vail symposium, the working group on **Leading by Example** identified the BR program as an area of developing NPS environmental leadership. Bill Gregg, NPS MAB Coordinator, was asked to give his thoughts on how the BR program could implement the Vail recommendations on leadership. Among his suggestions:

A BR managers workshop to assess progress and recommend new steps;

Increased incorporation of BR objectives in planning documents of BR parks;

Guidelines for including BR responsibilities in position descriptions of those responsible for BR program coordination;

Improved Servicewide recognition and interpretation of biosphere reserves;

Increased financial and FTE support for regional BR programs and international BR linkages.

* * *

The MAB Directorate on Tropical Ecosystems has developed an interesting and ambitious core program on sustainable development and conservation in the **Maya tri-national region** of Belize, Guatemala, and Mexico. This area includes the Calakmal and Montes Azules BRs in Mexico and the Maya BR in Guatemala as well as agricultural and forestry lands. Much of the landscape remains relatively undisturbed, and a core program goal is to provide government decision-makers and resource managers with information that will help them guide development in a way that does not significantly impede normal ecosystem functioning or adversely affect species diversity and viability. The program takes a management-oriented approach to research: Managers and government officials will be asked what the problems are, and research will be designed to address these problems. Creating a communication network among all researchers in the region is another goal.

Napier Shelton
NPS Washington Office

meetings of interest

1992

Aug. 3-7, MAPPING AND MONITORING GLOBAL CHANGE, is the theme of a 4-way Congress and Convention in Washington, D.C., involving the Int'l Soc. for Photogrammetry and Remote Sensing, the Amer. Soc. for Photogrammetry and Remote Sensing, the Amer. Cong. on Surveying and Mapping, and Resource Technology 92 .

Sept. 10-12, NATIONAL WATCHABLE WILDLIFE CONFERENCE, Missoula, MT. Contact: Napier Shelton, NPS Wildlife and Vegetation Division, P.O. Box 37127, Washington, D.C. 20013-7127: (202) 343-8124.

Oct. 27-30, 19TH ANNUAL NATURAL AREAS CONFERENCE and 14TH ANNUAL MEETING OF THE NATURAL AREAS ASSN., at U/IN campus, Bloomington. Contact: Division of Nature Preserves, U/IN, 402 W. Washington St., Rm. W 267, Indianapolis 46204; (317) 232-4052.

Oct. 27-30, REDISCOVERING AMERICA: Natural Areas in the 1990s, the 14th Annual Natural Areas Conference, at Indiana Memorial Union, Indiana University, Bloomington. Contact: Indiana U Conf. Bureau, IMU Room 677, Bloomington, IN 47405; (812) 855-6451.

Nov. 16-20, PARTNERS IN STEWARDSHIP, the George Wright Society Conference on Research and Resource Management in Natural and Cultural Parks and Reserves, Jacksonville, FL. Contacts: John Donahue, NPS, 18th & C Sts NW, Washington, DC 20240 (202) 208-4274 and Harry Butowsky, NPS, PO Box 37127, DC 20013-7127 (202) 343-8155.

1993

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. Nov. 15 deadline for abstracts. Contact: Dr. Monica G. Turner, Envir. Sciences Div., Oak Ridge National Lab, P.O Box 2008, Oak Ridge, TN 37831-6038; (615) 574-8282.

When Is A Visit Really a Visit? Public Use Reporting Study at Acadia NP

By Kenneth Hornback and Robert Manning*

"The Government (is) very keen on amassing statistics. They collect them, add them, raise them to the nth power, take the cube root, and prepare wonderful diagrams. But you must never forget that every one of these figures comes in the first instance from the village watchman, who just puts down what he damn well pleases."

– Sir Josiah Stamp, 1880-1941

Despite the cynicism of the above epigraph, the National Park Service places considerable emphasis on measuring and reporting public use. In fact, the NPS has collected information regularly about public use since 1904. In the early days when park visitation was low and sporadic, superintendents themselves counted park visitors and recorded where they came from and how they got to the parks. In today's world, where visits to the national parks number in the hundreds of millions annually, this system will no longer suffice! Public use reporting has become more sophisticated.

Public Use Reporting is governed by NPS-82 and is administered by the Socio-Economic Studies Division (NPS Denver). The public use reporting system's objective is to design and implement a statistically valid, reliable, and uniform method of collecting and reporting public use data for each independent unit administered by the NPS. Public use statistics serve a variety of purposes, including measuring the impact of park visitation, gauging monthly work load requirements, and tracking visitation history and trends. Among the most important components of the public use reporting system are definition of terms, counting and reporting instructions, surveys, and audits.

Definitions

A visit is the central unit of analysis in the public use reporting system. A visit is defined as the entry of any person, except Service personnel, onto lands or waters administered by the NPS. However, there are three kinds of visits which must be counted and reported separately: *Recreation visits* [visits for recreation purposes]; *Nonrecreation visits* [visits for nonrecreation purposes, including (1) persons going to and from inholdings; (2) commuter traffic; (3) other through traffic; (4) trades-people with business in the park; (5) any activity a part of or incidental to the pursuit of a gainful occupation; (6) government personnel other than NPS employees with business in the park; (7) citizens in the park to discuss or hear about park business (e.g. public hearings)]; and *Nonreportable visits* [visits by (1) NPS employees, (2) their families, (3) concessioner employees, (4) members of Cooperating Associations, (5) activities associated with NPS cooperative agreements, (6) tenants of NPS property if not crossing significant NPS territory for access, (7) persons engaged in pursuit of specific legal rigthts of use (e.g. subsistence hunting and fishing), and (8) NPS contractors.]

Finally, *duplicate counting* (multiple entries on a single day) must be avoided. The major forms of duplicate counting are associated with (1) commuter traffic back and forth through the park, (2) visits to more than one area of a park with discontinuous boundaries, (3) visitor traffic back and forth to visit outside vendors, and (4) visitors residing outside the park making morning and afternoon visits.

Counting and Reporting Instructions (CRIs)

CRIs are prepared to reflect the unique site characteristics of each park. CRIs contain the procedures for measuring, compiling, and recording public use. For very straightforward and small scale areas, CRIs can be prepared informally. For larger and more complex areas, formal audits are needed.

Audits

Audits of each NPS unit are periodically conducted by the Statistical Office. Audits constitute detailed looks at the public use complexities of each park unit.

Surveys

Measurement of public use requires some knowledge of and about park visitors. This information is derived from periodic surveys. Visitor surveys produce multipliers or conversion factors used in public use reporting. Surveys are conducted (usually at three year intervals) to keep up with local economic, transportation, and demographic changes.

A Case Study: Acadia National Park

Acadia NP is exceptionally complex from the standpoint of public use reporting. It occupies about half of Mt. Desert Island, Maine, and consists of a patchwork of public lands interspersed with private lands. Numerous uncontrolled entrances and exits and park roads are traveled by large numbers of visitors, local residents, and others.

Acadia was audited by the Statistical Office in 1989 and, because of its complexity, a survey was deemed necessary in order to develop new Counting and Reporting Instructions. The emphasis of the public use reporting system was to be based on a "double sampling" procedure. This technique is commonly used where visitation is highly dispersed and difficult and expensive to count directly. A second more easily measurable variable is created and statistically related to visitation. Visitation then can be estimated by means of this new variable. In automobile-oriented parks such as Acadia this new or second variable often is automated automobile traffic counters. A traffic counter at Sand Beach, a principal park attraction, was designated as the focus of the double sampling system at Acadia.

The survey was begun in summer 1990 and conducted in each of the four major use seasons. Chosen for sampling were 30 park sites, representing the diversity of visitor attractions. Sampling was done on 70 days, and 2,873 visitors were given a short questionnaire. Variables of principal interest included reason for visit (recreation, nonrecreation, nonreportable), persons per vehicle, length of stay, and whether or not the visitors tripped the Sand Beach traffic counter on the days they were interviewed.

Survey findings are presented in Table 1. The first variable, the Sand Beach traffic counter multiplication factor, was calculated on the basis of the percentage of visitors who tripped the Sand Beach traffic counter. For example, during the summer season 46.9 percent of visitors sampled did not trip the counter on the day they were interviewed. This means the traffic counter is underestimating the number of visitor vehicles in the park and its reading must be adjusted upward accordingly. A majority of visitors (51.2%) tripped the traffic counter once, thus no adjustment is needed for these visitors. However, 1.8 percent of visitors tripped the counter twice, and an additional .1 percent tripped it three times, requiring an appropriate downward adjustment of the counter reading.

Aggregating all these adjustments, Sand Beach traffic counter readings should be adjusted upward using a multiplication factor of 1.81 for the summer season. Other variables needed to estimate public use are persons per vehicle (2.99 for the summer season) and type of visit (recreation visits=96.6%, nonrecreation visits=2.8%, non reportable visits=.6% for the summer season). Finally, length of stay can be factored in to further quantify public use. It is interesting to note the seasonal differences found among several of these variables.

Conclusion

Based on the above survey findings, a new CRI has been prepared by the Statistical Office and implemented at Acadia. The survey has provided an information base that substantially enhances the validity and reliability of public use reporting and ensures that the public use reporting system is in conformity with NPS guidelines.

Hornback is with the NPS Socio-economic Studies Division, Denver; Manning is Professor and Chair of the Recreation Management Program, School of Natural Resources, U/VT, Burlington.

Table 1.	Season			
Variable	**Summer**	**Fall**	**Winter**	**Spring**
Sand Beach traffic counter multiplication factor	1.81	1.73	5.88	4.02
Persons per vehicle	2.99	3.01	2.42	3.75
Type of visit				
Recreation	96.6%	97.8%	97.1%	99.2%
Nonrecreation	2.8%	2.0%	1.2%	0.8%
Nonreportable	0.6%	0.2%	1.7%	0.0%
Length of stay				
Recreation, day use	5.05 hrs	6.54 hrs	6.57 hrs	5.79 hrs
Recreation, overnight use	101.47 hrs	54.67 hrs	42.71 hrs	56.31 hrs

Litter Arthropod Forest Communities After the 1988 Yellowstone NP Fires

By Tim Christiansen, Robert Lavigne, and Jeffrey Lockwood

Most of earth's biodiversity is inconspicuous. Probably only 1 to 2 percent of all species are higher plants and less than 0.2 percent are vertebrates. The remainder are a vast array of invertebrates, fungi, algae, and other microorganisms that provide important ecological services (Wilson 1985). Arthropod ecology has not been of special interest except in cases of pest species and the occasional listing of endangered arthropod species that undoubtedly represent but a tiny fraction of the actual numbers of arthropods facing extinction.

Studies recently have illustrated the role of arthropods in ecosystem processes such as nutrient cycling, litter decomposition, and plant productivity (Christiansen et al. 1989; Schowalter et al. 1991; Lavigne and Kumar 1974; McBrayer 1977). A disturbance, such as fire, changes the habitat structure and this, in turn, can affect arthropod community structure and function. With this in mind, we conducted a 2-year study of the effect of the 1988 Yellowstone NP fires on litter arthropod communities.

Data collection for the first year began in early July 1989 and continued through September (Christiansen et al. 1991). Data from the second post-fire year were gathered between May and early September 1990. Nine heavily burned forest sites (where fire left very little litter or logs) and 9 unburned lodgepole pine forest sites were established randomly at locations throughout the park. Three permanently placed 100 m transects were situated in each site, from which litter samples were collected every 10 days. Berlese funnels were used to isolate the litter arthropods.

Site description included: Litter biomass, herbaceous cover, and the densities of saplings, logs, standing dead trees, and older trees. Analysis of variance and principal component analysis were used to correlate arthropod density and species composition with habitat data. Our general conclusions have been verified by the use of repeated measures analysis.

Springtails (Collembola) are a major component of the litter community. These insects feed on plant litter, fungi, algae, and bacteria. Springtails are

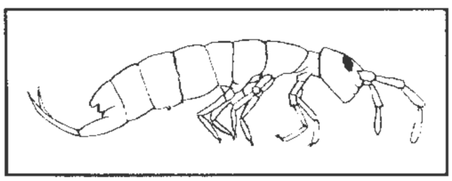


Figure 1. A typical Collembola (springtail) found in leaf litter.

important in initiating litter decomposition, maintaining nutrient cycling, and regulating fungi and other organisms that help in the decomposition process. Density and species composition of springtails were greater in unburned sites containing more than 10 tree seedlings per square meter, at least 12 logs per hectare, at least 36 saplings per hectare, and 50 grams of litter per square meter.

The importance of both tree seedlings and logs was evident in burned sites. Tree seedlings and

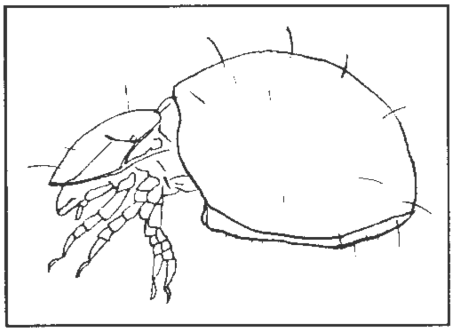


Figure 2. A typical Oribatida mite found in both leaf litter and soil.

fallen trees had to be present by the second year for burned sites to support springtails. Tree seedlings and logs provide protection against predators and the elements, and represent food sources for springtails. Dindal and Metz (1977) reported decreased springtail populations in prescribed forest burns. As found by this earlier study and reemphasized by our work, some springtail species are more tolerant of fire than others. In order to recover, burned forest sites will need arthropods such as springtails, as well as fungi and bacteria, to initiate decomposition and the release of essential nutrients.

Mites (Acari) also are important to ecological processes through involvement in litter decomposition or regulation of other organisms, such as fungi and bacteria, which decompose litter. Litter mite density in unburned forest sites was found to be significantly greater where there were at least 10 seedlings per square meter, 14 logs per hectare, and 45 grams of litter. Additionally at least 40 percent vegetative ground cover was necessary before mite density became statistically significant.

Thus, several conditions are necessary in order to support large mite communities. These conditions were not present in heavily burned sites. Data showed that mite communities in burned sites had only 10 percent of the density and 20 percent of the species found in unburned forest sites even 2 years after fires. The combination of reduced density and species richness of mites and springtails could delay decompositional processes until both these arthropods regain their prefire community structure.

Ants (Formicidae) are important seed predators, soil mixers, and pollinators in forest habitats. Unburned sites with greater than 30 seedlings per square meter contained higher ant densities than sites with less than 30. The more seedlings in an area, the more cover and other resources were available to ant communities. Burned sites containing any type of cover and/or tree seedlings one year after the forest fire contained significantly more ant species and greater ant densities than burned sites, which lacked cover in the form of seedlings or logs. Ants can disturb soil crusts, create soil pores for water penetration, and import seeds from unburned sites. Thus, ants may be important in helping reestablish forest communities by aiding in succession.

Most beetle species (Coleoptera) are not harmful, despite population explosions of *Ips* and other tree damaging species. For example, some beetles such as carabids, prey on tree-damaging beetles. Others may carry seeds, while some are polinators. As expected, the 1988 forest fires seriously disrupted beetle communities. Species of ground beetles were significantly greater by the second post-fire year in burned sites with at least 35 percent herbaceous cover, numerous logs, at least 25 grams of litter, and 10 tree seedlings per square meter. Again, as seen in mite, springtail, and ant communities, some vegetative cover (or log cover) is necessary for these invertebrates to exist.

Many different types of other litter arthropods were found in unburned habitats that were not

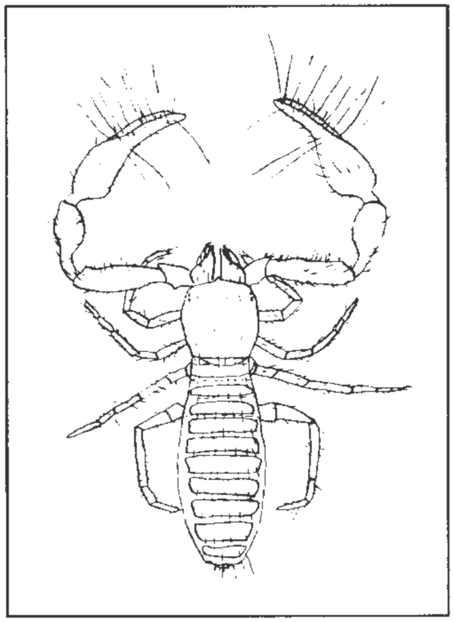


Figure 3. A pseudoscorpion which was found in leaf litter.

found more than occasionally, even after 2 years, in burned forested sites. These arthropods also are connected with ecosystem processes. They included (1) bark lice, (2) webspinners, (3) pseudoscorpions, (4) centipedes, and (5) millipedes.

Disruption of predators, prey, decomposers, and

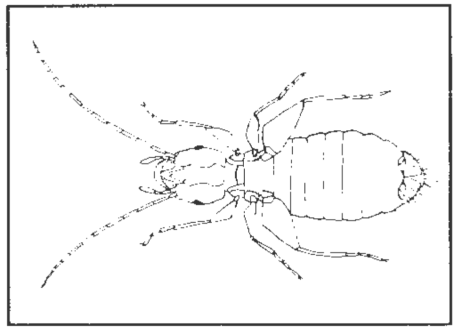


Figure 4. A psocoptera (bark lice) which was found in leaf litter.

other trophic levels may severely impact nutrient cycling, litter decomposition, seed dispersal, and plant growth and succession. Animals, both large

Continued on page 25

Environmental Significance of Historical Parks: A Study of Evolving Park Values

By Robert Manning and Marjorie Smith

It has been traditional to think about national parks and equivalent reserves in terms of basic "types" or "categories" of parks. Classically we tend to label parks as "natural," "historical" or "cultural," and "recreational." These labels are based on what are viewed as the park's most significant resource or value. But is this the way visitors view parks? Do park values evolve in the minds of visitors? Can parks serve multiple values? We explored these questions in a study of visitors to Roosevelt Campobello International Park.

The Study

Roosevelt Campobello International Park is located on Campobello Island, New Brunswick, Canada. The park was created to commemorate U.S. President Franklin D. Roosevelt. The original and traditional focus of the park is the historic Roosevelt family cottage. Created in 1964 by international treaty, the park was initially comprised of the Roosevelt Cottage and the surrounding 10 acres of grounds. However, over the years the park has acquired nearly 3,000 acres of surrounding lands, which include a variety of fine inland and coastal ecosystems.

Under terms of the treaty creating the park, the Roosevelt Campobello International Park Commission requested technical assistance in park planning and management from the U.S. National Park Service. Accordingly, a survey of park visitors was conducted under the auspices of the North Atlantic Region in the summer and fall of 1989. Park visitors were sampled on 10 randomly selected days.

Sampling consisted of contacting 1,000 randomly selected visitors and soliciting their participation in the study. Names and addresses of visitors were collected and participants were mailed a mail-back questionnaire upon their return home. Using two follow-up mailings, we attained a response rate of 90.2 percent – 902 completed questionnaires. Questions concerned visitor characteristics and their opinions and attitudes about selected park management issues.

Findings

Several findings relate to the ways in which visitors value the park. First, respondents were asked directly whether they preferred that park management emphasis be placed (1) primarily on historical resources with natural resources of secondary importance, (2) primarily on natural resources with historical resources of secondary importance, or (3) equally on historical and natural resources. The vast majority (76.7%) preferred the third alternative, indicating that in the minds of most visitors the park clearly has evolved from a primarily historical site (as it was established initially to be) to a park with at least equal importance as a natural area.

Second, the activities in which visitors participate and that they rate as important indicate that park values in their eyes may be changing. The participatory activities now tend to be somewhat passive and oriented toward the park's historical values – the four most popular activities were touring the historic cottages, driving scenic roads, photography, and visiting the flower gardens. However, respondents also were asked to indicate which activities they considered most important for the park; that is, which should the park be sure to plan for. Considered in this context, the answers tended to place more active and environmentally-oriented activities higher on the priority list. While touring the historic cottages remained the most important activity, driving scenic roads and photography declined in relative importance. Instead, walking or hiking trails, picnicking, and nature study increased in importance.

Third, the age distribution of park visitors, and its apparent influence on park values, indicates that the public significance of the park may be evolving. The current visitor population is skewed heavily toward the older age categories. More than 60 percent of visitors are 50 years or older and nearly 40 percent are 60 or beyond. Most of these older visitors have direct knowledge and memories of Franklin Roosevelt and his importance in national and international affairs. Consequently, their attention tends to focus on the Roosevelt theme of the park – particularly the purely historical elements of this theme. However, younger visitors evidence a stronger orientation toward the park's natural and environmental resources. Also, they are interested in more active recreational pursuits which are focused on the environment.

For example, younger visitors hiked and beachcombed more often and toured flower gardens and viewed the orientation film less often than older visitors. Younger visitors also rated hiking, beachcombing, and bicycling as more important park activities than did older visitors, relegating historic cottage and flower garden tours to less important status. Younger visitors also visited the natural areas of the park more often and tended to favor more park management emphasis on natural resources. They were more strongly in favor of preserving the park's natural resources and less favorable about the management practice of vista clearing.

Greater interest in the natural aspects of the park on the part of younger visitors also may translate into somewhat less interest on their part in the traditional historic resources of the park. Younger visitors felt they learned less than older visitors about Franklin D. Roosevelt and his life on Campobello Island.

Conclusion

Roosevelt Campobello International Park originated as a traditional "historical" area. However, it appears to be evolving toward significant environmental and related recreational values as well. This is due to changes in the park itself, as it has expanded to surrounding natural areas, but it also is due to changes in the visitor population. The great majority of visitors recognize the significant natural resource base now contained within the park. Perhaps even more important as a management consideration is the evidence that a new generation of younger visitors is clearly more oriented toward this natural resource base than toward the traditional historical values of the park.

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Litter Arthropods *Continued from page 25*

and small, affect forest composition and regeneration by a multiplicity of interactions (Probst and Crow 1991). In total, it appears that arthropods and other invertebrates dominate the fauna of Yellowstone NP in terms of biomass, biological diversity, and ecosystem regulation. Thus, conservation of species – including arthropods and other invertebrates – is more than the saving of biodiversity. These organisms are vitally important in ecological process functions and need further study if our parks are to survive the increasing influx of humanity.

Christiansen is a post-doctoral researcher in the U/WVA Dept. of Forestry at Morgantown, WV; Lavigne and Lockwood are professors in the U/WY Dept. of Plant, Soil, and Insect Sciences, Laramie, WY. *This work was supported by U/WY's National Park Research Center.*

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Biomonitoring Techniques for Assessing Toxicity In National Park Waters

(Part I of Two Parts)

By Del Wayne Nimmo, John Karish, Terence Boyle, Nancy Hoefs, Mary Willox, and William Lamar

Throughout recent history, animal and plant species have served as indicators of environmental quality. For instance, fishery biologists have long associated the presence of robust populations of fish to good water quality in lakes and streams, and the presence of certain species of plants have been used to classify wetlands in the U.S. for special protection.

Recently, the decline of the delta smelt, *Hypomesus transpacificus*, populations has received much attention in San Francisco Bay, California, as an indicator of decreasing water quality. These examples are considered by scientists to be *biomonitors*. "Bi" or "bio" is derived from the Greek bios or mode of life, and "monitor" means to check, test, watch, or keep track of. In other words, biomonitoring is analogous to a thermostat, which senses and controls the temperature of a room. But instead of a mechanical device measuring temperature, living organisms are used to monitor or track the positive or negative changes in aquatic environments.

Prior to the mid-1970s, the EPA and predecessor agencies typically used technology-based and/or chemical-by-chemical approaches to regulate toxic pollutant and develop water quality standards in our nation's wastewaters (Karr 1991). A special group of toxic pollutants, representing only a small fraction of the substances found in the environment, were targeted. Consequently, this placed emphasis on both the constraints of the technology and/or the use of chemical analyses to ensure that the standards were being met. In many instances, even though water quality standards *were* being met, aquatic communities were not present. Standards did not take into account the direct effects of (1) combinations of various toxicants in the water, or (2) the interaction of physical characteristics of natural waters (i.e. pH, dissolved oxygen) with the toxicant(s).

It is these limitations, and a new emphasis on a key phrase in the Water Pollution Control Act of 1972 (and successive enactments) that prompted a change in national policy. In the enactments, the charge to "restore and maintain the physical, chemical, and biological integrity of the nation's waters," was translated into the popular axiom, "fishable [and] swimmable" to strengthen the emphasis on the biological underpinning of the law.

EPA has subsequently introduced biomonitoring in conjunction with, but not in place of, chemical analyses to regulate substances in wastewater (Federal Register 1984). Because living organisms are better indicators than individual chemical analyses in detecting the combined effects of chemical and physical factors in surface waters, this new focus has resulted in a savings of money, time, and resources in addressing complex water resource problems.

Management actions based on biomonitoring have resulted in the restoration and maintenance of the "biological integrity" or "community health" of waters and are more appropriate when used as the basis for detecting toxicity, protecting aquatic resources, and improving the overall water quality. As a result, mitigation has neither been under- nor over-protective of the water resources because the degree of treatment is based on the health of aquatic communities in streams or lakes rather than being based solely on the results of technology.

Lastly, biomonitoring can be used to assess the condition of surface waters due to other factors in a watershed, such as mining impacts (Nimmo et al. 1990), urbanization (Nimmo et al. 1991), or pesticides from agricultural runoff (Norberg-King et al. 1991).

Biomonitoring of surface waters can include both laboratory and/or field studies – bioassays and biosurveys respectively (Table 1). These studies, using bioindicators to assess the health of the aquatic environment, are better than traditional chemical sampling alone, because the living organisms directly reflect the integrated dynamics of the chemical, physical, and biological environment they inhabit.

Table 1. *Biological indicators used to assess the condition of a water resource to protect both human and aquatic health (Modified from Karr 1991).*

BIOASSAY – procedure of exposing test organisms, usually in a **laboratory setting**, to various concentrations of suspected toxicants or dilutions of whole effluent.

A. Single Species
(may involve selection of indicator species)
1. Tissue analysis for bioaccumulation
2. Biomarkers – genetics or physiology
3. Biomass/yield
4. Growth rates
5. Gross morphology (external or internal)
6. Behavior
7. Disease or parasitism frequency

BIOSURVEY – process of collecting a representative portion of the organisms **from the environment** *(in situ)* of interest to determine the characteristics of the aquatic community.

A. Single Species
(may involve selection of indicator species)
1. Tissue analysis for bioaccumulation
2. Biomarkers – genetics or physiology
3. Biomass/yield
4. Growth rates
5. Gross morphology (external or internal)
6. Behavior
7. Disease or parasitism frequency

B. Population/Community
(may involve indicator taxa or guilds)
1. Abundance/density
2. Variation in population size
3. Population age structure
4. Species richness/diversity
5. Relative abundances among species
6. Tolerants/intolerants
7. Abundance of opportunists
8. Dominant species
9. Community trophic structure

Bioassays, both acute and chronic (short and long term) use a variety of single species test organisms. The daphnid, *Ceriodaphnia dubia* (Fig. 1), is a common crustacean found in lakes and ponds throughout the U.S., and when maintained in the laboratory, will reach maturity and reproduce in just 4 days. The survival or reproduction rates (test endpoints) of the daphnids directly reflect the quality of the water in which they are maintained. The number of young produced over a 7-day period in water from a study site then are compared to those produced in a control water known to be free of toxicants. Fewer young are produced when toxicants are present, and when toxicants are high, the test organism will die. Growth rates of larval fathead minnows, *Pimephales promelas* (Fig. 2), also reflect the integrity or health of their environment. If they are exposed to toxic water, the fish will not grow normally or may show signs of stress; again, if concentrations of the toxicant are high enough, they – like the daphnids – will die.

Figure 1. *A mature daphnid,* Ceriodaphnia dubia. *Actual size approximately 2mm.*

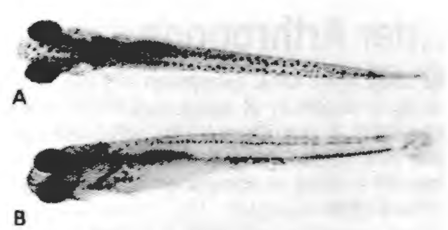

Figure 2. *Larval fathead minnow,* Pimephales promelas. *A is a dorsal view; B is a ventral-lateral view. Actual size is approximately 9mm in length.*

Alterations in feeding behavior of an organism occur as a result of environmental conditions. When the amphipod, *Hyalela azteca*, is exposed to test water, either in the laboratory or *in situ* (in the field), the amount of leaf material it consumes is an indi-

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Living Organisms as Environmental Indicators *Continued from page 26*

cator of the water's quality (Nimmo, unpub. mss.). Plants such as the grass seed, *Echinochloa crus-galli*, also are used as biomonitors. Germination success and growth rates of seedlings are altered when exposed to toxic water (Walsh et al. 1991). Again, if the water is toxic, the seeds will not germinate or grow as well as in the control water.

Biosurveys of various community and population attributes are used to assess the health of the environment (Table 1). These studies involve the collection of an assemblage of organisms and populations that occur together and interact with one another in their aquatic environment. Density of organisms, the total number of taxa present, the number of pollution-sensitive taxa present, and calculations of community diversity are commonly used by state and federal agencies. Indices such as the Index of Biotic Integrity and the Invertebrate Community Index combine these and other individual fish and macroinvertebrate community and population attributes such as species richness, relative abundances of specific tolerant or intolerant populations, and opportunistic or dominant species, to reflect the prevailing health of the aquatic environment.

A study of Wilson's Creek National Battlefield, Missouri (WICR) demonstrated the use of both biosurveys and bioassays in identifying impacts from nonpoint sources within the Wilson's Creek watershed. Initial biomonitoring conducted on 4 separate occasions in 1988 and 1989 within the battlefield, included macroinvertebrate and fish population and community surveys. Results indicated that macroinvertebrates in Wilson's Creek were conspicuously low in number or absent altogether. The number of pollution-sensitive EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa expected in a typical Ozark stream is between 18 and 22 (Dieffenbach and Ryck 1976); however, only 8 EPT taxa were found in Wilson's Creek.

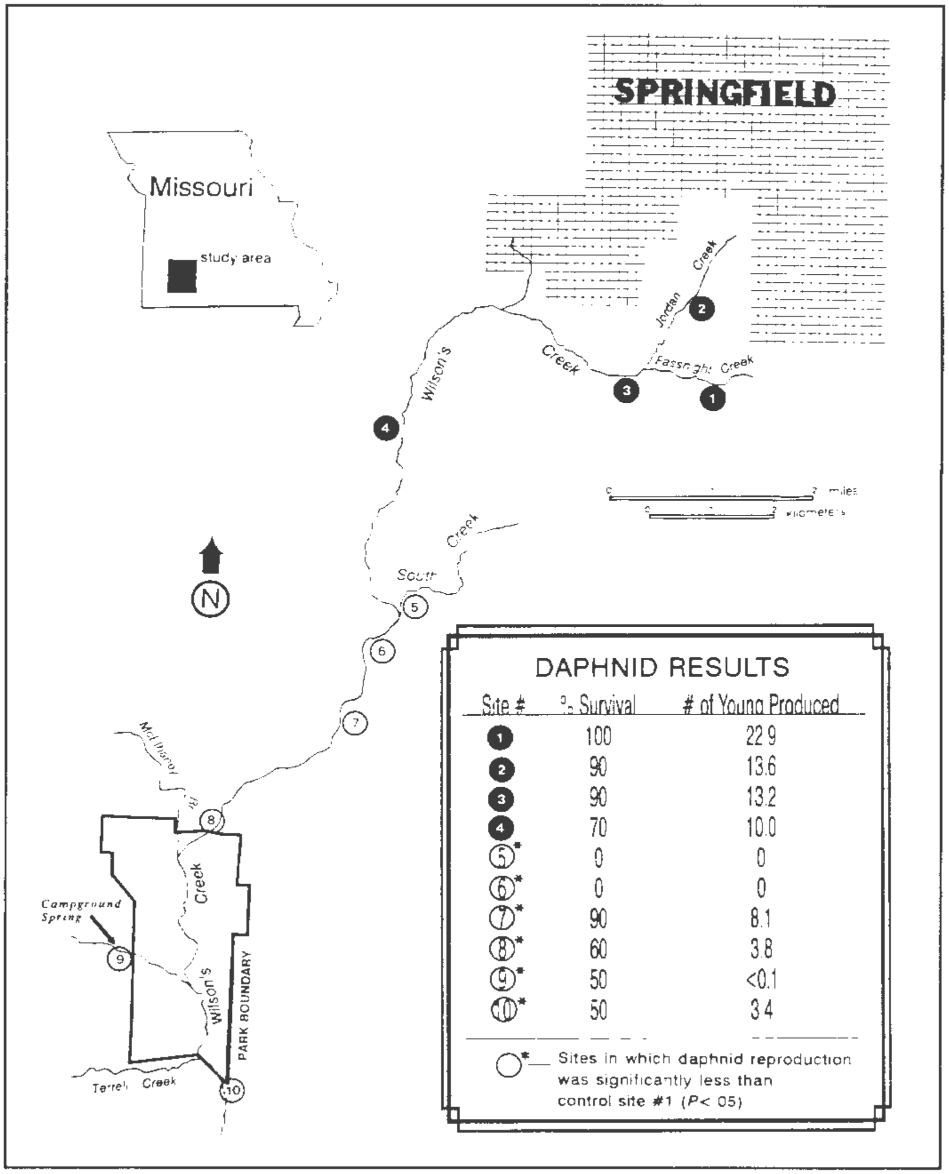
Plecoptera, considered extremely sensitive to organic enrichment and heavy metal pollution (Surdick and Gaufin 1978) were conspicuously low in numbers or absent from collections. Species diversity also was lower than expected for an Ozark stream. Diversity values, measured using Shannon *H'*, ranged from 0.89 to 2.53, unlike a pristine stream in the region where values greater than 3 would be expected (K.W. Stewart, U TX, pers. comm.). Fish community biosurveys indicated the relative percent of pollution tolerant species found in Wilson's Creek was markedly higher than in the reference streams within the region, and pollution intolerant species were depleted or missing. The number of percids (darters) and centrarchids (sunfish), including both smallmouth, *Micropterus dolomieui*, and largemouth bass, *M. salmoides*, found in Wilson's Creek also were fewer than would be expected in the region.

These findings prompted additional biomonitoring studies involving single species bioassays with daphnids. Results of these bioassays, done in the fall of 1989, indicated that several tributaries and segments of the creek, both inside and outside the park (Sites 5-10, Fig. 3), were chronically toxic, significantly different from control site #1 ($P < 0.05$). Two conclusions derived from the bioassay were (1) that whatever affected the macroinvertebrate and fish communities apparently was toxic to daphnids, and (2) that toxicity could have been enhanced by severe drought conditions that concentrated toxicants from a variety of sources in the drainage.

Additional bioassays of the Wilson's Creek watershed were conducted approximately 18 months later (May 1991) under normal precipitation conditions. Toxic conditions again were identified at site 6 (Fig. 3) using single species bioassays with daphnids. In sum, the result of the Wilson's Creek biomonitoring studies indicated that the biological health of Wilson's Creek was being impacted from nonpoint sources. As a result, special techniques referred to as Toxicity Identification Evaluation (TIE) procedures (Norberg-King et al. 1991) were used on water collected from site 6 to (1) identify the physical/chemical characteristics of the toxicant(s) and (2) determine the appropriate analytical techniques to verify the toxicants responsible.

We are convinced that the use of biomonitoring is valuable for assessing the biological integrity/health of waters that travel through our national parks. After 3 years of conducting such studies in 4 additional parks, we agree with Hester (1991), who stated, "many of the issues parks face are the same issues the nation faces . . . often actions many miles away that pollute water or air will affect parks downstream or downwind." We believe that incorporation of biomonitoring into resource inventory and monitoring programs is needed to assure the health of the aquatic resources within our National Riverways and Parks.

Continued on page 28



Site #	% Survival	# of Young Produced
1	100	22.9
2	90	13.6
3	90	13.2
4	70	10.0
5*	0	0
6*	0	0
7*	90	8.1
8*	60	3.8
9*	50	<0.1
10*	50	3.4

Figure 3. *Biomonitoring sites along Wilson's Creek, MO, fall 1989. The table depicts the results of a chronic 7 day single species bioassay using the test species* Ceriodaphnia dubia. *Percent survival refers to young daphnids that survived, matured, and produced young within 7 days. The number of young produced is the average reproduction rate of adult female daphnids within 7 days.*

NPS Publishing Program

From Donna O'Leary, NPS Publications Coordinator, comes word that NPS Associate Director for Natural Resources F. Eugene Hester has signed an Interagency Agreement with the USFWS to provide publishing services for the NPS Scientific Monographs and the Transactions and Proceedings series.

Dr. Paul Opler, managing editor, editing section, USFWS Office of Information Transfer, already has contacted many of those asked to serve as reviewers for a proposed monograph and two proceedings. (An announcement will appear in *Park Science* when these publications are available.)

On June 1, Dr. Paul Vohs, also with the USFWS, began serving as a subject editor on NPS manuscripts and contacting other NPS scientists to serve as reviewers. Dr. Vohs has a bachelor degree in agriculture and a master and doctorate in zoology. Dr. Hester has provided two support positions for NPS manuscripts, duty-stationed with USFWS in Fort Collins. The NPS technical publications writer-editor is Jerry Cox. Cox has a bachelor degree in geology and a master in technical communication. He will be contacting authors.

The second position, for an editorial assistant, has not yet been filled. O'Leary expressed appreciation to NPS authors for working with the USFWS on NPS manuscripts and asked that any questions be addressed to her at (303) 969-2156.

*Although the **Natural Resources Publication Management Handbook** has been out for several months, a brief summary of natural resource series that are available for disseminating information on natural resource topics is presented in Table I. The first three series are published only at the national level; the other three are available at the national and regional levels.*

Table 2 presents the major requirements for regional series. Regions currently are in the process of meeting regional requirements.

***Table 2.** Major Requirements for Regional Natural Resources Publication Series*

Regional Series*	Approval Authority	Review Procedures	Manuscript and Production Requirements	Management and Printing Authorities	Dissemination

1. Science Reports** (Annual)
2. Technical Reports
3. Natural Resources Reports
	USDI/NPS Approval (550A/550 forms)
	
	Regional Chief Scientist
		- Formal step-by-step review and approval procedures to ensure technical quality and accuracy and consideration of NPS policy and sensitive issues
		- Minimum of two peer (colleagues) reviewers w/subject-area expertise for Technical Reports and w/subject-area/managerial expertise for Natural Resources Reports
			Handbook, Chapter 5
			- Style Manuals
			- Numbering Systems
			  - One series numbering system each/series
			  - NPS reference number (Technical Information Center)
			- Standard Information
			  - Cover, inside cover, title page, inside back cover
			- References
				Handbook, Chapter 6
				- Printing/Duplicating Regulations
				- Specific Policies (ink color, paper, etc.)
				- Typesetting
				- Reprints
				- Public Domain
				- Copyright Issues
					Handbook, Chapter 7
					- 1 copy to WASO Coordinator (for filing at Technical Information Center)
					- 11 copies or 1 copy and $20 to National Technical Information Service

* Refer to previous table for content of these three series.
**Regional Chief Scientist review/approval only.

Note: Refer to *Natural Resources Publication Management Handbook* (USDI, NPS 1991).
Refer to Handbook, Chapter 1:1-2 for listing of authorities, laws, regulations, and references.

Biomonitoring Techniques

Continued from page 27

Nimmo is an aquatic toxicologist, Boyle is a research ecologist, Hoefs is a researcher, and Willox is a technician, all with the NPS Water Quality Division in Fort Collins, CO; Karish is Chief Scientist of the NPS Mid-Atlantic Region; Lamar is a resource management specialist at Wilson's Creek.

Details of additional biomonitoring studies in 4 additional parks will be discussed in the next issue of *Park Science* and both articles will be published together as an upcoming WRD (Water Resources Division) Technical Series report.

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Gets Interagency Support

Table 1. National Natural Resources Publication Series

National Series	Content	Audience	Planning Process	Review Procedures
1. Scientific Monographs Published only at National Level	Biological, physical, and social science research of significant natural resources; research of scholarly quality	Scientists Resource Managers w/technical background Educated Lay Public	Submit Proposal Form Call for Proposals from Regional Chief Scientist July	Regional Chief Scientist approval NPS/FWS Interagency Agreement - FWS Subject Editor/Referee - Provides subject edit - Conducts review - Anonymous Reviewers - Minimum one NPS Reviewer/ms - ADNR Reviewer/ms
2. Transactions and Proceedings Published only at National Level	Compilations of papers given at NPS conferences and symposia on scientific research conducted in units of national park system	Scientists Resource Managers w/technical background Educated Lay Public	Submit Proposal Form Call for Proposals from Regional Chief Scientist July	Regional Chief Scientist approval NPS/FWS Interagency Agreement - FWS Subject Editor/Referee - Provides subject edit - Conducts review - Anonymous Reviewers - Minimum one NPS Reviewer/ms - ADNR Reviewer/ms
3. Park Science Bulletins Published only at National Level	Resource management problem case studies and research, feature articles, short articles of interest to scientists and resource managers, regional highlights and calendar activities, information crossfile, and regional publications round-up	Superintendents Resource Managers Scientists Technical and Nontechnical Personnel Interpreters Lay Public	Deadlines: Handbook, Chapter 3:18	- Superintendent and Regional Chief Scientist approve articles before submission - NPS Park Science Editorial Board review
4. Science Reports (Annual) Optional at Regional Level	Listing of each research project that was ongoing or completed during a given calendar year	Scientists Resource Managers Technical Personnel Superintendents Interpreters Educated Lay Public	Researchers enter data into data base Regional Chief Scientist administers data compilation and submits to Wildlife and Vegetation Division April	- Wildlife and Vegetation Division compiles data base from regions, coordinates review by regions, WASO divisions, and others, and produces report
5. Technical Reports Optional at Regional Level	Biological, physical, and social science research that address natural resources management issues; natural resources inventories and monitoring activities; scientific literature reviews; bibliographies; and peer (colleague) reviewed proceedings of technical workshops, conferences, and symposia	Scientists Resource Managers w/technical background Educated Lay Public	Submit Proposal Form Call for Proposals from Regional Chief Scientist July	- Regional Chief Scientist provides management review/approval & approves author's list of potential reviewers - WASO Coordinator conducts peer (colleague) review - Minimum of two colleagues - ADNR Reviewer/ms
6. Natural Resources Reports Optional at Regional Level	Information on technologies and resource management methods, "how to" resource management papers, peer (colleague) reviewed proceeding of resource management workshops and conferences, and natural resources program descriptions and resource action plans Popular articles are disseminated through yearly Highlights Report through this series.	Superintendents Resource Managers Scientists Technical and Nontechnical Personnel Interpreters Lay Public	Submit Proposal Form Call for Proposals from Regional Chief Scientist July	- Regional Chief Scientist provides management review/approval & approves author's list of potential reviewers - WASO Coordinator conducts peer (colleague) review - Minimum of two colleagues - ADNR Reviewer/ms

Water Rights and the National Park Service

By Owen R. Williams

Editor's Note: This is the first of a 2-part article by the Chief, Water Rights Branch, NPS Water Resources Division in Fort Collins, CO. The opinions expressed are those of the author and do not necessarily reflect those of the Dept. of the Interior or of the National Park Service.

The fundamental purpose of the NPS is defined in 16 U.S.C. #1 as follows:

...to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

This language is unequivocal and encompassing. It would appear that the land areas administered by the NPS are, by virtue of their designation, protected from impairment and that, reasonably, similar protection is afforded to streams, rivers, lakes, and other bodies of water. While land areas do enjoy this protection, water bodies in western NPS units do not enjoy the same guarantees.

This arises from the way state law treats water. In eastern states the use of water is governed by the Doctrine of Riparian Rights, which was largely imported from Great Britain with the settlement of the New World. The right to use of water is based on ownership of land adjacent to water bodies and the "reasonableness" of the use. In contrast, western states embrace the Doctrine of Prior Appropriation. In this doctrine the right to use water is based upon its diversion out of its natural course for "beneficial use" and priority in use as determined by tim of first use.

What follows is a description of western water law and its relationship to NPS mandates.

The Nature of Western Water Law

Congressional Silence: Congress encouraged settlement of the western frontier with a series of Acts such as the Homestead Act of 1862, the Act of May 10, 1872 (U.S.Mining Laws) and the Desert Land Act of 1887. With the settlement of these largely semi-arid lands, there arose conflicts over the right to use the limited supply of water. These conflicts were settled largely through local custom, which emphasized the interests of commerce and seniority of use.

Custom grew into law over time, in part because Congress was silent with regard to the law that would govern the use of water on lands of the Public Domain. As local customs were codified into statutes in the several western states, remarkably similar laws resulted. There were differences, of course, but these were mostly related to specifics.

Roots of State Water Law: The body of water law embraced in the west grew largely out of the necessities of mining and farming. The first and most fundamental principle of this law was the idea that the citizens of the state held an inherent right to take and use water. So fundamental was this principle that it was even incorporated into some state constitutions.

The next important principle underpinning western water law was found in the tenet that the person to **first** take and beneficially use water derived a better right as against all persons to do so later in time. It is easy to see this idea evolving quickly out of the frenetic activity surrounding development of gold camps as the west's mineral riches were unearthed. This principle gave rise to the doctrine's common sobriquet, "First in Time, First in Right."

As irrigation farming took hold, the Doctrine of Prior Appropriation continued to evolve and proved especially adaptable to the needs of rapid agricultural and municipal growth. It rewarded the "old guard" who had first arrived to lay claim to land and water, and it penalized newcomers with failed crops during years of drought. Of course this changed when the newcomers added money to the recipe. With capital in hand, they could buy their way to the "front of the line."

Elements of State Water Law: Prior Appropriation varies a little from state to state, but certain elements of the doctrine are shared by all states that embrace it. Specifically:

- Persons have the right to appropriate and use water through an act to divert and apply it to beneficial use;
- The only uses deemed beneficial are those specified by the state, usually in statute;
- Once made, an appropriation creates a right to the **use** of water, not to the **corpus** (body) of the water; and
- The right enjoys as its priority the date upon which appropriation was made (in some cases—application for permission to appropriate) and is superior to subsequent and inferior to prior appropriations.

The right is a property right, which may be sold without loss of priority. However, if sold, the amount of diversion that can be transferred is limited to the original appropriation and is further limited to that amount **actually** used beneficially. The type of beneficial use and its location may be changed, and so too, the location of the point of diversion. However, all transfers are conditioned with the proviso of no injury to other appropriators (senior **and** junior).

The right is not without its frailties. It can be forfeited if not beneficially used for a period of time specified in statute. Further, while a water right attaches to a quantity, a time of use, and a purpose, it generally does not guarantee any particular quality of water.

Water may be stored by an appropriator when abundant, for delivery during those times of shortage when the appropriator's junior priority would otherwise preclude diversion. However, a right to store does not create a right to divert, and vice versa.

Federal Enclaves: While Congress was ignoring the developing western water law, it continued to encourage settlement and sought to "pacify" the Indian. It attempted to change nomadic behavior into settled agrarian by "placing" tribes on reservations. "Reservations" also were created from the Public Domain for other federal purposes. This led to designations of areas as Forest Reserves, military Reservations, Power Site Withdrawals, and eventually Parks and Monuments.

Thus, with the passage of time, a complex pattern of land ownership evolved with particular parcels, or Federal Enclaves, being set aside and designated for specified Congressional or Proclamation purposes. Most of these areas also needed water, and a tension with accepted state water law soon developed.

The manner by which this tension was resolved and the long-term consequences to NPS management will be discussed in the conclusion of this article in the next issue of ***Park Science***.

NPS Coordinates Study Of Proposed Water Diversions In Nevada

The NPS Water Resources Division has undertaken coordination of technical efforts by NPS, the USFWS, BLM, and the Bureau of Indian Affairs (hereafter referred to as "the bureaus") to conduct hydrologic studies related to water rights applications filed by the Las Vegas Valley Water District (LVVWD) in Nevada. If approved, LVVWD's applications for additional water for the growing city of Las Vegas would allow water diversions from 4 counties in east central and southern Nevada and from as far as 200 miles from Las Vegas.

The water would be diverted primarily from aquifers in the carbonate rock province, which encompasses local, intermediate, and extensive regional groundwater flow systems. Groundwater flow systems in the province feed springs, streams, and lakes; yield water to wells; and support threatened and endangered species, vegetation, wildlife, fish, wild horses and burros, recreation, and other resources of concern to the Bureaus.

The NPS filed 130 protests with the Nevada State Engineer's office because of possible effects in Death Valley National Monument (DEVA), Lake Mead National Recreation Area (LAME), and Great Basin National Park (GRBA). Both DEVA and LAME contain springs that are fed by regional groundwater flow systems that could be tapped by LVVWD. At GRBA, water for adminstrative and visitor facilities could be threatened.

A project of this magnitude will require considerable study and preparation to examine adequately the potential effects. The USGS's Nevada District Office, is providing technical assistance to the Bureaus. In addition, a private consulting firm has been contracted to assess potential effects on Bureau water rights and water resources and to assist the Bureaus in preparing for and participating in State water right hearings and discussions with LVVWD. Assessments will require the use of ground water flow models of various scales to examine potential effects to Bureau water rights and resources associated with the groundwater flow systems.

By adequate preparation and participation in the State's administrative proceedings, the NPS is afforded the best prospect for ensuring that its water rights and related resources will be protected.

Alice E. Johns, *Hydrologist, Water Rights Branch NPS Water Resources Division, Fort Collins, CO*

Biocontrol Recognized as a Management Approach To Control Plant Aliens in Protected Natural Areas

By Donald Gardner and Clifford Smith

The VIII International Symposium on Biological Control of Weeds was held Feb. 1-7, 1992 at Lincoln University, Canterbury, New Zealand; in attendance were several biocontrol practitioners from Hawaii. Because of the many disruptive introduced species present in Hawaii and the vulnerability of island ecosystems to alien encroachment (Mueller-Dombois and Loope 1990), Hawaii is a uniquely important region for biocontrol research and its application.

The symposium included 68 formal paper and poster presentations on weed biocontrol with insect agents, 32 with plant disease agents through the classical approach, 26 on theory and general application of biocontrol, and 5 on biocontrol with mycoherbicides.

The number of presentations on plant pathogens, both in classical and bioherbicide applications, is evidence of the growing emphasis on the use of plant diseases in weed control. The science of biocontrol had its development largely in the field of entomology, with potentially effective disease agents sometimes overlooked. However, plant pathogens, particularly certain groups of fungi such as the rusts, are frequently highly host specific and sufficiently virulent to offer promise as biocontrol agents. The production of resistant spores by certain pathogenic fungi enables development of mycoherbicides, consisting of mass-produced fungal propagules combined with an inert carrier and applied to weed infestations in much the same manner as are chemical herbicides. Success in the development and registration of mycoherbicides as commercial products was reported at the New Zealand symposium.

Whereas traditionally biocontrol falls within the purview of agriculture, it is particularly significant that the New Zealand symposium included a section on biocontrol of weeds in protected natural areas. National Parks with alien plant problems are turning increasingly to biocontrol as an alternative to the conventional approaches of mechanical removal or use of chemical herbicides (Gardner 1990). In fact, weed invasion is so severe in some parks, such as those of Hawaii and New Zealand, that resource managers look to biocontrol as the only feasible solution to degradation of native habitats by certain widespread weeds.

Classical biocontrol, the approach currently applicable to most alien plant problems in natural areas, involves introduction of foreign insects or pathogens, after pre-release testing has shown their host specificity and virulence to be suitable for biocontrol. Symposium discussions indicated that weed biocontrol in national parks of other countries, such as New Zealand, is currently hampered by policy prohibiting introduction of alien organisms into natural areas for any purpose, including biocontrol. According to one paper, government solicitors in New Zealand are investigating the possibility of obtaining a policy exception to allow introduction of foreign biocontrol agents to these areas.

U.S. NPS policy, while generally prohibiting introduction of alien species, recognizes biocontrol as an acceptable approach and already permits exceptions to the policy for this purpose (U.S.D.I. NPS 1988). The operation of a foreign insect quarantine facility by Hawaii Volcanoes NP (Gardner and Smith 1985) indicates the growing commitment of NPS to act directly in addressing weed problems of concern in natural areas. The NPS biocontrol program in Hawaii represents a significant departure from the usual practice of land managing agencies of borrowing biocontrol approaches already developed primarily for agricultural applications.

. . . the fact that this topic was selected at all for discussion represents an important upward step in environmental awareness at biocontrol meetings.

The New Zealand symposium provided expression to an international audience of the NPS commitment to alien species control for preservation of natural areas. Likewise, we became aware of biocontrol research directed at weed problems similar to ours elsewhere, and were able to make personal acquaintance with the scientists doing the work. Several research programs in Europe, Africa, and South America had direct bearing on high priority Hawaiian weed problems, as well as those in protected natural areas of the continental U.S., such as with tansy ragwort (*Senecio jacobaea*) and paperbark tree (*Melaleuca quinquenervia*).

Biocontrol, because of the alien origins of target species, depends on national and international contact and cooperation perhaps to a greater extent than does other NPS-sponsored research. As illustration, NPS scientists and those working on behalf of Hawaiian parks and other natural areas have established cooperative relationships with scientists in Brazil, Venezuela, Chile, Colombia, New Zealand, Portugal, Spain, and the United Kingdom. They also have corresponded with researchers in India, Britain, Australia, Ecuador, and Peru and in other states and territories of the U.S. concerning biocontrol possibilities.

Some invasive weeds, such as gorse (*Ulex europaeus*), are widespread problems and provide researchers opportunities to cooperate on an international basis in progressive biocontrol programs against this species. Gorse biocontrol research consequently shows perhaps the most promise of the several projects currently under investigation in the Hawaii Volcanoes NP quarantine facility.

Aside from the biological factors influencing the success of biocontrol (i.e., availability of suitable agents), political considerations, those involving conflicting purposes among various interests, are a major concern. For example, several alien species of grass are disruptive invaders of native ecosystems in Hawaii and would be candidates for biocontrol, but the grasses also are valued pasture species. Furthermore, because of perceived threats to sugarcane, Hawaii's most important crop, targeting of any grass for biocontrol is not currently practical.

Presentations at the New Zealand symposium indicated that the opposite situation also occurs; biocontrol agents are host-range screened for their effects on economic species, but often little attention has been given to their possible detrimental effects on native species. Significantly, this was the subject of an evening workshop titled "Should we use agents that attack native and other non-target plants?" Some participants stressed economic profitability as the only important consideration to biocontrol application, whereas others were prepared to consider other values. Expanded host-range testing to satisfy environmental concerns was viewed as unnecessarily combersome by many of the participants. While this position was disturbing, the fact that this topic was selected at all for discussion represents an important upward step in environmental awareness at biocontrol meetings.

Continued on back cover

Potential Threat to U.S. Prickly Pears

Cactoblastis cactorum is a phycitine moth that has been used with remarkable success as a biological control agent against prickly pear cacti, *Opuntia* spp., in Australia, the Caribbean, Hawaii, India, and South America. Solid stands of prickly pears have been reduced to a few stragglers in all these areas within a very short time. The moth whose larvae feed within the cladode (pad) often is cited as one of the best examples of effective biological control.

The moth was introduced to the Caribbean in 1957 to control the prickly pear on Nevis. Later it was taken to other islands but also dispersed naturally to areas such as Puerto Rico. Recently it was found in the Florida Keys and since has spread as far north as Key Biscayne.

There are many species of *Opuntia* in North America, where they form an important element of the flora of certain ecosystems, e.g., deserts. Some of these species now are quite rare. They already are attacked by native phytophagous insects. The introduction of *Cactoblastis*, however, is a very serious threat to the genus. Pesticides are only effective during the period when the larvae are penetrating the pads. Thereafter they are generally protected by the thick outer cuticle of the pad. A number of natural enemies of *Cactoblastis* are known, but their efficacy and host specificity need evaluation. It is unlikely that such a study will occur unless considerable pressure is brought to bear on state and federal agencies.

More detailed information on the insect and the problem can be had from Drs. D.H. Habeck and F.D. Bennett, Dept. of Entomology and Nematology, IFAS, Univ. of Florida, Gainesville 32511. Ask for Entomology Circular 333 – *Cactoblastis cactorum* Berg (Lepidoptera: Pyralidae), a Phycitine New to Florida.

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A controversial issue of particular relevance to NPS objectives is the direct targeting for biocontrol of native plants considered agricultural weeds in the continental U.S. Work under way against several such species was discussed in a paper by a USDA scientist. Whereas in the past native plant control efforts were perhaps of little concern, increasing public environmental awareness may soon call such practices into question. The USDA-Animal and Plant Health Inspection Service (APHIS:), which oversees U.S. biocontrol research, chairs the Technical Advisory Group (TAG). Through TAG, NPS representatives now have opportunity to review biocontrol proposals for environmental acceptability, thereby providing a healthy balance with economic interests.

A proposed reorganization of USDA-APHIS would establish the National Biological Control Institute, through which evaluation of biocontrol programs would be hastened by clearly stating the scope of host screening necessary for each proposal. Public review of proposed biocontrol projects through publication in the ***Federal Register*** also is under consideration.

Biocontrol clearly is assuming a new and more expanded role in weed management. As illustrated by the New Zealand symposium, this approach, while not without pitfalls, offers increasing promise for application in protected natural areas.

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In the Next Issue

Part 2 of "The use of biomonitoring techniques for assessing nonpoint sources of toxicity in NP waters" by Del Nimmo et al; Part 2 of "Water rights and the National Park Service" by Owen Williams; "Marine debris on NPS beaches: a plastic, glass, metal nightmare" by C. Andrew Cole; "Mercury threat to wildlife resources and human health in Everglades NP" by William Loftus and Oren Bass, Jr.; "Hemlock wooly adelgid threatens eastern hemlock in Shenandoah" by J. Keith Watson; a related article on the hemlock wooly adelgid from David Hayes at Roosevelt-Venderbilt NHS; "A GIS analysis of slope and land use in a portion of the Buffalo National River basin" by Tim Stephenson and David Mott," and, as the realtors like to say, "much, much more."