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U.S. Fish & Wildlife Service

ENDANGERED Species BULLETIN

Fall 2008 Volume 33, No.3

Family Ties

The U.S. Fish and Wildlife Service (Service) and the U.S. Geological Survey (USGS) have historic ties when it comes to research on threatened and endangered species. Many USGS scientists started their careers in the Service or other Department of the Interior agencies. Today, the USGS is a multidisciplinary science organization that weaves together research on biology, geography, geology, geospatial information, and water. It provides much of the best information available to meet the science needs required by the Endangered Species Act (ESA).

This special issue of the Endangered Species Bulletin was designed to reflect the range and nature of the research and conservation actions that the dynamic partnership between our two agencies has produced. For the Service to meet its responsibilities under the ESA, it must consider the many and complex factors that affect plants, animals, humans and the ecosystems in which we all live. To meet the broad mission of serving the Nation's natural science needs, USGS takes a multidisciplinary approach to study the threats that can affect endangered species. USGS researchers study disease, population dynamics, complex changes in habitat driven by climate, increased demands for water and other resources for human use, and interactions between invasive species and species-at-risk.

Meeting our shared missions has produced research that spans the Nation, and includes efforts to understand issues as diverse as the distribution of grizzly bears across the Yellowstone ecosystem to the genetics of fairy shrimp confined to a few vernal pools in California. Meeting the science information needs for endangered species in the timeframes required by the ESA in turn requires a long-term commitment to ecosystem-level research and monitoring as well as specialized research on individual species and habitats.

Cooperation over many years has provided the foundation for addressing the endangered species issues that are in today's headlines. Together, and with other public and private partners, the Service and USGS will continue to use science and the tools it provides to conserve and recover the Nation's precious heritage of biodiversity.

Mark D. Myers
Director, U.S. Geological Survey

H. Dale Hall
Director, U.S. Fish and Wildlife Service

ENDANGERED Species BULLETIN

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A green sea turtle is about to be tagged as scientists study the endangered animal's habitat in the greater Everglades ecosystem.
photo by Kristen M. Hart

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The Bulletin welcomes manuscripts on a wide range of topics related to endangered species. We are particularly interested in news about recovery actions and conservation partnerships.

Please send us your comments and ideas! E-mail them to us at esb@fws.gov.

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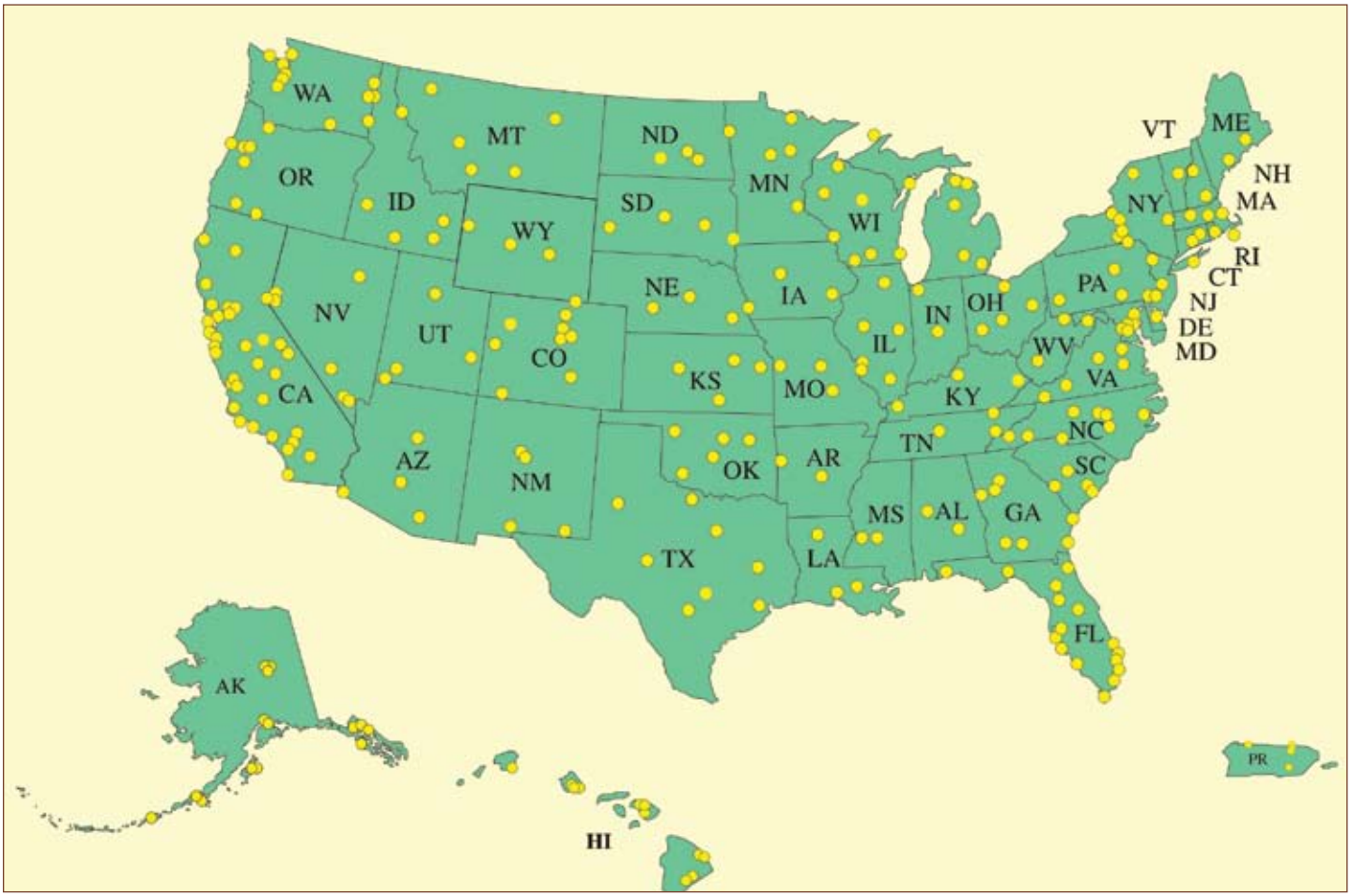
A Natural Connection: USGS and Endangered Species Research

by Rachel Muir and
J. Michael Scott

USGS
science for a changing world

The U.S. Geological Survey (USGS) is an independent science agency within the U.S. Department of the Interior (DOI). USGS scientists conduct research on diverse topics in geology, biology, water, and such earth hazards as earthquakes and volcanic eruptions. Many of our research issues are in the headlines, such as our studies of earthquakes and floods. Our research is also used to support decisions on the listing and recovery of animals and plants under the Endangered Species Act (ESA). USGS biologists provide scientific information to assist other agencies in conserving endangered species, based on a foundation of three strategies:

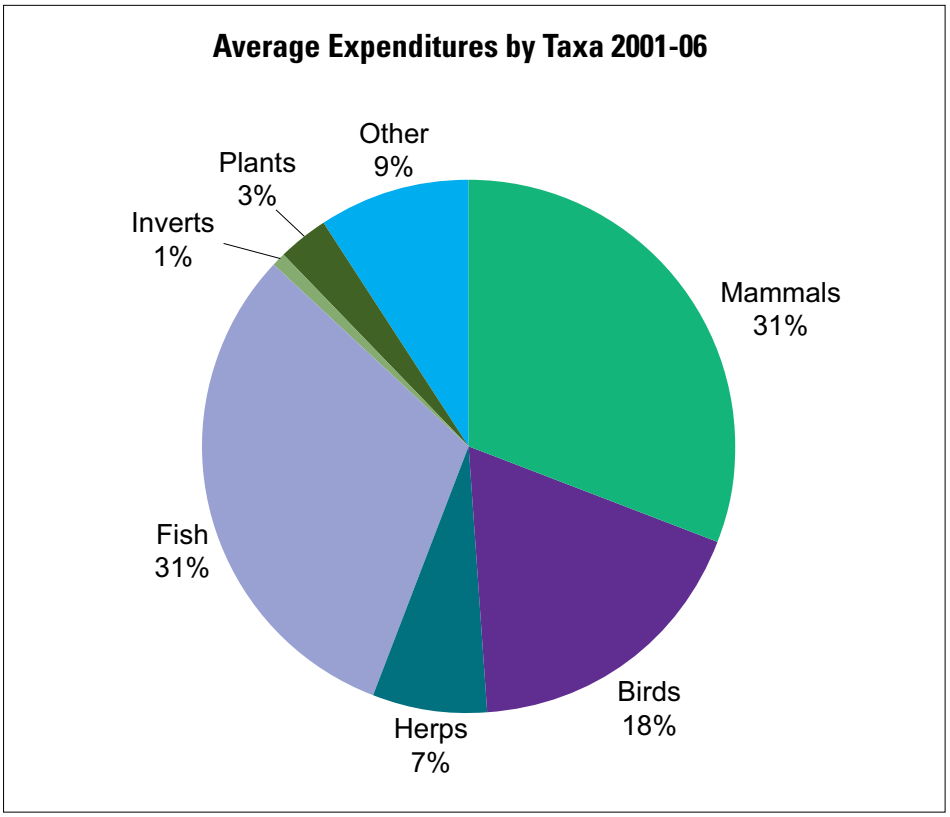


Location of major USGS Offices and Science Centers and Cooperative Research Units.

1. USGS provides peer-reviewed, independent, and unbiased science of the highest quality.

The USGS has no regulatory or land and water management responsibilities; our sole job is to provide quality science and data to our governmental and non-governmental partners and the public. The steps our agency takes to ensure the quality of our science and open access to our science products makes USGS a trusted resource for government and the public. Our work takes place in science centers, field stations, and Cooperative Fish and Wildlife Research Centers from Maine to Hawaii and American Samoa to Alaska. The USGS dedicated more than $14 million dollars to support research on listed species in 2007. It also conducts significant research on species proposed for listing and candidate species in support of the U.S. Fish and Wildlife Service and other partners.

Government agencies and the public have entrusted the USGS to provide unbiased science and data to inform difficult decisions regarding endangered species on listing, delisting, and habitat planning for charismatic species such as polar bears (*Ursus maritimus*), spotted owls (*Strix occidentalis*), and West Indian manatees (*Trichechus manatus*). However, we conduct research on lesser known species as well, such as the endangered Chiricahua leopard frog (*Lithobates chiricahuensis*), which is found only in the southwestern mountains of the U.S. and Mexico; Mead's milkweed (*Asclepias meadii*), a prairie plant of the central Midwest; and the elkhorn coral (*Acropora palmata*), a reef-building species of the Caribbean. The USGS funded research on more than 150 endangered and threatened species in 2007. Studying all the 1,343 species listed (as of July 23, 2008) as threatened or endangered under ESA would be a daunting task. However, in addition to our research targeted to specific endangered species, the USGS works to expand our knowledge regarding the ecosystems that endangered species and all species depend on. In this way, we are able to stretch our resources and develop the basic science that broadly informs endangered species conservation.



Percentage of expenditures for listed species by taxa, 2001-2006. Direct USGS expenditures per year during that period ranged from $11 million to $14 million.

2. USGS maintains long-standing interactions with the natural resource agencies that have responsibility for managing listed species and their habitats.

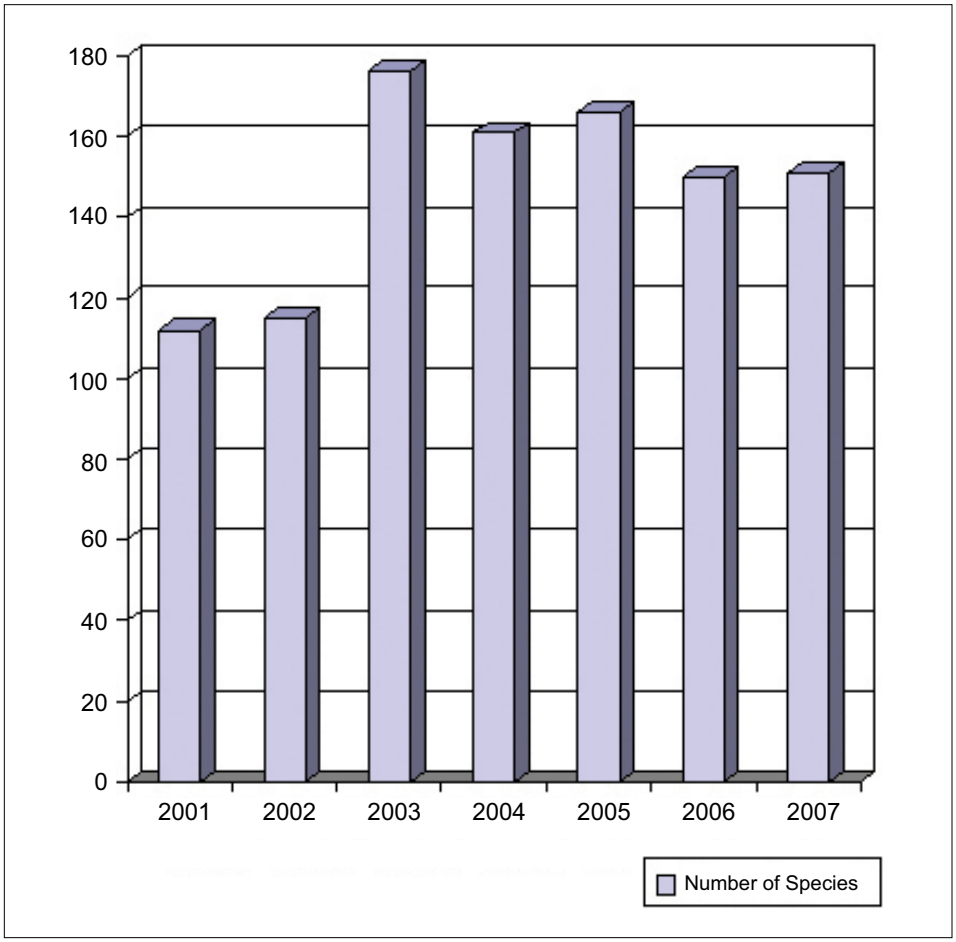
The USGS has a long-standing relationship with our sister agencies in DOI1. In fact, many of our researchers began their careers in the National Park Service, Fish and Wildlife Service, or Bureau of Land Management and came to the USGS through the consolidation of DOI research capabilities into the National Biological Survey (NBS). In 1994, the NBS changed from an independent agency to become the Biological Research Discipline of the USGS. Many of our offices and research facilities are located within national parks or other public lands, and many adjoin the offices of other federal agencies. We also work

closely with state and local partners in setting research priorities.

The ties of USGS scientists to endangered species research date back before passage of the ESA. Prior to 1973, future USGS scientists working at Fish and Wildlife Science Centers and Cooperative Research Units collaborated on recovery options for declining species, and accounts of their research are among the early papers published in the *Endangered Species Bulletin*[1]. Two of the scientists from these early research efforts, David Mech and Mike Scott, continue their work today as USGS scientists. Their stories, including their current research and continued links to our partners, are told below:

Dr. Mech, a mammalogist with the USGS Northern Prairie Wildlife Research Center, began studying wolves in 1958 and joined the Department of the Interior in 1969, prior to passage of the Endangered Species Act. Since then, the recovery of the gray wolf (*Canis lupus*) in the northern Rocky Mountain states and the upper Midwest has been one of the success stories of the ESA. In 1970, there were only about 650 gray wolves in the contiguous 48 states, and the Mexican wolf (*C. l. baileyi*) and the red wolf (*Canis rufus*) were nearly extinct in the wild. Since then, gray wolves have rebounded to the point that populations are estimated at over 4,000 in the upper Midwest and 2,000 in the northern Rocky Mountain region. Wild populations of the Mexican wolf in the southwest and red wolf in the Southeast have been reestablished. Mech attributes research success in large part to the cooperation of land management partners such as the National Park Service, Fish and Wildlife Service, and Forest Service. "Having parks and other public lands available had been a wonderful and key resource for our wolf research," he says, "and having the cooperation of agency resource managers has been one of the keys to recovery."

Dr. J. Michael Scott is another pioneer in endangered species research still active in USGS research activities. His early research was in the Hawaiian Islands, where he worked with the National Park Service and other federal and state agencies in conducting the Hawaii Forest Bird Survey. Their task was to determine the distribution, abundance, habitat associations, and status of Hawaiian forest birds. Results of that effort were used to establish Hakalau Forest National Wildlife Refuge.[2] Later, he served as leader of the California Condor Research Center, and today he is working with Fish and Wildlife Service biologists on recovering endangered species, assessing the biological diversity and health of the National Wildlife Refuge System, and studying the conservation status of species and ecosystems in a changing environment.



Number of species on which USGS conducted research (2001 through 2007).

3. The USGS research portfolio is principally landscape-based, multidisciplinary, and long-term.

The USGS contributes to understanding the status and trends of our Nation's imperiled species and other natural resources. Our research may be specifically targeted to a single question – such as, where and for how long does the endangered pallid sturgeon (*Scaphirhynchus albus*) live along the 2,341 miles (3,767 kilometers) of the Missouri River? – or toward more general science questions, such as how do migratory birds and native plants respond to climate change?

The USGS conducts landscape-level science because the science questions of today are large and complex. Many of the threats to species are not local impacts but the result of regional- or even global-scale habitat changes. The Breeding Bird Survey, a cooperative effort between USGS and the Canadian Wildlife Service's National Wildlife Research Centre, is one example of monitoring and research combined to address continental scale changes in wildlife populations (see http://www.pwrc.usgs.gov/BBS/). Nevertheless, research is still needed on "the basics," meaning the specific life history requirements, status and trends, and genetics of single species. The leadership of USGS scientists in the developing field of conservation genetics is of particular importance to endangered species conservation. Conservation genetics is a vital tool to identify species and subspecies and to evaluate the genetic diversity of populations of plants or animals, a key to their survivial[3].

The major USGS disciplines of Biology, Geography, Geology, and Water Resources address many of the basic information needs for where listed species occur, what threats they face, and how they can be protected in a landscape being transformed rapidly and directly by urbanization, or more gradually by climate change. Scientists of all the USGS disciplines are improving our capacity to integrate scientific expertise in our agency. Our new strategic plan, "Facing Tomorrow's Challenges – USGS Science in the Decade 2007-2017," identifies the big questions we face in preserving ecosystems, researching climate change, providing a scientific foundation for energy and water management and use, protecting human health, and assessing and anticipating the effects of natural hazards.

USGS

In 1969, Dr. David Mech began pioneering research on gray wolves. Here, in September 1970, he injects a young wolf using a syringe on a stick in preparation for attaching a radio collar.

Increasingly, the conservation of endangered species will hinge on an understanding of how ecosystems work and how they respond to changes in temperature patterns, land use, human and wildlife populations, disease, and invasive species. We are working to improve the information and models we use to predict changes in habitat and wildlife populations. Endangered species research needs will be met through multi-disciplinary programs such as the USGS Global Climate Change Research Program http://geochange.er.usgs.gov/. However, we will continue supporting endangered species-related research through programs such as the Science Support Program (http://biology.usgs.gov/ssp/), and the Gap Analysis Program (http://gapanalysis.nbii.gov/portal/server.ptto).

Independent quality science, partnerships, and large-scale/long-term research will continue to guide our research and monitoring efforts in support of our conservation partners. Our basic and applied science supports the Nation's ability to anticipate large scale change in ecosystems and help prevent the loss of animal and plant species that might result from such changes.

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[1]*Endangered Species Technical Bulletin*, 1977, Vol. 2. No.11, pp. 6-9. "Patuxent's Endangered Wildlife Research Program."

[2]*Endangered Species Technical Bulletin*, 1976, Vol. 1, No. 5, Special Insert, pp.1-4. "Recovery Efforts Intensifies to Save Hawaii's Endangered Wildlife."

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by Kathryn McEachern

Recovering Endemic Plants of the Channel Islands

At the California Channel Islands, off the state's southern coast, cold waters from the north mix with warmer waters from the south. Each of the eight Channel Islands, which were never connected to the mainland, developed unique floras as colonizing plants adapted to their new island homes. This part of California is one of only five Mediterranean climate regions in the world, characterized by hot, dry summers and cool, wet winters. Thus, the islands support a truly unusual assemblage of plants and animals found nowhere else.

The northern five islands comprise Channel Islands National Park, established by Congress in 1980. Programs to protect the islands' flora and fauna and

K. Chess/USGS

***Santa Cruz Island live-forever* (Dudleya nesiotica)**

Taxon	Status*	Total populations	Islands**
Herbaceous Annuals			
Hoffmanns's slender-flowered gilia *(Gilia tenuiflora* ssp. *hoffmannii)*	E	2	SRI
Santa Cruz Island chicory *(Malacothrix indecora)*	E	6	SCI, SRI, SMI
Island malacothrix *(Malacothrix squalida)*	E	1	SCI
Island phacelia *(Phacelia insularis* var. *insularis)*	E	1	SRI, SMI
Santa Cruz Island lace pod *(Thysanocarpus conchuliferus)*	E	8	SCI
Herbaceous Perennials			
Hoffmann's rock cress *(Arabis hoffmannii)*	E	5	SCI, SRI, (AI)
Succulent Perennials			
Santa Cruz Island live-forever *(Dudleya nesiotica)*	T	1	SCI
Santa Barbara Island live-forever *(Dudleya traskiae)*	E	10	SBI
Small Shrubs			
Soft-leaved paintbrush *(Castilleja mollis)*	E	2	SRI
Sea-cliff bedstraw *(Galium buxifolium)*	E	8	SCI, SMI, (SRI)
Island rushrose *(Helianthemum greenei)*	T	36	SCI, SRI, SCT
Full Shrubs			
Santa Rosa Island manzanita *(Arctostaphylos confertiflora)*	E	3	SRI
Island barberry *(Berberis pinnata* ssp. *insularis)*	E	5	SCI, (AI , SRI)
Santa Cruz Island bush mallow *(Malacothamnus fasciculatus* var. *nesioticus)*	E	4	SCI

* T means threatened; E means endangered.
** AI = Anacapa Island, SBI = Santa Barbara Island, SCI = Santa Cruz Island, SCT = Santa Catalina Island, SMI = San Miguel Island, SRI = Santa Rosa Island; parentheses () indicate presumed extirpated.

Table 1. Listed plants of Channel Islands National Park

restore habitat damage caused by earlier management began shortly after the park's creation. The park islands support 75 endemic plant taxa, 14 of which are listed as threatened or endangered under the Endangered Species Act.

From the beginning, the restoration of the Channel Islands was a daunting task. For about 150 years, these islands had been used for ranching, and large areas of native scrub and woodland were converted to stands of non-native annual grasses. An important first step was the removal of non-native grazing animals from the islands. This task, nearly complete, is a major step toward ecosystem recovery.

K. Chess/USGS

***Santa Cruz Island lace pod* (Thysanocarpus conchuliferus)**

For the last decade, U.S. Geological Survey (USGS) research has focused on gaining the scientific knowledge needed for recovering the listed plant taxa, searching for remaining populations, sampling their habitats, monitoring population changes and distribution, and conducting recovery experiments. Our research approach has asked three basic questions:

- Where are the listed plants found now?
- How are their populations doing?
- Are there threats that we can identify and do something about?

We use the answers to develop recovery actions, along with our partners in management, the National Park Service, the Santa Barbara Botanic Garden, the University of California Reserve System, the U.S. Fish and Wildlife Service, and The Nature Conservancy.

The 14 listed plant taxa span a range of life histories, from tiny annuals that complete their life in one year to slow-growing shrubs that can live for decades (Table 1). Although they differ vastly in stature and longevity, they have all had to contend with the same environmental challenges. For example, each of the listed taxa evolved in response to a particular suite of environmental factors that made them successful at reproducing in the unique conditions found on the Channel Island environments. The ranching that had been practiced for decades before establishment of the park changed their ecosystems, reducing their populations and restricting them to a few small patches of the specialized habitat.

The largest native mammal on the islands is an endemic fox, so the island endemic plants did not evolve mechanisms for coping with the grazing and trampling of large grazing animals. Invasive plants, intentionally introduced for forage and crops or accidentally brought to the islands, became widespread. Most of the endemic plants were unable to cope with the combination of grazing impacts and aggressive invasive species, and these natives became trapped in ever-shrinking habitats. Ultimately, they became endangered because they were reduced to a very low number of populations with only a few plants each, isolated from one another and from unoccupied but otherwise good patches of habitat.

Almost all of these endangered plants grow best in shaded locations, or in places with substantial amounts of fog, such as coastal bluffs or terraces. Climate change is shifting these moisture patterns, with the result that a few of the endangered taxa are not able to reproduce as well as before. The effects of these ecological changes – grazing, invasive species, and climate change – can be seen in the listed plants today. However, our monitoring and research results are showing us ways to help them recover, now that non-native animals are being taken off the islands and we have begun to control invasive plant species. Our goal is to help the native plants reoccupy enough of their former ranges and grow in population size so that they can become resilient enough to cope with continuing environmental challenges, such as those anticipated with climate change.

The good news for these rare Channel Island plants is that the raw material for recovery is still there. Most rare plant populations known earlier in the 1900s still persist, even though they are small. Their habitats are usually dominated by more common native plants, some of which appear to be expanding into the surrounding areas, thereby creating additional shaded habitat suitable for colonization by these rare plant species. Our studies show that most of the endemic taxa produce seeds that germinate readily, and we have found ways to encourage more seed production by such actions as hand pollination or by weeding competitive, non-native plants. Some native plant populations may be able to expand on their own as habitats recover.

Another successful recovery technique has been to find suitable but unoccupied habitats for many of the endangered plants. That enables us to "jump start" recovery by establishing new populations in places where it might take years for these plants to colonize on their own. So far, we have had good success developing new populations of two taxa from seeds and cuttings. We have also documented that existing populations of a few native taxa have expanded soon after non-native animal removal. We have high hopes that ecosystem recovery spurred by the non-native animal removal programs will stimulate recovery of these endemic plants, and we are developing ways to help those taxa that have problems recovering on their own. USGS research is guiding rare plant management in the Channel Islands National Park, and together with our partners, we are translating our research results into successful recovery actions.

K. McEachern/USGS

Island rushrose **(Helianthemum greenei)**

D. Rodriguez/NPS

Santa Rosa Island manzanita **(Arctostaphylos confertiflora)**

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Conserving Bird Communities in the Sagebrush Sea

by Steven T. Knick and
Ruth W. Jacobs

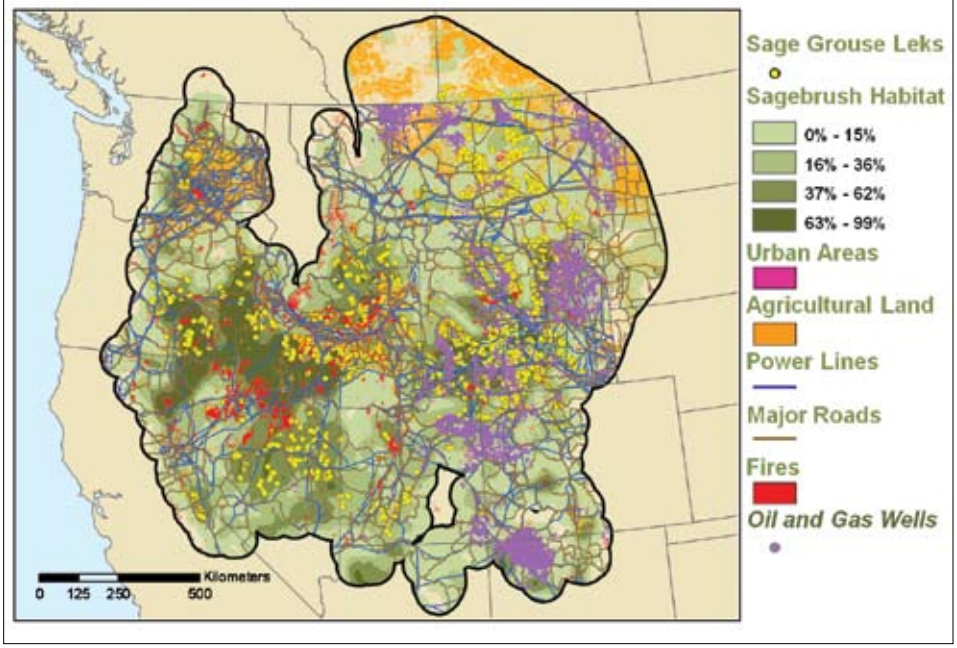
The sagebrush ecosystem, which occupies about 120 million acres (485,600 square kilometers) across 14 western states and 3 Canadian provinces, is one of the largest in North America, and one of its most imperiled. Decades ago, warnings began to appear about the loss of sagebrush habitats and the consequences for biodiversity. Today, many species of shrubland birds are declining, some severely. The greater sage-grouse (*Centrocercus urophasianus*), which depends on sagebrush habitats to survive, is again being considered for listing

An example of sagebrush habitat in Central Nevada.

Steve Knick/USGS

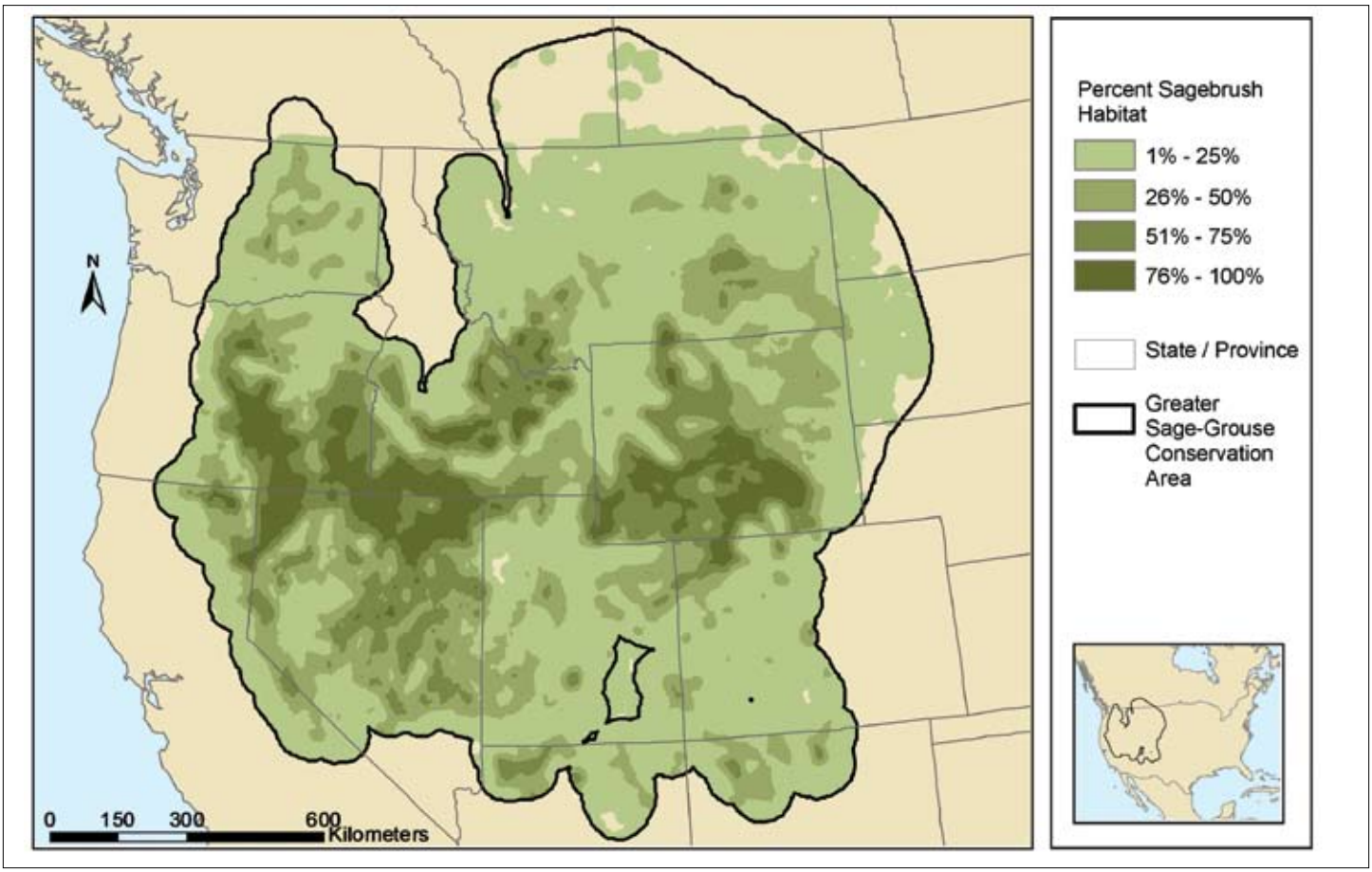
under the Endangered Species Act. To be successful in conserving this ecosystem and the birds that depend upon it, managers need a better understanding of how human use is affecting sagebrush habitats, which habitat components are most critical, the importance of wintering grounds and migration pathways, and how to monitor and estimate bird population trends.

First, managers need more information regarding how human uses, such as oil and gas development or livestock grazing, are affecting sagebrush habitats. As part of a 2004 conservation assessment for sage-grouse, a partnership of state, federal, and university scientists conducted such an analysis. For more than a year, they compiled and analyzed data from thousands of sources to identify, characterize, and quantify the dominant factors (such as agriculture, energy development, and grazing) that influence sagebrush habitats. They systematically documented that almost all sagebrush habitats used by sage-grouse were influenced by one or more significant land uses. They also described how land uses can act synergistically. For example, those uses that cause the spread



Combined breeding and wintering ranges of Brewer's sparrow, sage sparrow, sage thrasher, green-tailed towhee, and gray flycatcher (reprinted from Knick et al. 2003 with permission from Cooper Ornithological Society).

Approximate current distribution of sagebrush habitats in western North America. The map represents the percent of the landscape dominated by sagebrush habitats.



© Terry Steele

Greater sage-grouse.

of fire-prone invasive plants, such as cheatgrass (*Bromus tectorum*), can result in increasing the size and frequency of fires that ultimately convert even more sagebrush habitat to grasslands. The analysis (available at http://sagemap.wr.usgs.gov/) also produced data for use in visualizing habitat change and in conducting additional studies. The result is a valuable baseline for future assessments of sagebrush habitats and other ecosystems in the western United States.

A second research need is basic information about food, cover, space, and water. Surprisingly, little of such information is known for many species of shrubland birds other than sage-grouse, a game bird in many states. Because of new tools to characterize large landscapes, scientists also are learning that the spatial variability in these habitat requirements is an important predictor of population distributions. From a study of shrubland birds and habitat that took three summers and required driving over thousands of miles of dirt roads throughout the Intermountain West, scientists documented that shrubland bird communities were arranged along two major habitat gradients; one ranged from grasslands, through sagebrush shrublands, into juniper woodlands, and the other covered the spectrum from large intact landscapes to highly fragmented systems. The characteristics that determined bird distribution and abundance were precisely aligned with the kinds of habitat changes occurring in sagebrush habitats. These extensive studies show that the distribution of native bird species depends principally on two factors: whether the habitats are predominantly grassland or sagebrush and how much disturbance from human activities have affected the sites.

A third research need emphasizes a better understanding of the importance of wintering grounds and migration pathways. For many species of birds, events during the wintering period may be a significant or even dominant factor in population trends. Obtaining the necessary information to evaluate the influence of the winter period has not been possible using traditional methods because few birds that are leg-banded on research studies are ever recaptured, and the tiny transmitters that can be used on shrubland birds have extremely limited signal strength and battery life. A new technique, based on analyzing feathers for concentrations of stable isotopes, is being used by scientists to link wintering and breeding grounds for shrubland birds. Molting birds replace their feathers on the breeding range each year during the summer. The proteins used to build the new feathers have subtle differences in levels of carbon and nitrogen that vary across the breeding range. Therefore, feathers collected from birds captured and released on the winter range retain this environmental signature that connects them to their summering range. From this study, managers will have essential information to consider the continental scale of influences on the birds breeding in sagebrush habitats.

A fourth research need is to improve methods for estimating bird population trends. Currently, the only consistent

range-wide data are collected by the USGS Breeding Bird Surveys. However, these surveys are not adequate to estimate many of the regional population trends that can be related to changes in habitat. Coordination, data-collection protocols, analysis procedures, technical support for data analysis, and data management are critical tasks to be considered. Technological advances for data recording also are needed, combined with new ways of information analysis involving disparate datasets.

Natural resource agencies have a daunting task to manage and restore sagebrush habitats and the associated species. Cumulative effects of land use and habitat change, coupled with long-term changes from climate change, could result in a large-scale collapse of this vast western landscape. Information systematically collected in the four areas of research described above can be crucial in raising awareness in the scientific community, among land managers, and ultimately of the American public about the challenges and the opportunities associated with conservation of this ecosystem and others. Although specialized skills and data-processing resources are needed to undertake such large-scale studies, that support is available in federal and state research organizations and universities. Most important may be the mindset to better appreciate the value of sagebrush ecosystems and to commit the resources necessary to undertake the studies and apply the knowledge gained for conservation actions.

The four research topics were presented in a paper published in The Condor in 2003. A reference for this paper and the two completed studies used as examples is provided below:

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Ice, Climate Change, and Wildlife Research in Alaska

by Anthony R. DeGange

What do polar bears, Pacific walrus, spectacled eiders, and Kittlitz's murrelets have in common? In a word – ice! Although the effects of climate change can now be observed almost anywhere in the United States, nowhere are the effects more prominent than in Alaska, where unprecedented rates of sea ice loss, tidewater glacier recession, coastal erosion, permafrost degradation, and other landscape changes presage major changes to Alaska wildlife populations.

Climate change will play an increasingly significant role in future decisions related to the Endangered Species Act (ESA), and research is critical to understand how wildlife and their habitats will change as the climate continues to

USGS

Pacific walrus

Steve Amstrup

warm. These four ice-related species exemplify the diverse approaches to research undertaken by biologists in the U.S. Geological Survey's Alaska Science Center (ASC) to help unravel the mysteries associated with climate change and wildlife in Alaska.

The summer of 2007 set another record in sea ice loss in the Arctic since satellite measurements began in 1979. Two species are emblematic of Arctic sea ice: the polar bear (*Ursus maritimus*) and the Pacific walrus (*Odobenus rosemarus*). The Secretary of the Interior announced the listing of polar bears as threatened under the ESA on May 14, 2008. Polar bears depend on sea ice for much of their life history needs. They mate and den on sea ice, travel on sea ice, and feed almost exclusively on seals captured from the sea ice surface. Pacific walrus are currently the subject of a petition to list under the ESA.

Polar Bear

The ASC's polar bear research team, under the direction of Steve Amstrup and George Durner, has been studying polar bears in Alaska for several decades. This extensive research record now enables comparisons of denning behavior, size and condition, and survival between periods when sea ice was abundant over the productive continental shelf and recent years, when it has been absent for increasingly longer periods of time. ASC biologists have documented a shift in the proportion of dens on sea ice to land in response to changing sea ice conditions, as well as declines in some measurements of body size and condition. Perhaps one of the most critical findings was the ability to link survival of polar bears to sea ice. In other words, survival of polar bears was higher in years when sea ice covered the continental shelf for longer periods of time, presumably because bears continued to have access to ice seals, their preferred prey. A similar relationship between sea ice and survival was also documented by ASC biologists, in collaboration with their Canadian colleagues, for polar bears in Western Hudson Bay, Canada.

In 2007, in response to requests from the Fish and Wildlife Service (FWS) and the Secretary of the Interior, the ASC assembled an international, interdisciplinary team of polar bear scientists, sea ice experts, and computer modelers to conduct analyses to help inform the listing decision on polar bears. In addition to understanding the current status of several polar bear subpopulations in Alaska and Canada, the team developed population and habitat models using sea ice forecasts from climate models to understand how the Southern Beaufort Sea polar bear population and polar bear sea ice habitat will change with future declines in sea ice.

The results of this study suggest a bleak outlook for polar bears. Polar bears were forecasted to decline throughout all of their range during this century, but the severity of the decline will depend upon the status of sea ice where they reside. In areas of seasonal sea ice, or where sea ice is receding far north of the continental shelf each summer and fall, extirpation was forecast as the most likely outcome for polar bears by mid-century. Polar bears were predicted to persist longer in areas of northern Canada and Greenland where sea is expected to be more stable. The ASC will continue its long-term studies of polar bears to evaluate and test the predictive models it recently developed. This is critical as sea ice continues to recede at unprecedented levels in the Arctic.

Pacific Walrus

Pacific walrus are even more inaccessible and difficult to work on than polar bears. Developing and implementing a suitable method to estimate the population size of this species has been a dominant research focus for ASC scientists Chad Jay and Mark Udevitz and their colleagues, Doug Burn and Suzann Speckman of the FWS. With the survey data collection complete and analysis underway, the ASC has shifted its focus to better understanding the effects of climate change and diminishing sea ice on walrus. For example, it developed a satellite tag that could be remotely applied to walrus by using a crossbow from a small boat. This precluded the need for sedating walrus on sea ice – a dangerous proposition for walrus and researchers alike. With the recent additions of a saltwater switch and a pressure sensor to the tag, the ASC can now document where a particular walrus is, how much time it spends hauled out on land or sea ice, and where and for how long it is foraging. This will enable future comparisons of foraging efforts between walrus hauled out on land and those that remain on the sea ice.

Like polar bears, Pacific walrus spend a considerable portion of their annual cycle on sea ice. After breeding on sea ice in the Bering Sea in spring, many males migrate to terrestrial haul-outs in Bristol Bay, Alaska, and on the Chukotka Peninsula in Russia. Females and their dependent young, in contrast, stay on the ice as it recedes into the Chukchi Sea, where they use sea ice as a moving platform from which they dive to the sea-floor bottom to feed on such invertebrates as clams. Research suggests that loss of sea ice in summer and fall, particularly over the continental shelf of the Beaufort and Chukchi seas, is having a pronounced effect on this species.

In 2007, sea ice in the Chukchi Sea receded far over the deep water polar basin. Satellite tagging revealed that walrus stayed over the shallow water

USGS

continental shelf where they had access to foraging areas for as long as possible by using small remnant ice flows for resting. Eventually, the ice disappeared and walruses used terrestrial haul-outs in Chukotka and Northwestern Alaska in unprecedented numbers. This behavioral change concerns wildlife managers and researchers for two reasons: walrus on land are at risk from disturbance, and reports from Chukotka suggest that many walruses were trampled during stampedes caused by human disturbances in fall 2007. Walrus also may increasingly compete with each other for food in the nearshore zone as they become concentrated in nearshore haulouts.

Marc Romano

Two radio-tagged Kittzlitz's murrelets at Glacier Bay, Alaska.

Birds

A discussion of climate change and wildlife in Alaska would be incomplete without mention of two unusual bird species also associated strongly with ice: the threatened spectacled eider (*Somateria fischeri*), which winters within the pack ice in shallow waters of the northern Bering Sea, and the Kittlitz's murrelet (*Brachyramphus brevirostris*), a small seabird that visits nearshore waters in summer and is associated with tidewater glaciers.

When research began on spectacled eiders, the wintering ground of this species was one of the great mysteries of ornithology in North America. In Alaska, that mystery was solved by ASC scientists Margaret Petersen and Dan Mulcahy, and Bill Larned of the FWS, with one of the first applications of implantable satellite transmitters. Since then, Petersen and Paul Flint of the ASC, and Chris Franson of USGS National Wildlife Health Center, used small portable x-ray devices to discover that spent lead shot deposited by waterfowl hunters on one of the eider's principal breeding grounds in Alaska was likely a critical factor affecting the survival of adult eiders.

ASC biologists are about to embark on a new satellite telemetry study of spectacled eiders in Alaska. The research will investigate how eiders are using nearshore areas of the Chukchi Sea that could be affected by oil and gas exploration and development. Equally important, the project also will allow investigators to reexamine how the eider's sea ice winter habitat in the northern Bering Sea may have changed since its discovery in the mid 1990s. This could be critical as commercial fisheries expand northwards towards critical habitat for wintering spectacled eiders.

The Kittlitz's murrelet, the only ESA listing candidate in Alaska, remains one of the most enigmatic of seabirds. Most of the world's population of this species, and all of North America's, breeds, molts, and winters in Alaska. They are locally abundant during the summer, nest solitarily, and probably disperse offshore over the continental shelf in winter. In southcentral and southeast Alaska, populations are usually associated with tidewater glaciers. Kittlitz's murrelets probably number fewer than 20,000 in Alaska. Steep declines in their population have coincided with the recession of Alaska's tidewater glaciers in recent decades, but the exact nature of the relationship between birds and glaciers is unknown. This question is under investigation in the Kenai Fjords of southcentral Alaska by ASC biologists John Piatt and Yumi Arimitsu. Piatt is also collaborating with Vernon Byrd, Bill Pyle, and other FWS biologists to investigate the breeding biology of murrelets at Attu Island and Kodiak Island in southwestern Alaska.

A warming climate is causing rapid changes to Arctic ecosystems. Some plant and animal species will respond favorably to these changes, others will not. This poses unprecedented challenges to fish and wildlife managers. As these research vignettes indicate, wildlife research has an important role to play in wildlife conservation in a changing Arctic, and they highlight the continuing need for a strong partnership between the FWS and the USGS.

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Bringing Back the Bonytail and the Razorback

by Gordon Mueller and
Jeanette Carpenter

A group of dedicated biologists are restoring two endangered fish species, the bonytail chub (*Gila elegans*) and the razorback sucker (*Xyrauchen texanus*), to portions of the Colorado River in the southwestern United States. Habitat alteration and the introduction of nearly 80 non-native species have brought these native fish to the brink of extinction. With their young being eaten by the introduced fish, none of the razorbacks or bonytails survive to replace adults as they die of old age. The last confirmed wild bonytail was captured two decades ago, and fewer than 1,000 wild razorback suckers remain.

Since the early 1980s, nearly 1 million bonytail and 12 million small razorback suckers have been stocked into the river. Unfortunately, these young, small fish were preyed upon by channel and flathead catfish, sunfish, and black bass that were introduced for recreational purposes. Today, resource managers must stock large (at least 14 inches or 35 centimeters long) bonytail and razorback suckers simply to maintain their presence in the river system. Some younger fish

Three age classes of razorback sucker. The only measurable recruitment of razorback suckers has been in ponds where predators were absent. Shown here are two adults, two juvenile fish slightly more than a year old, and three fry only a few months old. The dorsal keel or "hump" forms as the fish mature.

USGS

Four age classes of Bonytail: Adult bonytail are streamlined fish built for swimming in powerful currents. Shown here is a large adult and three juveniles (ages 2 years, 1 year, and several months).

do survive and spawn, but their young continue to be eaten by the introduced fish.

Recognizing the imminent loss of these unique fish, a small group of biologists led by Tom Burke of the U.S. Bureau of Reclamation and Gordon Mueller of the U.S. Geological Survey (USGS) started a program in 1989 to save the razorback sucker in Lake Mohave, a 67-mile (108-kilometer) stretch of the Colorado River straddling the southern tip of Nevada and northwestern Arizona. Biologists from the U.S. Fish and Wildlife Service, National Park Service, Nevada Division of Wildlife, Arizona Game and Fish Department, and Arizona State University joined the effort, and this recovery work has now been expanded to the entire lower river.

One of the first steps in recovering these fish was to improve the survival rates of larval fish. Researchers discovered that razorback sucker larvae, like moths, are attracted to light. These fish spawn in late winter; so, before the wild larvae can be eaten by predators, volunteers venture out onto Lake Mohave with lights and small aquarium dip nets to capture them. Tom Burke, who has led this effort for more than a decade, explains: "We fondly refer to these ¼ -inch larvae as 'two eyes and a wiggle.'" The larvae are then transported to the nearby Willow Beach National Fish Hatchery, where they are raised to at least 14 inches in length before being released. The approach of using wild-born fish is unique in that it maintains the genetic diversity of the reservoir population; thus, these stocked fish originate from hundreds of wild parents rather than from a few dozen, which is usually the case with hatchery production.

The process of working with these species revealed other critical secrets about their biology. Fish and Wildlife Service biologist Chuck Minckley (now retired) discovered that both bonytails and razorback suckers spawned and produced young in an off-channel pond at Cibola National Wildlife Refuge, near Blythe, Arizona. Prior to this, biologists believed these fish required river conditions to successfully complete their life cycle. It soon became clear that both species are adaptable to varied environmental conditions. However, their young are completely defenseless against introduced predators. The key, then, was to separate the two.

Although recovery programs have been removing non-native fishes from the Colorado River for over a decade, it simply hasn't been possible to reduce these predators to a level that will benefit native species. This and other problems led to the development of "A Conservation Plan for Native Fishes of the Lower Colorado River" (Minckley et al., 2003, in BioScience 53(3):219-234), which calls for the creation of a network

Gordon Mueller (USGS) shows off a bonytail chub.

Mitch Thorson (FWS) is pouring a bucketful of bonytail into the first sanctuary established for the species. When these fish spawned a month later, thousands of young were found enjoying their new home. These fish sanctuaries are the only place in the wild where bonytail young are surviving.

of isolated fish-rearing sanctuaries. Sanctuaries would allow for the repatriation of fish into floodplain habitats where they could grow to a size less susceptible to predation, while other work continues on minimizing or reducing threats to native fish recovery in the mainstem river.

"We speculated for years that these fish were totally dependent upon the river," explains Mueller. "It turns out that these fish have the remarkable ability to thrive in both rivers and ponds. This suggests a survival strategy uniquely suited for the Colorado River, which historically was renowned for its severe flooding and prolonged droughts. The real beauty of this discovery is that, while we can't control predators in the river, we can in small floodplain ponds."

In 2005, with support from the Bureau of Reclamation, USGS scientists and agency partners began developing native fish sanctuaries in existing floodplain ponds in the Lower Colorado River basin. To date, 15 sanctuaries are in development; of these, 12 have been stocked, and natural reproduction has been observed in two. USGS scientist Jeanette Carpenter is studying what makes these small communities tick. "We are finding that these sites vary considerably in terms of physical morphology, water quality, and aquatic communities," says Carpenter. "We have a unique opportunity to study bonytail and razorback suckers in different types of environments throughout their life cycles, free of the impacts of introduced fish. From this research, we should learn which types of environment provide the optimal conditions for fish rearing, reproduction and survival."

Thirty years of stocking the river has shown us what doesn't work. We are finally making progress by reestablishing small, more manageable native fish communities. The information gained by these small successes will provide the information and experience needed to tackle larger and more complex recovery issues. These agency partnerships are essential to bring together the innovative thinking, expertise, and resources necessary to save these fish for future generations.

For further information on this project, the bonytail, and the razorback sucker, please visit www.fort.usgs.gov or contact Jeanette Carpenter at Carpenterj@usgs.gov or 303-445-2230. Gordon Mueller recently retired.

The California Clapper Rail and Multispecies Recovery Planning

by Michael Casazza, Cory Overton, Melissa Farinha, John Takekawa, and Tobias Rohmer

The California clapper rail (*Rallus longirostris obsoletus*) lives in remnant tidal marshes of San Francisco Bay, where less than 20 percent of the historic tidal wetlands remain. Listed as an endangered species in 1970 by the Fish and Wildlife Service (FWS), this enigmatic bird faces a myriad of threats, including habitat loss due to urban encroachment, sea-level rise caused by climate change, alteration of native habitats by invasive plants, non-native predators, and exposure to mercury and other pollutants. The FWS is in the process of revising the existing recovery plan for California clapper rails and is including

USGS biologists place a small radio transmitter on an endangered California clapper rail to track its movements.

Sebastian Kennerknecht

the rail in a multispecies recovery plan directed towards imperiled salt-marsh ecosystems. Sound scientific information is critical to the success of any recovery plan, but even more so when dealing with complex multiple-species interactions within an ecosystem.

Secretive and wary, rails are a challenge for biologists to observe and study. In 2007, U.S. Geological Survey (USGS) scientists worked with the support of the FWS, State Coastal Conservancy, and East Bay Regional Parks to initiate a project using radio-telemetry to examine aspects of the ecology of the California clapper rail in San Francisco Bay marshes. The initial study focused on home-range size, habitat requirements, survival rates, breeding success, and movement patterns. The birds were captured using a variety of techniques, including drop-door traps, flushing the birds into open water and plucking them from the bay with salmon nets, or simply capturing the birds by hand. The rails were then fitted with tiny backpack transmitters.

Radio-tracking was an essential tool to study these elusive birds as they travel through the dense vegetation and intricate tidal marsh channels, which criss-cross the marsh like a spider web. Locations of rails could be monitored from over a kilometer away. The transmitters were equipped with sensors that indicated whether or not each bird was alive, enabling each bird's survival to be closely monitored. Rails were tracked daily across tide cycles, often multiple times each day, to better understand the relationship between habitat use and movements with respect to tides. Frequent monitoring also allowed scientists to identify predators, such as raptors, introduced red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), and feral cats (*Felis catus*). Rail transmitters were recovered from unusual locations, including the nest of a northern harrier (*Circus cyaneus*), under several inches of soil (where it was presumably buried by a fox), and at a feeding station for a feral cat along the bay shoreline. The identification of major predators supported FWS recovery planning by providing solid evidence to guide predator-management strategies.

Another aspect of this ongoing study examines habitat relationships. Scientists use a highly accurate global positioning system to map tidal channels and model the habitat use of radio-marked rails in relation to the location, width, and depth

A California clapper rail fitted with a backpack radio-transmitter and ready for release back to its tidal marsh home.

Sebastian Kennerknecht

Sebastian Kennerknecht

Stalking a wary California clapper rail in a tidal marsh.

of these channels. Home ranges are being calculated for each radio-marked bird during breeding, post-breeding, and wintering periods. Together with information about annual movement, this information will help managers understand how much habitat these birds need to survive as well as determine how population densities vary with different habitat structure.

The results from this research program are providing new, detailed information about the clapper rail, which can be applied to a multi-species recovery plan being established for the remaining tidal wetlands of the San Francisco Bay region. The data will be integrated with findings for other endangered tidal marsh species, such as the salt marsh harvest mouse (*Reithrodontomys raviventris*). Future recovery efforts may include potential reintroduction of rails to restored marshes, a goal that not long ago seemed highly unlikely. By increasing our knowledge of the movements and ecology of California clapper rails, we hope to provide the foundation for the continued protection and recovery of other tidal marsh species and their native habitats.

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Tracking Sea Turtles in the Everglades

by Kristen M. Hart

The U.S. Geological Survey (USGS) has a long history of conducting research on threatened, endangered, and at-risk species inhabiting both terrestrial and marine environments, particularly those found within national parks and protected areas. In the coastal Gulf of Mexico region, for example, USGS scientist Donna Shaver at Padre Island National Seashore in Texas has focused on "headstarting" hatchlings of the rare Kemp's ridley sea turtle (*Lepidochelys kempii*). She is also analyzing trends in sea turtle strandings onshore and interactions with Gulf shrimp fisheries.

Along south Florida's Gulf coast, the USGS has focused on research and monitoring for managing the greater Everglades ecosystem. One novel project involves the endangered green sea turtle

An endangered juvenile green sea turtle captured in Everglades National Park.

Kristen M. Hart

Adam Brame

Keith Ludwig and Kristen Hart, both of the USGS, prepare to glue a satellite tag on the carapace of a juvenile green sea turtle.

(*Chelonia mydas*). The ecology and movements of adult green turtles are reasonably well understood, largely due to decades of nesting beach monitoring by a network of researchers and volunteers. In contrast, relatively little is known about the habitat requirements and movements of juvenile and subadult sea turtles of any species in their aquatic environment.

With funding from the Fish and Wildlife Service, I have been leading a USGS team that conducts a capture and tagging study on juvenile green turtles. Our study site is in the Big Sable Creek (BSC) mangrove complex of the southwest coastal area of Everglades National Park, an ecosystem of internationally recognized importance. The sightings of green turtles that we have collected over six years in and around the BSC study site is made up of more than 70 individual records. Some of the sightings have occurred in headwater regions of the BSC complex, approximately 2 kilometers (1.2 miles) inland from the Gulf coast. These saline headwater streams contain a surprising density of submerged, algae-covered logs that seem to be remnants of old red mangroves (*Rhizophora mangle*), possibly felled by hurricanes. In the headwaters, there are also clear, salt-water seeps that may be linked to groundwater or filtered seawater. Most of the other sighting records have been concentrated in nearshore coastal areas in the study site.

I believe these relatively inaccessible headwater areas and shallow nearshore environments may provide previously unknown foraging and nursery grounds for endangered green turtles. To test this hypothesis and determine habitat use patterns of young green turtles in the park, my team of USGS researchers conducts capture-recapture efforts, deploys satellite tracking devices on individual turtles to record daily movements (via Argos satellites), and takes blood samples from each turtle for molecular genetic analysis to identify the most likely country of origin.

To date, satellite-tagged juveniles are using nearshore habitats in the Everglades, spending considerable time not only within the park boundaries but also making routine use of mangrove tidal creeks. Individual turtles sampled for diet are feeding on both red and green algae, and a preliminary analysis of genetic samples indicates a possible link to the Cuban nesting population of green turtles.

Adam Brame

Kristen Hart releasing a juvenile green sea turtle after work-up and tagging.

Until recently, the use of nearshore and headwater creeks by juvenile green turtles was unknown in the southwest coastal Everglades. Thus, management strategies for protecting this early life stage of green turtles have not been designed. If young individuals are in fact spending more time than previously recognized in coastal creeks and nearshore habitats, their exposure to human-derived nutrients and contaminants may be of concern. USGS investigators Bill Orem and Carol Kendall have conducted extensive monitoring of nutrients and contaminants through Everglades food webs, and future work with juvenile sea turtles should evaluate levels of contaminants (e.g., methylmercury) in the blood of juvenile green turtles. Thus far, USGS data show fibropapillomas (tumors) on 58 percent of the juvenile green turtles sampled, and it is unknown whether this problem is in some way connected with their use of coastal streams and springs that may have altered water quality.

Our USGS team continues to uncover facets of juvenile green turtle ecology that were previously unknown, despite the challenges inherent in any research on endangered species in a remote environment. Among these challenges is keeping satellite tags affixed to relatively fast-growing young sea turtles for periods of more than a few months. Because young sea turtles must grow quickly in response to predators (e.g., seabirds and sharks), they shed the outer layers of bony plates called scutes that make up their shell quickly compared to adults. Also shed are the satellite transmitters that are glued to their scutes. Thus, we are exploring unique and novel methods of tag attachment, as well as other positional data-logging technologies, such as acoustic telemetry.

We are extending the approach taken in the Everglades green turtle project to explore habitat use patterns of endangered sea turtles in the waters of the Dry Tortugas National Park (DRTO) southwest of peninsular Florida. Through funding provided by the National Park Service and USGS Priority Ecosystem Studies and Coastal Marine Geology programs, we employ capture-recapture and satellite and acoustic tracking techniques to determine the amount of time endangered sea turtles are spending within and around recently-designated "no fishing"

Kristen M. Hart

USGS employees BJ Reynolds (left) and Adam Brame (right) with USGS volunteer Autumn Sartain aboard the USGS research houseboat with two satellite-tagged juvenile green sea turtles.

zones of DRTO. We also use molecular genetic methods to reveal connections between Tortugas sea turtles and others previously sampled in south Florida.

Through this exciting research, the USGS will provide a more comprehensive understanding of endangered species use of national parks and other habitats over time. Such information will be instructive in forming management strategies that benefit endangered species and the resources upon which they rely.

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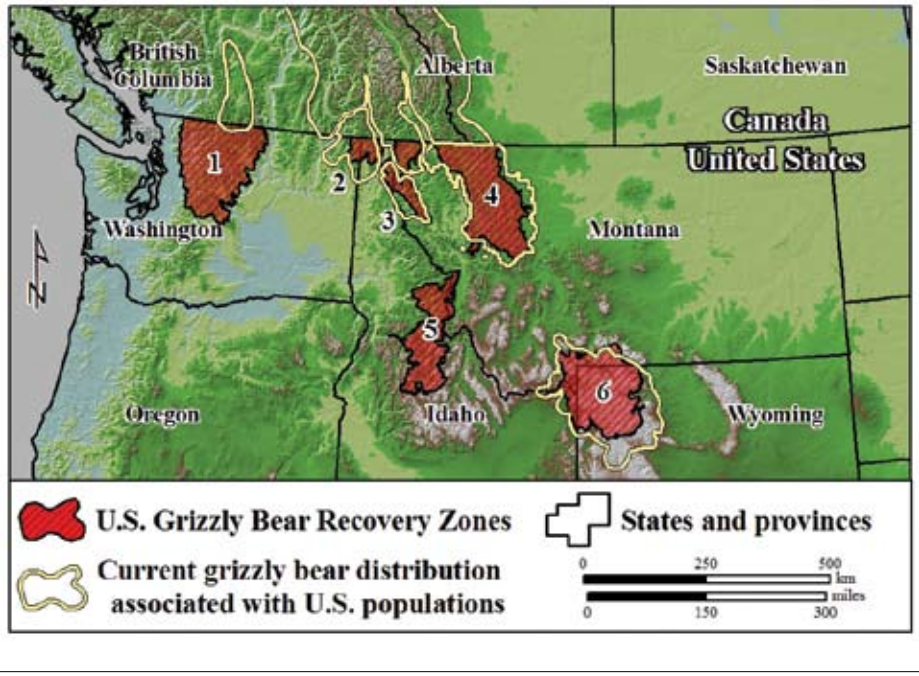
Hair Samples Shed Light on Grizzly Bears

by Amy Macleod, Jeff Stetz, and Katherine Kendall

Grizzly bears (*Ursus arctos*) in the Northern Continental Divide Ecosystem (NCDE) of the northern Rocky Mountains of Montana were listed in 1975 as threatened under the Endangered Species Act. The NCDE plays a critical role in the long-term persistence of grizzly bears in the United States outside of Alaska due to its linkage to populations in Canada (Fig. 1, #4).

The USGS-led Northern Divide Grizzly Bear Project Research was initiated in 2002 to determine the abundance and distribution of grizzly bears in the NCDE. Our 31,410–square kilometer (7.78 million–acre) study area incorporated the NCDE Grizzly Bear Recovery Zone and included all lands reportedly occupied by grizzlies in the region, up to the Canadian border (Fig 2). The study area included all of Glacier National Park; portions of five national forests (Flathead, Kootenai, Lewis and Clark, Lolo, and Helena); five designated wilderness areas (Bob Marshall, Great Bear, Scapegoat, Mission Mountains, and Rattlesnake); parts of the Blackfeet Nation and Confederated Salish and Kootenai Tribe lands; and hundreds of private land holdings.

Figure 1. Recovery zones and current distribution of grizzly bears in the greater Northern Continental Divide Ecosystem in northwestern Montana, USA.



USGS – Northern Divide Grizzly Bear Project

Grizzly bear rubbing on a tree in Glacier National Park, Montana.

We used two concurrent non-invasive sampling methods, hair traps and bear rubs, to collect bear hair for genetic fingerprinting. Hair traps consisted of a single length of barbed wire encircling 3 to 6 trees or steel posts at a height of 50 centimeters (20 inches), with a scent lure poured in the center. By mimicking the smell of a carcass, the lure attracts bears to the site, where their hair is snagged on the barbs as they cross the wire to investigate. Over 2,500 hair traps were systematically distributed throughout the study area using a grid of 7- by 7-kilometer (4.35- by 4.35-mile) cells (Fig. 2a). We also conducted over 18,000 visits to 4,795 bear rub sites found across 80 percent of the study area (Fig. 2b). Bear rubs are objects such as trees, posts, and power poles that bears naturally rub on; no attractant was used to draw the bears to these sites. Short strands of barbed wire were attached to facilitate hair collection.

From June to September of 2004, 210 field technicians collected 33,741 grizzly bear and black bear (*U. americanus*) hair samples. Genetic analysis of the collected hair samples identified 545 unique grizzly bears. We also genotyped tissue samples from grizzly bears handled in the NCDE during research and management activities from 1975 to 2006. From live captures and mortalities during 2004, we identified 18 bears in our study area during our sampling period that were not detected at hair collection sites. This brought the total minimum number of grizzly bears documented in the NCDE in 2004 to 563.

To estimate the total number of grizzly bears in the NCDE, we developed a mark–recapture modeling approach that allowed us to combine data from our three sampling methods (bear rubs, hair traps, and live captures) to construct individual bear encounter histories. Our use of multiple sampling methods increased our chances of detecting more of the population and improved the precision of our population estimate. Using this approach, we estimated the 2004 population size was 765 grizzly bears. We also found that, overall, the genetic health is good and that grizzly bears occupy a range that now extends 2.6 million acres beyond the NCDE recovery zone boundary.

This study produced the first rigorous ecosystem-wide estimate of grizzly bear population size, distribution, and genetic connectivity in the NCDE. Our results provide baseline values against which future trends will be monitored and information essential to agency decisions about recovery status and delisting.

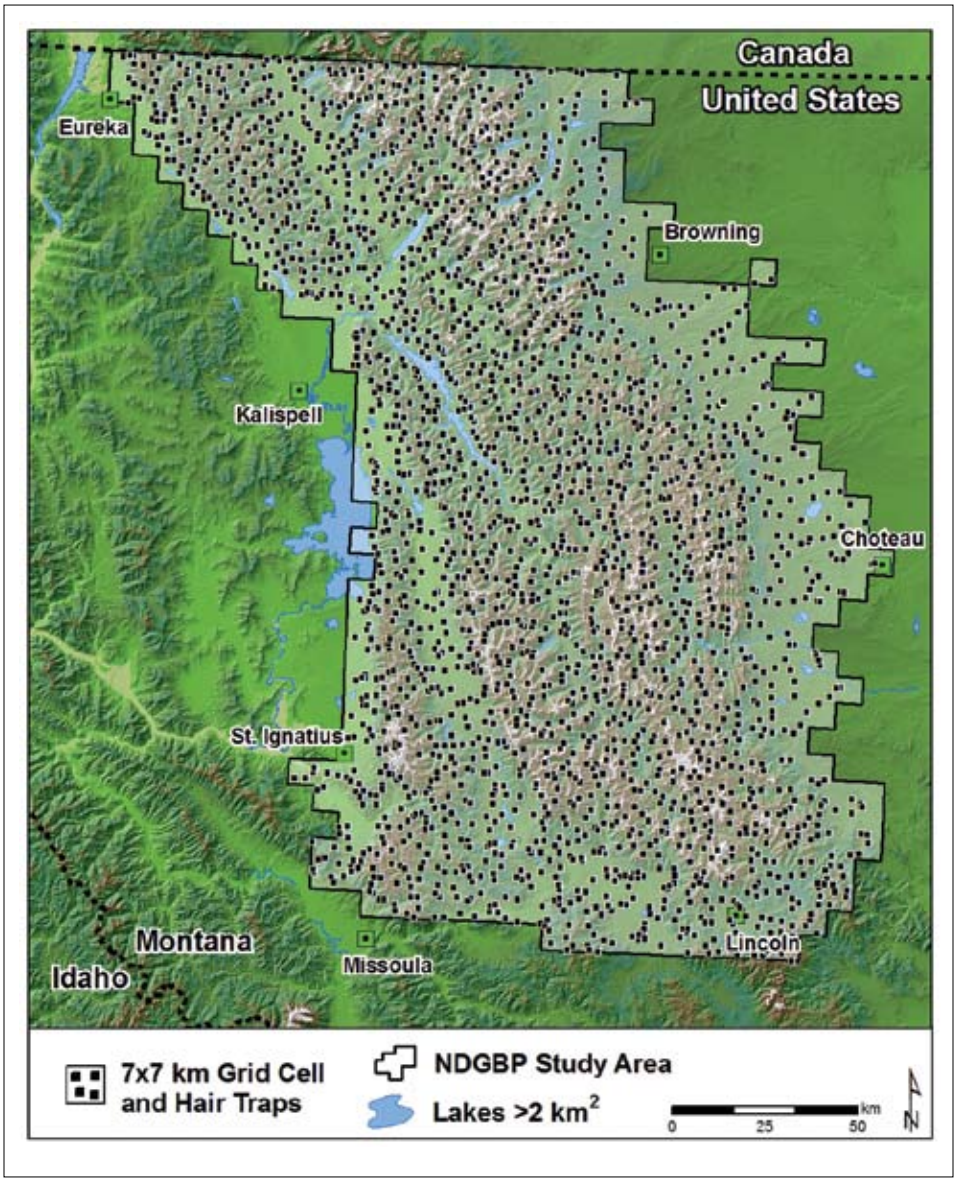


Figure 2. Northern Divide Grizzly Bear Project study area, 2004, in northwestern Montana.

Because understanding population trends is necessary for determining recovery status, our study was designed to dovetail with a new long-term trend monitoring study by Montana Fish, Wildlife and Parks.

The success of this landscape-scale project was due in no small part to the cooperation of many partners, including a dozen state, federal, and tribal agencies, as well as university, non–profit organizations, and hundreds of landowners. They contributed outstanding support in terms of their time, effort, expertise, and communication networks. We are also indebted to the hundreds of technicians and volunteers who performed the demanding field, office, and lab work.

The complete results of this study are published in the January 2009 issue of The Journal of Wildlife Management.

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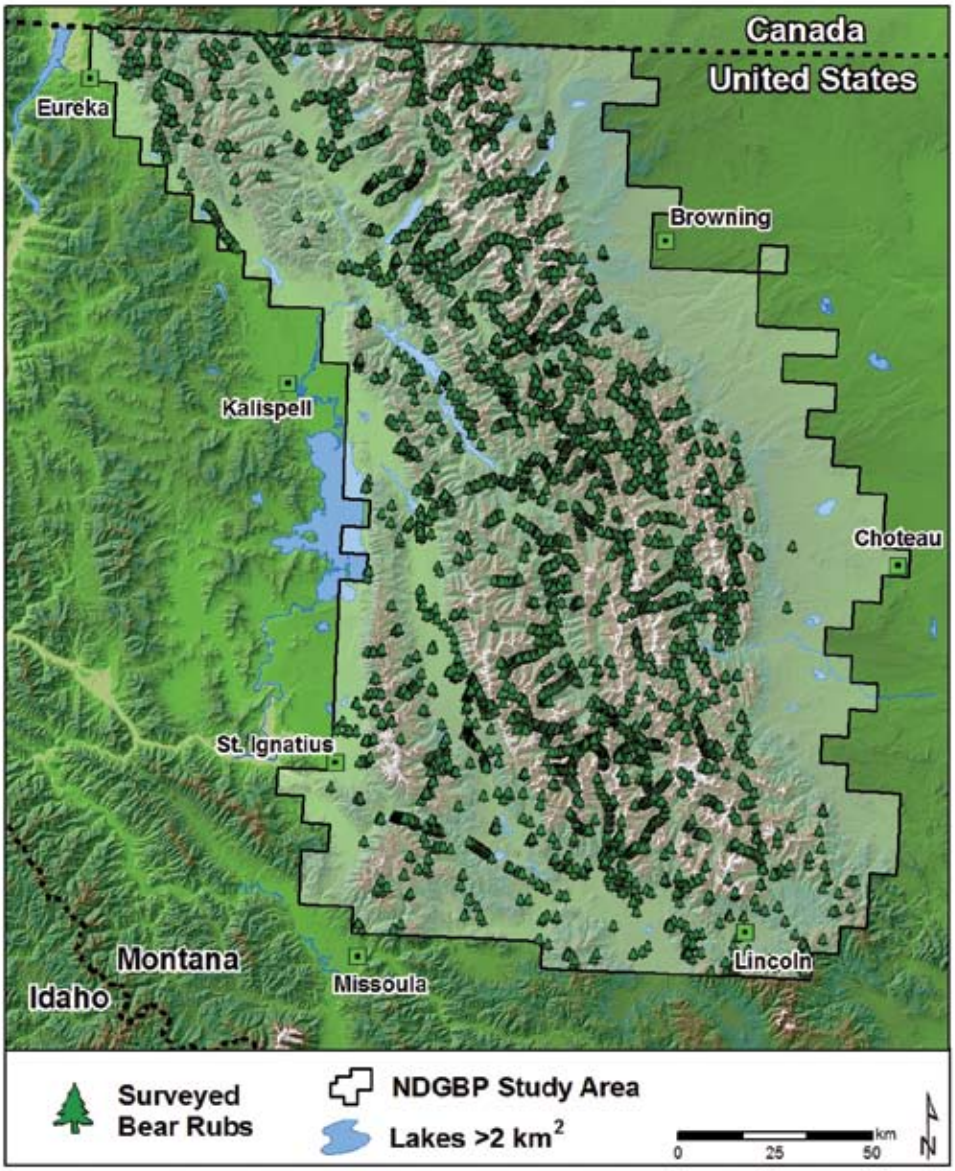


Figure 2b. Surveyed bear rub sites.

USGS – Northern Divide Grizzly Bear Project

Grizzly bear with cubs in a barbed wire hair trap in Glacier National Park, Montana.

Understanding Pallid Sturgeon in the Big Muddy

by Jeanne Heuser

The swift current of the longest river in the United States is home to the pallid sturgeon (*Scaphirhynchus albus*), an elongated, whitish-grey fish armored with protective bony-like plates called scutes. Pallid sturgeon can live up to 60 years, and grow to 6 feet (1.8 meters) and 80 pounds (36 kilograms) in size.[1] This predatory fish uses its protruding mouth to suck up prey, which are found with the aid of four fleshy barbels under its snout. The pallid sturgeon matures slowly; it is estimated to take from 15 to 20 years for a female to reach breeding age. Spawning is less frequent than with most fish.[1] Because of low population numbers and little evidence of successful reproduction, the pallid sturgeon was listed by the Fish and Wildlife Service in 1990 as endangered.[1] Threats to the species include habitat loss, flow alteration, commercial harvest for caviar, and pollution.[1]

Historically, the Missouri River consisted of braided channels that moved from year to year across a wide flood plain. As snow melted in the Rocky Mountains and Great Plains, great pulses of water entered the river, causing unstable banks to erode. Massive quantities of sediment moved through the "Big Muddy," creating new channels, sandbars, islands, and backwaters. Efforts were underway to stabilize the banks by 1900, and in the 1940s, Congress authorized the construction of a channel on the Lower Missouri River for navigation and six large dams on the upper river for flood control, irrigation, and hydropower production. Today, these engineering changes are associated with fish and wildlife habitat loss and a disrupted flow regime.[1]

Researchers at the U.S. Geological Survey's (USGS) Columbia Environmental Research Center in Missouri met with the Fish and Wildlife Service, Army Corps of Engineers, and state wildlife agencies in 2004 to assess the pallid sturgeon's ecological requirements for reproduction and survival.[2] They identified numerous information gaps in the life cycle of the fish that may be bottlenecks to recovery efforts. Since that meeting, a multidisciplinary team of USGS scientists has been exploring the adult stages of the life cycle with studies on fish movement and behavior, physiology, reproduction, and habitat use and availability. Because the pallid sturgeon is so rare, researchers also study the genetically similar and more abundant

USGS ecologist Aaron DeLonay conducts pallid sturgeon reproductive behavior studies on the Lower Missouri River.

USGS

The shovelnose sturgeon (left) and endangered pallid sturgeon (right).

shovelnose sturgeon (*Scaphirhynchus platorynchus*).

To understand sturgeon behavior and identify spawning locations, USGS ecologist Aaron DeLonay, fishery biologist, Gerald Mestl from Nebraska Game and Parks Commission, and their field crews follow the migrating fish in the Lower Missouri River. In 2007, they implanted 195 sturgeon—176 shovelnose and 19 pallid—with transmitters. The scientists used boats equipped with telemetry receivers and global positioning systems to track the tagged fish. Records of water temperature and depth used by the sturgeon were acquired through a data storage tag implanted in the fish. The team developed successful methods to capture and recapture the fish, allowing researchers to map hundreds of sturgeon locations and learn that sturgeon can migrate over 500 miles (800 kilometers).

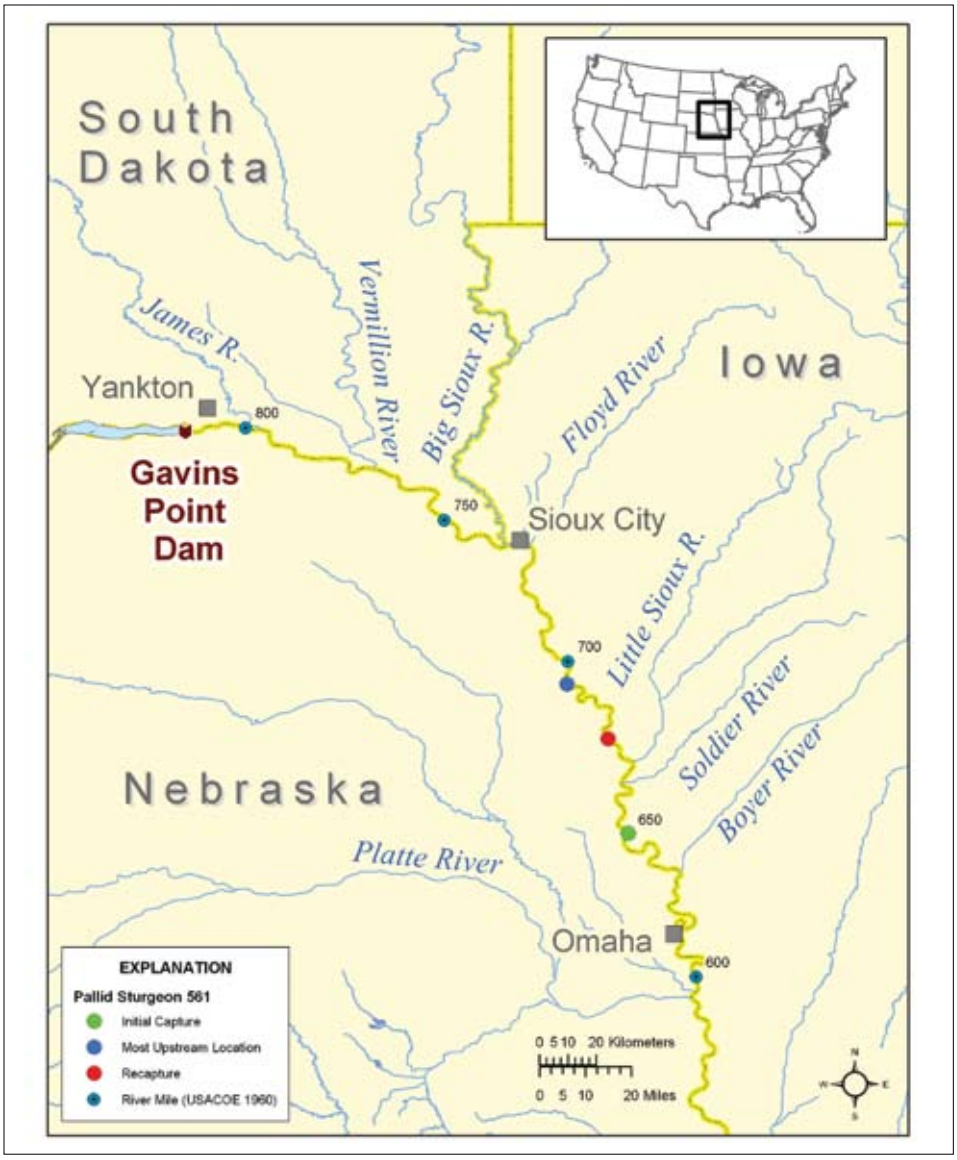
Determining whether or not a sturgeon spawns and the conditions under which it spawns are key challenges. USGS ecologist Mark Wildhaber and his team developed ultrasonic and endoscopic imaging techniques to determine fish sex and reproductive stage in the field. In the Columbia lab, USGS physiologist Diana Papoulias and her team use blood samples and an egg measurement called the polarization index to estimate how soon spawning will occur. These and other indicators help identify how fish are responding to environmental factors such as day length, water temperature, and water flow.

For two months during the spring of 2007, field crews tracked fish movement 24 hours a day. This intensive effort identified likely locations and timing of pallid sturgeon spawning in the Lower Missouri River mainstem. Two gravid (egg-carrying) pallid females that had been relocated over 100 times each were recaptured after their upstream migration. Examinations of these fish documented that they had indeed released their eggs in the river at different times and locations.[3]

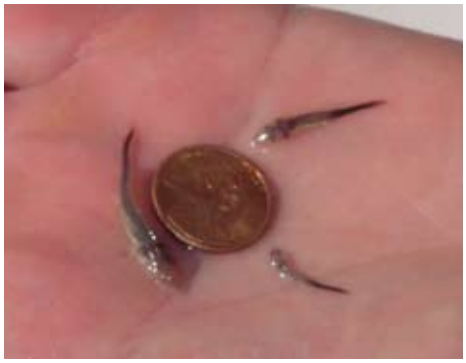
Documenting that two females released eggs is an important finding; what remains unknown is whether the eggs were fertilized and, if they were, whether the eggs hatched into larvae. Locating larvae in the Missouri River is much harder than locating juvenile or adult fish, but this is what USGS fishery biologist Darin Simpkins did with fishery biologist Steven LaBay from South Dakota Game, Fish, and Parks. Their field crews conducted sampling from May through August in 2007 at 5 tributary and 22 main channel sites, collecting more than 100,000 larvae of numerous species. To date, 117 larval shovelnose or pallid sturgeon have been confirmed from the fish samples. These data will help to confirm the timing and location of sturgeon spawning in the Missouri River between Gavins Point Dam and the mouth of the Platte River.

When sturgeon are relocated in the river by field crews, the sites are provided to USGS hydrologist Robert Jacobson, who deploys his team to conduct hydroacoustic assessments of the habitats. Their equipment uses sound in water to obtain information about the river's physical characteristics, such as river depth, water velocity, and substrate type. From 2005 to 2007, as many as 378 sturgeon locations were mapped in 153 river reaches. Jacobson has also collaborated with the USGS Nebraska and Iowa Water Science Centers to assess habitat change over time in four reaches of the Lower Missouri River. Monitoring of channel erosion and deposition and hydraulic modeling are used to assess the sensitivity of habitats to changing conditions.

Fish locations, larval fish catches, physiological data, and habitat assessments are integrated in a complex database and geographic information system developed by USGS data management specialist Kim Chojnacki. This system enables field crews to retrieve location information and spawning conditions of fish found the previous day. In the future, USGS intends to mine this database and other information to



On March 29, 2007, researchers captured female pallid sturgeon #561 at river mile (RM) 650.3, determined she was ready to spawn, followed her 45 miles to RM 695, and recaptured her May 25 at RM 676.7 where it was determined she had successfully spawned.



USGS

Young of the year sturgeon prove challenging to locate in the Missouri River.

populate a *Scaphirhynchus* life history model.[4] The model is intended to be dynamic and responsive to new information and changes in river management. It will enable scientists, stakeholders, and managers to better understand the effects of management actions on native sturgeons of the Big Muddy.

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Update: Biologists from the Neosho National Fish Hatchery (NFH) stocked endangered pallid sturgeon into the Missouri River near Bellevue, Neb., on September 23. The 401 fish were marked with PIT tags the previous week and were from the 2007 brood year. Originating from wild brood stock that was captured in the Missouri River, these pallid sturgeon were delivered by plane from Garrison Dam NFH as small fry. Hatchery staff at Neosho NFH reared them on brine shrimp and bloodworms to obtain the stocking length of 9.58 inches.

Surveys Reveal Decline of the Palila

by Paul C. Banko[1], Chris Farmer[2], Kevin W. Brinck[2], David L. Leonard, Jr.[3], and Jay Nelson[4]

The endangered palila (*Loxioides bailleui*) is a flagship species of Hawaiian forest bird conservation. Due mainly to long-term ecological research by U.S. Geological Survey (USGS) biologists and many hundreds of volunteers from Hawai'i, the mainland, and around the world, more is known about palila than any other Hawaiian forest bird species. Palila exemplify the special vulnerability of many other Hawaiian birds to extinction. Thus, it is especially troubling that palila are declining despite receiving the longest sustained dedicated funding for research and management of any Hawaiian forest bird species.

A palila works to remove a māmane seed pod. The selected pod will be bitten off at the stem, after which the bird will move to a suitable perch where it will hold the pod against the branch with one foot and rip open the pod with its bill, exposing the seeds. The bird extracts each seed by removing the exposed seed coat and digging out the tender immature seeds with its bill.

Photo by Jack Jeffrey.

Over the past five years, palila have declined by over 50 percent, from an estimated 6,523 birds in 2003 to only 3,076 in 2008, according to multi-agency surveys. Additionally, the range of the palila has contracted during the past 20 years and is now less than 5 percent of its historic range. Palila numbers have been monitored annually since 1980, longer than any other Hawaiian bird species, and the 2008 population estimate has fallen to levels not seen since the early 1990s. Especially significant is that the 2008 palila survey represents the fifth consecutive year of declining numbers, whereas no previous decline exceeded two years.

Palila, like other extinct and endangered Hawaiian birds, have specialized feeding requirements, with unusual bill shapes and sizes and low reproductive capacity. Among the larger Hawaiian Islands, palila are the sole surviving species of an extraordinary guild of about 21 species of Hawaiian honeycreepers (an endemic subfamily of finches) that specialized on seeds or small fruits. Food specialization may have contributed to the vulnerability of bird species to introduced predators, diseases, competitors, and habitat stressors. Recovering from alien threats is especially difficult for specialists because they lay few eggs and they spend long periods incubating their eggs and caring for their young.

Historically, palila ranged from Mauna Kea to Hualālai and Mauna Loa volcanoes on Hawai'i Island, but they are becoming increasingly restricted to the western slope of Mauna Kea above 6,000 feet (1,830 meters) in elevation.

Their range contraction has followed the long-term destruction of māmane (*Sophora chrysophylla*) forests by cattle ranching and feral populations of other browsers. Māmane trees produce seed pods that are the primary food of palila, but introduced ungulates, particularly sheep, goats, and cattle, eat the leaves and young shoots of māmane. Browsing damages adult trees, and retards forest regeneration by removing seedlings and saplings. To protect māmane forests and the watersheds of Mauna Kea, territorial foresters removed nearly 47,000 sheep, 1,500 pigs, and 800 goats between 1937 and 1947. However, sheep populations quickly grew back to damaging levels, resulting in federal court orders to eradicate them and other browsers from palila critical habitat. This prompted another round of ungulate removal, which has been in progress for nearly three decades. Thinning populations of ungulates has allowed limited māmane regeneration to occur, but palila will not benefit until saplings have grown to the larger-sized trees that they prefer, which requires at least 30 years. Moreover, as long as māmane continues to be damaged or killed by browsing, the forest and the palila population cannot be expected to fully recover.

The 2006 U.S. Fish and Wildlife Service (USFWS) Revised Recovery Plan for Hawaiian Forest Birds discusses major threats that should be eliminated or minimized to protect palila and promote their recovery. Among the most serious dangers are the continued browsing of māmane by the non-native sheep within critical habitat, potential destruction of māmane forest by fire, degradation of habitat by invasive weeds and introduced plant diseases, predation by feral cats, and the spread of alien insect pests that reduce caterpillars, which are an important food of young palila. Notably, palila are not affected in their present high-elevation range by introduced bird diseases like malaria and pox, which are significant threats to native birds in lower elevation habitats. Disease may eventually affect the palila if global warming allows blood parasites and mosquitoes to move upslope. Another concern is that climate change could result in more frequent and severe droughts, which reduce māmane pod crops and reduce palila survival and reproduction.

With support from the Federal Highway Administration to compensate for impacts associated with rerouting a road through palila critical habitat, the USGS experimentally reestablished a small breeding population of palila in formerly-occupied habitat on northern Mauna Kea near Pu‘u Mali. From 1996 to 2006, USGS biologists transported 188 wild palila from the core population on the western slope to Pu‘u Mali. Additionally, the Zoological Society of San Diego has released 21 captive-reared palila near Pu‘u Mali, with support from Hawai‘i Division of Forestry and Wildlife (DOFAW), USFWS, and USGS. This small experimental population is not currently self-sustaining, but it has yielded valuable information for palila recovery. Other research for restoring and protecting palila and their habitat has led to recent management action, such as removing feral cats and planting māmane seedlings by DOFAW biologists on lands temporarily withdrawn from cattle ranching. USFWS is providing funds for fighting fires, reducing browsing threats, and fencing a portion of critical habitat, and USGS continues research to improve our understanding of how to restore and protect palila habitat.

Given that critical habitat designation, federal court orders, and concerted research have not prevented the recent decline of the palila population, more effective recovery methods are needed. Preventing yet another extinction in Hawai‘i will require further vigorous, sustained efforts to reduce alien threats, restore habitat, and expand the range and population of the palila.

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How Temperature Affects Juvenile Coho Salmon

by Mary Ann Madej

Water temperature influences many aspects of a salmon's life cycle, including egg development, juvenile appetite and growth, migration, and distribution. Coho salmon (*Oncorhynchus kisutch*), like most salmonids, need cool water for rearing, and they typically reside in a stream for a minimum of one year after hatching. Historically, coho were found throughout most of the 67-mile (108-kilometer) mainstem of Redwood Creek in Humboldt County, north coastal California. During at least the last decade, however, juvenile coho distribution in this area was limited to the last 12 miles (20 km) of the mainstem and a few large low-gradient tributaries.

In 1997, the Southern Oregon/ Northern California "Evolutionary Significant Unit" of the coho salmon, part of which inhabits Redwood Creek, was listed under the Endangered Species Act as threatened. In addition, Redwood Creek is currently listed as temperature- and sediment-impaired under the Clean Water Act because of past timber harvest, removal of riparian vegetation, widespread streamside landsliding, and channel aggradation. Staff from the U.S Geological Survey (USGS) and Redwood National Park are cooperating in a stream temperature monitoring project that uses in-stream temperature recorders, coupled with imagery from a thermal infrared flight over Redwood Creek, to relate coho distribution to water temperature.

Unlike many rivers reported in the literature that get warmer as they flow downstream, Redwood Creek reaches its maximum temperature in the middle basin and becomes cooler farther downstream. Coastal fog and shading by old-growth redwood trees in the riparian zone of the lower basin (within Redwood National Park) contribute to the cooling trend there. Currently, coho are found primarily in this downstream reach (Reach 4, Figure 1). Coho habitat in the headwater reach of Redwood Creek (Reach 1) is beginning to recover from past damage, in terms of pool frequency and depth, shading by alders, and adequate spawning gravel size. In addition, stream temperatures in this reach, measured at a USGS gaging station, are becoming cooler. In the 1970s, average daily water temperature during July

Juvenile coho salmon from the Redwood Creek watershed.

Redwood National Park collections

and August ranged from 24 to 28 o C (75 to 82°F), but now they range from 20 to 22°C (68 to 72°F). The temperature regime in the non-coho-bearing Reach 1 is similar to the coho-bearing Reach 4 near the mouth of Redwood Creek. In between are Reaches 2 and 3, totaling 33 miles (50 km), where summer water temperatures, at 24 to 28°C (75 to 82°F), are still significantly warmer than the temperatures preferred by coho (less than 18°C, or 64°F). Not only are maximum temperatures too high, but the river does not cool appreciably at night, and minimum daily temperatures of greater than 18°C (64°F) are still considered unfavorable for juvenile coho. The durations of high temperatures are also highest in Reaches 2 and 3.

Scattered along the hot stretches of Redwood Creek are small pockets of cool water fed by springs or tributaries. They act as thermal refugia for fish, where they can escape the high summer water temperatures. A thermal infrared flight was useful in identifying the locations of these cool water refugia, which were several degrees cooler than the main channel flow (Figure 1). In 2003, a helicopter flight surveyed 59 miles (95 km) of Redwood Creek to collect thermal infrared (TIR) and color video imagery of Redwood Creek and its riparian zone. The TIR data captured water temperature at mid-afternoon on July 29, which corresponded to the highest.water temperatures of the year. The TIR data indicate that springs are more common in the downstream reach of Redwood Creek, a finding that may be related to the underlying bedrock geology in this area. More detailed field measurements of these cool patches are planned for this summer to determine their distribution, extent, persistence, daily temperature range, and use by fish.

The California Department of Fish and Game has been operating downstream migrant fish traps on Redwood Creek since 2000. The trap data, in conjunction with snorkel surveys conducted by the National Park Service, documented that, for many years, coho were only found in lower Redwood Creek. Then, in 2007, six young-of-the-year coho salmon were found in Reach 2, and in 2008 two one-year-old coho smolts were found in this reach (Figure 1) (Sparkman, CDFG, personal communication). It is too early to determine if coho will be successful in reoccupying former habitat in this reach, but continued recovery of riparian and channel conditions, combined with the presence of thermal refugia, may assist in the recovery of this population. Continued monitoring through cooperative studies with other agencies and landowners will help answer these questions.

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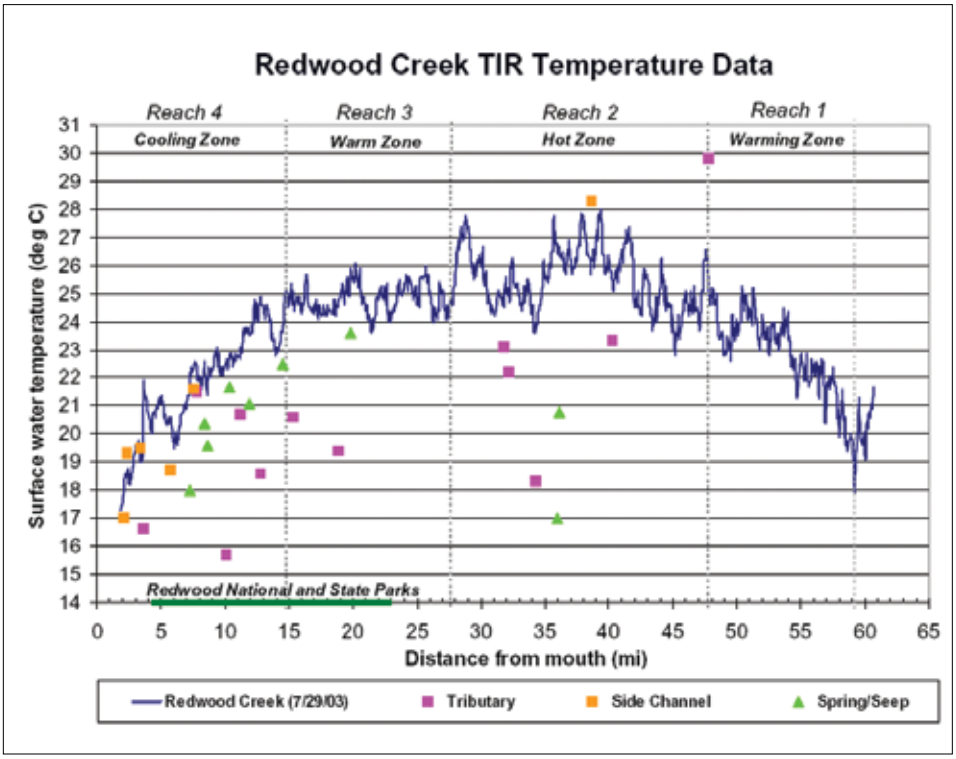
Figure1: Median surface water temperature based on thermal infrared (TIR) imaging along Redwood Creek. Surface flow temperatures in tributaries and springs were also recorded by the TIR imagery.



Bridging the Information Gap for Mussels

by Rita Villella Bumgardner, Ed Pendleton, and Bill Lellis

The conservation of freshwater mussel species in the United States is a major challenge. Freshwater mussels are the most imperiled fauna in North American. Of 297 recognized taxa, 213 are endangered, threatened, or of special concern. Their decline can be attributed to a variety of causes, including water pollution, sedimentation, channel dredging, invasive zebra mussels, and the loss of fish species that serve as hosts for mussel larvae. Mussels have important ecological value. As filter feeders, they improve water quality by removing particulates from the water column. They also serve as food for fish, otters, and other animals, and they help stabilize the riverbed by burrowing in the substrate.

Locating mussels in their native habitat and identifying them by species can be time consuming and difficult. Ecologists at the Leetown Science

Diving for mussels on the Allegheny River.

USGS

Center, a U.S. Geological Survey (USGS) facility in Kearneysville, West Virginia, first developed a mussel survey method that combines both qualitative and quantitative measurements to define distribution and abundance among and within mussel beds. USGS geneticists are analyzing DNA to determine taxonomic status and population structure of the endangered species mentioned below as well as other declining mussels in Atlantic slope streams and the Ohio River basin.

The survey method and molecular genetics results have been applied to a series of studies on the Allegheny River in Pennsylvania that were conducted in cooperation with the Fish and Wildlife Service and the Pennsylvania Department of Transportation. The Allegheny is one of the last large rivers in the East to maintain a diverse, self-sustaining community of freshwater mussels, and it is known to support the healthiest and most abundant remaining populations of two endangered mussels, the clubshell (*Pleurobema clava*) and northern riffleshell (*Epioblasma torulosa rangiana*). USGS ecologists responded to needs for robust surveys of the upper Allegheny, with particular emphasis on evaluating the impacts of bridge construction and replacement at several points to determine how this site-specific disturbance affects the two endangered species and other members of the mussel community.

After surveying around the bridge sites, a sample of mussels was removed and relocated to upstream mussel beds, where their growth and survival, and that of the existing mussels at the transplant sites, was monitored. The recovery of mussels in the bridge construction "footprint" was also monitored. Ultimately, biologists surveyed the distribution of mussels over a 75-mile (122-kilometer) stretch of the river, and they are now analyzing the data. The survey repre-

USGS genetic technician Kristine Playfoot collecting freshwater mussel tissue samples for DNA analysis.

Sara Lopata, USGS

sents the first comprehensive survey to estimate population density of rare and listed mussels in a big river system in the East. The survey documented the largest known populations of the northern riffleshell and clubshell, as well as the largest known population of the sheepnose mussel (*Plethobasus cyphyus*), a listing candidate. The conservation of these populations may help in the recovery of the imperiled mussels.

Leetown Science Center ecologists have also been working on conservation of the endangered dwarf wedgemussel (*Alasmidonta heterodon*) in the Delaware River, which borders the states of Pennsylvania, New York, and New Jersey. The mussel was first discovered in the upper basin in 2000 during extensive surveys of two units of the National Parks System, the Upper Delaware Scenic and Recreational River and the Delaware Water Gap National Recreation Area. Since then, over 200 miles (322 km) of river mainstem and tributaries in and around the parks have been surveyed, and several additional populations of the dwarf wedgemussel have been discovered. Mussel survey data are being used to develop rangewide landscape-level habitat models to aid in the search for additional populations of this species.

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USGS fishery technician Jeff Cole surveying for freshwater mussels in the Upper Delaware Scenic and Recreational River.

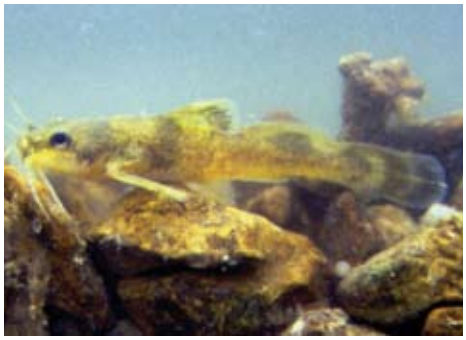
Photos by Don Hamilton/USGS

Neosho Madtom: A Small Fish with Complex Problems

By Mark Wildhaber

The Neosho madtom (*Noturus placidus*) is a small catfish endemic to the mainstems of the Neosho and Cottonwood rivers in Kansas and Oklahoma and the Spring River in Kansas, Oklahoma, and Missouri. Much of the species' historical habitat has been inundated or isolated by reservoirs and low-head dams Additional habitat has been degraded by in-stream gravel mining, feedlot operations, historical lead-zinc mining, sedimentation, and flow manipulation. In 1991, the U.S. Fish and Wildlife Service (FWS) listed the Neosho madtom as threatened.

Neosho madtoms occupy riffles of pebble and gravel bars and feed at night on larval insects (Wildhaber 2006). Recruitment of young-of-year (YOY) to the adult population occurs annually when the previous year's adults begin to disappear. Neosho madtoms spawn in nests constructed under large objects. Spawning occurs from May through July



Neosho madtom

A low-head dam on the Upper Neosho River, Kansas.

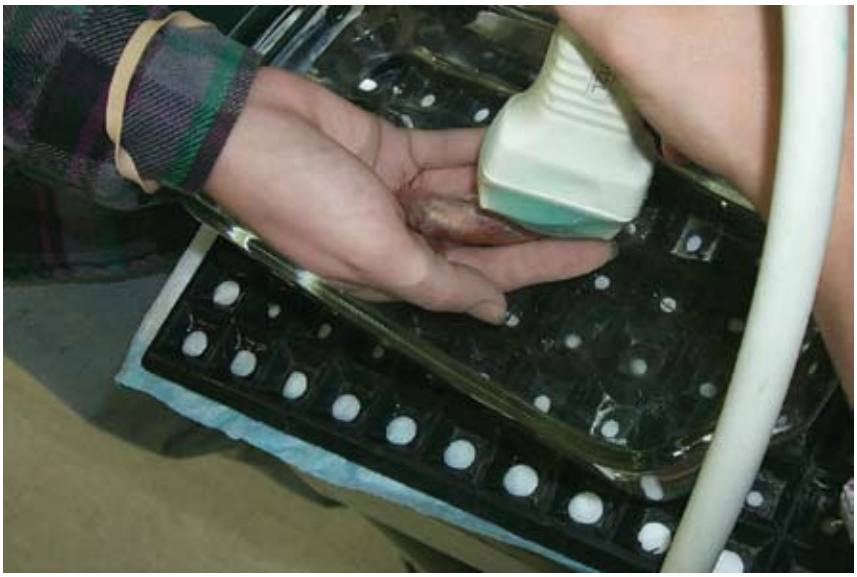
as temperatures approach 77°F (25°C). Male parental care has been observed in the laboratory and lasts 8 to 9 days.

In 1993, the Columbia Environmental Research Center (CERC) of the U.S. Geological Survey (USGS) began a study to assess effects of historic zinc-lead mining on Neosho madtom populations (Wildhaber 2006). The work, expanded to address issues associated with the ecology and recovery of Neosho madtoms, continues today. Its success is due to collaboration with, and funding from, partners that include the FWS; Environmental Protection Agency; universities in Missouri and Kansas; Kansas, Missouri, and Oklahoma state natural resource agencies; Army Corps of Engineers; and many private landowners. The study has provided much needed information regarding the relationship of habitat, flow, and contaminants to Neosho madtom populations. Work on low-head dams has demonstrated localized effects on not only Neosho madtom populations but the entire aquatic ecosystem (Tiemann et al. 2004; Gillette et al. 2005). Analysis of long-term population trends demonstrated a strong relationship between water regulation patterns and survival and recruitment of Neosho madtoms (Wildhaber 2006). Spring River research and modeling demonstrated that fish community patterns are related not only to presence of heavy metal contamination but also lack of high-quality habitat and food availability (Wildhaber 2006). Additionally, CERC research extended the known distribution of the Neosho madtom in Spring River to Willow Creek in Kansas (Wildhaber 2006) and demonstrated that competition with other species was not likely limiting Neosho madtom populations (Wildhaber 2006).

In 1996, researchers at Emporia State University in Kansas successfully spawned Neosho madtoms (Wildhaber 2006). More recently, our laboratory research demonstrated relationships between light, temperature, and flow and Neosho madtom reproductive behavior, including how Neosho madtom select nesting sites (Wildhaber 2006). We used highly innovative approaches, including time-lapse infrared videography, underwater cameras, and simulated winter conditions to assess laboratory stimulation of reproductive development, and medical ultrasound to validate gender and estimate fecundity over several annual cycles. Twenty-one pairs of Neosho madtoms reproduced and provided the first visual record of madtom spawning (Albers and Wildhaber 2002).

This experimental tank equipped for controlling temperature, flow, and photo-period in Neosho madtom research is monitored by external and underwater cameras.

USGS



USGS

A researcher uses ultrasound to determine the sex and reproductive condition of Neosho madtoms.

This research has provided natural resource managers with critical information needed to recover the Neosho madtom, and it is being used by the Army Corp of Engineers to assess the benefits of low-head dam removal and the potential impact of increased water storage. The CERC continues to work with the FWS on population status and trends, the University of Kansas on population genetics, and the Peoria Tribe of Indians of Oklahoma on developing hatchery facilities for Neosho madtoms for the Tribe's reintroduction efforts. Although the madtom is a small fish rarely seen or appreciated by the public, its status reflects the overall health of the aquatic community. By addressing the needs of the Neosho Madtom, all aquatic residents of these streams will benefit.

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Invasive Plants and Pollinator Interactions

by Diane L. Larson

Walking through a North Dakota mixed-grass prairie on a sunny June morning reveals an abundance of blooming forbs and the busy insects that rely on the floral rewards. Native plants are not the only ones offering pollen and nectar, however. Invasive plants, which often occur in monotypic stands (stands of a single species), can provide a dense source of sustenance for insects that rely on floral resources. To a human observer, a stand of the invasive forb leafy spurge (*Euphorbia esula*) can seem alive with the buzzing of flies and bees, all attracted by the pollen-laden anthers and sweet drops of nectar that glisten in the sun.

Although invasive plants often compete with native plants for resources such as light and nutrients, they also may attract pollinators away from native flowers. On the other hand, a dense stand of flowering invasive plants may attract more pollinators to the area and, in the process, enhance pollination of neigh-

Theodore Roosevelt National Park, North Dakota.

USGS

Butterfly on a spurge.

boring natives. However, if insects are carrying a mixed pollen load when they visit native flowers, they may deposit pollen of non-native species, rather than the pollen needed by the native plants for reproduction.

In addition to potential effects on native plant reproduction, invasive plants also may influence pollinator communities. For example, insects that can best exploit the floral structure of invasive plants might be favored, or the density of shoots and rhizomes may limit nesting sites for some ground-nesting insect species. These concerns take on added importance as pollinators continue their world-wide decline.

Over a two-year period, my colleagues Ron and Margaret Royer and I have studied the effects of one invasive plant species, leafy spurge, on pollination of its native neighbors and on the insect communities that visit native flowers. Our study site was the South Unit of Theodore Roosevelt National Park in western North Dakota. Here, the native prairies have been protected for more than 50 years, but leafy spurge has been making its way across the park since the 1970s. We focused on six native species that were abundant and had floral morphologies (flower shapes) that varied from legumes with hidden nectaries and anthers (purple locoweed [*Oxytropis lambertii*] and American vetch [*Vicia americana*]), to species with dish-shaped flowers and obvious pollen and nectar (prairie flax [*Linum lewisii*], yellow sundrops [*Calylophus serrulatus*], and scarlet globemallow [*Sphaeralcea coccinea*]), to the bell-shaped flowers of blue bellflower (*Campanula rotundifolia*).

A fly visits a spurge.

All bloomed at the same time as leafy spurge and occurred both within spurge stands and in non-infested areas.

Of our findings, two are of particular importance to people interested in endangered species. First, stigmas collected from native flowers in infested areas typically had significantly less conspecific pollen (pollen from the same species) than those collected in non-infested areas. This was true in both years of the study. We found very little leafy spurge pollen on the stigmas of native flowers. Non-conspecific pollen was actually less abundant on the stigmas of native flowers in infested areas than in non-infested areas, likely because the diversity of plant species was lower in infested areas. Native flower morphology had no effect on how much conspecific pollen they received.

Second, despite a general increase in visits by native bees (family Halictidae) in non-infested areas between the first and second year of our study, visits in infested areas were down substantially over the same time period. We don't know the reason for this difference; however, it may be related to habitat requirements of the bees or to aspects of the floral community that we did not measure. Flies (family Diptera) were the most common visitors to leafy spurge in both years, so it did not seem likely that native bees were being lured away from the native flowers by leafy spurge.

The management implications of our study are twofold. Because we intentionally chose abundant native species for our study, conspecific flowers were always available within the foraging range of the pollinators. We suspect that the

decline in conspecific pollen on stigmas in infested areas will be greater in uncommon or rare species that have fewer local plants of the same species flowering concurrently. We can imagine a scenario in which rare native perennials persist for a number of years without successfully reproducing, resulting in a form of "cryptic extinction"; in other words, without reproduction, the species disappears as the remaining plants grow old and die. In addition, the year-to-year variability in insect pollinator populations, along with the difficulties in identification, present challenges to monitoring. Many years of data will be required to detect population trends in the presence of high variability.

The good news, at least in the northern Great Plains, is that leafy spurge is beginning to decline, largely as a result of the flea beetles (*Aphthona* spp.) that have been released as biological control organisms. In many (unfortunately, not all) previously infested sites, native plants are again dominant. In assessing the need for restoration of these previously infested sites, we encourage managers to look not only at the vegetative composition, but also at the reproductive success of the native forbs that rely on pollinators. If seed production is limited, it may suggest the need for active restoration of pollinator communities before the ecosystem can fully recover.

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Bee in a cactus flower.

Identifying Roadblocks to Recovery

by J. Christian Franson

Knowledge of wildlife health-related issues is critical to the restoration of many endangered species. Since the establishment of the National Wildlife Health Center (NWHC) in the mid-1970s, its pathologists have conducted more than 8,500 necropsy evaluations of endangered species carcasses to identify causes of mortality. Although birds comprise the major species group investigated at NWHC, a variety of taxa, including individuals of nearly 1,000 endangered mammals and over 900 amphibians and reptiles, also have been examined.

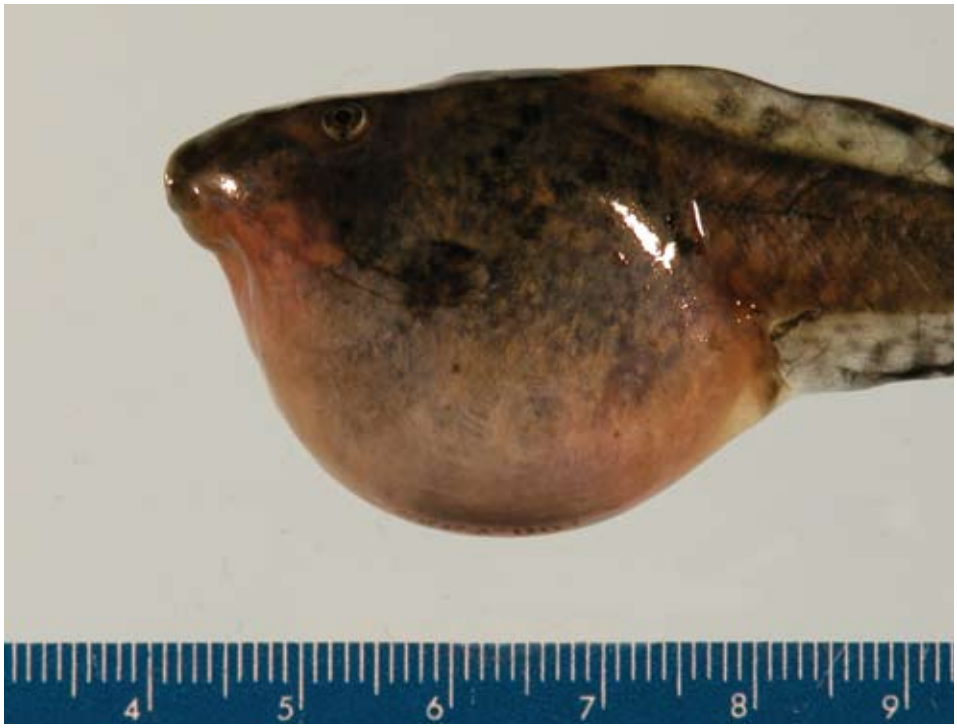
The NWHC is a U.S. Geological Survey facility in Madison, Wisconsin. Data gathered from cause of death determinations are interpreted by NWHC scientists, providing a resource to address existing and emerging health issues of listed species, and forming a basis for recommendations in recovery plans

Necropsy of a whooping crane at the USGS National Wildlife Health Center.

Nathan Ramsay/USGS

and management actions. The NWHC conducts most of its work throughout the U.S. and six freely-associated states and territories in the Pacific Basin. However, NWHC scientists are also asked to consult on problems abroad, such as the recent identification of mortality and population declines of endangered vultures in Pakistan associated with feeding on dead livestock that had been treated with an anti-inflammatory drug (see http://www.nature.com/nature/journal/v427/n6975/full/nature02317.html).

For many years, the NWHC has investigated disease in high-profile species, such as the bald eagle (*Halieeatus leucocephalus*), gray wolf (*Canis lupus*), red wolf (*C. rufus*), southern sea otter (*Enhydra lutris nereis*), whooping crane (*Grus americana*), and Mississippi sandhill crane (*G. canadensis pulla*). Data from these investigations have been used as the foundation for legislation and mitigation practices to reduce mortality from poisonings by pesticides and metals, electrocution and trauma from power line strikes, vehicular impacts, and a variety of infectious diseases that impeded recovery efforts. A brief summary of some health issues of concern for endangered species are listed below:



D. Earl Green/USGS

Mississippi gopher frog tadpole with distended abdomen caused by a yet to be named protozoan.

D. Earl Green/USGS

A Chiricahua leopard frog with reddened feet caused by chytrid fungus infection.

Plague and the black-footed ferret (*Mustela nigripes*) Sylvatic plague, caused by the bacterium *Yersinia pestis* and transmitted by the bites of fleas, has hampered efforts to restore black-footed ferrets to their historical range. Laboratory experiments at NWHC demonstrated that vaccinated black-footed ferrets survived ingestion of plague-infected mice, and field trials have shown that survival of vaccinated ferret kits was twice that of unvaccinated kits. Efforts are being made now to vaccinate all black-footed ferret kits released as part of the recovery program. Plague can also decimate black-tailed prairie dogs (*Cynomys ludovicianus*), the ferret's preferred prey. Experimental trials at the NWHC indicated that more than 50 percent of immunized prairie dogs survived plague transmission from four to five flea bites. The NWHC is currently testing an improved vaccine in prairie dogs and evaluating appropriate baits for field use.

Diseases of amphibians and reptiles In recent years, the NWHC has diagnosed various viral, bacterial, fungal, and parasitic diseases affecting endangered amphibians and reptiles. One of the most severe is chytrid fungus (*Batrachochytrium dendrobatidis*), which has caused amphibian mortality

Nathan Ramsay/USGS

Necropsy of a gray wolf at the USGS National Wildlife Health Center.

associated with population declines in many areas of the world. (See examples in http://www.fws.gov/endangered/bulletin/2008/bulletin_spring2008.pdf.). A recently discovered disease, caused by a yet to be named protozoan, also has affected amphibians in the eastern U.S., including the Mississippi gopher frog (*Rana sevosa*).

Humpback chub (*Gila cypha*) Surveys by the NWHC, in collaboration with the Arizona Game and Fish Department and the USGS Grand Canyon Monitoring Center, have revealed the presence of the Asian fish tapeworm (*Bothriocephalus acheilognathi*) in the Little Colorado River, the primary remaining spawning area of the endangered humpback chub. Although all fish in the Little Colorado were infected, the humpback chub hosted 54 percent of the tapeworm infections. It is unknown if the parasite has contributed to the decline of the humpback chub population, but experimental infections at NWHC of the endangered bonytail chub (*Gila elegans*), a close relative of the humpback, resulted in increased mortality and decreased growth. Surveys by NWHC have found the Asian fish tapeworm in four of eight tributaries of the Colorado River, information that should be valuable for evaluating potential fish relocation projects within the canyon. Because the tapeworm has been found in the warmer tributaries of the Colorado River, it will be important to monitor water temperature changes and any effects temperature control devices at the Glen Canyon Dam might have on the spread of this parasite into the main stem of the river.

Pacific marine species

The NWHC's Hawaii Field Station (HFS) was established in 1992 to provide technical assistance, diagnostic services, and disease surveillance support for wildlife health issues in Hawaii and the Pacific. In recent years, the HFS has devoted increased emphasis to such marine species as corals, urchins, fish, sea turtles, and marine birds. The HFS routinely works with the Fish and Wildlife Service, National Marine Fisheries Service, and the State of Hawaii (among many other agencies) to accomplish its mission. Recent activities include:

- **Laysan duck (*Anas laysanensis*)**: The HFS collaborated on an interagency project involving translocation of the Laysan duck from Laysan Island to presumed former habitat on Midway Atoll National Wildlife Refuge, providing help in identifying and understanding mortality factors and monitoring the health of translocated ducks (see http://www.fws.gov/endangered/bulletin/2007/2007_highlights.pdf).
- **Green sea turtle (*Chelonia mydas*) tumors**: The HFS is collaborating with the National Marine Fisheries Service to investigate the possible causes of green sea turtle fibropapillomatosis (FP), a tumor disease affecting threatened green turtles in the Pacific. A herpes virus is associated with the disease, and turtles with FP are immuno-suppressed, but it is unknown if the virus causes FP. Current efforts include the development of tests to detect the virus in the host and the environment.

- **Disease of corals:** Corals are subject to a variety of diseases that have contributed to the decline of coral reef cover in some areas of the world. The HFS is evaluating biomedical methods to assess the health of coral, including *Acropora palmata*, which has been proposed for listing under the Endangered Species Act. Working collaboratively with the Fish and Wildlife Service, National Park Service, National Oceanic and Atmospheric Administration, and others, the HFS has led reef health surveys targeted to understanding the pathology and pathophysiology of coral diseases in the Pacific Basin.

The NWHC will continue its support of the Endangered Species Program by serving as a resource for diagnostic services and consultation on wildlife health problems. Please visit our website (http://www.nwhc.usgs.gov/) for further information.

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The NWHC's Hawaii Field Station is investigating diseases of corals in the Pacific Basin.

Thierry Work/USGS

Restoring Endangered Mussels

by Richard Neves

North America is the global center of freshwater mussel diversity, but over-exploitation and extensive human-caused habitat alterations have led to the extinction of about 30 species and the listing of 70 others as endangered or threatened. Recent advances in the discipline of aquaculture provide opportunities to apply captive reproduction techniques to conserve and restore imperiled mussel species in remaining habitats in the United States.

Research on freshwater mussel propagation is not new, however. In 1914, the U.S. Bureau of Fisheries (forerunner of the Fish and Wildlife Service) established the first freshwater mussel propagation facility at Fairport, Iowa, in

A sampling of endangered mussels that reside in the Clinch River.

Jess Jones

response to the over-harvest of mussel shells for a booming pearl button industry. Although this station on the banks of the Mississippi River provided more than two decades of biological research and a wealth of information on mussel biology and ecology, the staff was unable to develop reliable methods for producing and culturing juvenile mussels to a size suitable for release into the wild.

The destruction of the laboratory by fire and the advent of plastic buttons ended mussel research for nearly 50 years, until passage of the Endangered Species Act in 1972 and the listing of numerous mussel species. Recovery plans for these threatened and endangered species recognized the requirement for life history information, as well as the need to develop propagation methods and technology to augment declining populations. Propagation is also used to reintroduce populations into historical habitats to promote species recovery.

Working cooperatively with the Water Resources Division of the U.S. Geological Survey (USGS) to identify suitable reaches of river for restoration, and with the Fish and Wildlife Service field offices in Virginia and Tennessee and state natural resource agencies to provide permits and guidance on priority species, a propagation assessment was completed by these cooperators in 1990. Research on propagation methods for these species began in the early 1990s at the Virginia Cooperative Fish & Wildlife Research Unit, a field station of the USGS, leading to the establishment of the Freshwater Mollusk Conservation Center (FMCC) at Virginia Tech University in Blacksburg.

Using the results of 15 years of previous graduate student research projects and the financial support of a host of state and federal agencies, the first successful captive propagation of an endangered mussel species, the tan riffleshell (*Epioblasma florentina walkeri*), occurred in summer 1997 in the Hiwassee River, Tennessee. From this humble beginning, the discipline of mussel propagation has blossomed to involve a diversity of facilities, states, and species.

Nick King

Hua Dan, Laboratory Manager of the Freshwater Mollusk Conservation Center at Virginia Tech, holds a batch of propagated juvenile mussels to be released to the river.

The propagation protocol at FMCC begins with the collection of gravid (pregnant) mussels from field sites that are targeted for augmentation with cultured juveniles. Once into the laboratory, the females are held in recirculating culture systems until their larvae, called glochidia, are mature and ready for release. One of the unique life-history adaptations of freshwater mussels is the need for a fish "host," during their early life stages. The glochidia temporarily attach to fish, allowing mussels to distribute themselves upstream and downstream and among watersheds. Many mussels will attach only to certain fish species.

Juveniles cultured at high densities attach themselves to each other with byssal threads (stong filaments by which mussels attach themselves to surfaces).

Hua Dan

Richard Neves

Juveniles are tagged prior to release to monitor survival and growth.

Before the female mussels release their glochidia in the lab, the appropriate fishes are collected from various streams to provide hosts for the parasitic larvae. Glochidia are removed from the gravid females by hypodermic syringe and placed in tanks under aeration. When the fish are added, the mussel larvae attach themselves to the exposed gills of their hosts. After an adequate exposure period, the host fish are removed and placed in aquaria while the larvae transform in to juvenile mussels. This process typically requires about 2 weeks. During this period of transformation from parasites to free-living juveniles, the glochidia undergo a complete metamorphosis to form the internal organs typical of all mussels and clams.

Once metamorphosed, the juveniles break free of the host fish and drop to the bottom of the tanks, where they are siphoned and placed into culture tanks with flowing water and a thin layer of sediment. The newly metamorphosed juveniles are fed unicellular algae cultured at the propagation facility and delivered to the young mussels at the proper amounts for growth and development. Water and sediment are changed periodically to maintain environmental quality during this sensitive early development stage. Juveniles grow slowly in the first few months, then faster once feeding and digestive systems are fully developed. They can be released after several weeks or months of age, but greater age and size enhances their survival in the receiving streams. Larger juveniles receive numbered tags glued to their shells to allow researchers to collect growth, mortality, and distribution information.

Following the establishment of the FMCC at Virginia Tech, other propagation facilities have been developed in 12 states in the East and Midwest. Some of these facilities are located at state and federal fish hatcheries (for examples, visit http://www.fws.gov/endangered/bulletin/2007/ES_Bulletin_02-2007.pdf), while others are affiliated with educational institutions. By the end of 2007, nearly 7 million young mussels of various species had been released into streams and rivers of the Mississippi and river basins of the eastern U.S.. The growing success of culture methods and facilities dedicated to freshwater mussel propagation provides a vital new tool for mussel recovery and conservation.

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Conservation Genetics and Species Recovery

by Ed Pendleton,
A. G. Vandergast, and
T. L. King

Recent advances in molecular genetics have proven to be extremely useful in efforts to conserve imperiled species. Genetics data are used to identify appropriate units of management (e.g., populations, metapopulations), effective sizes of breeding populations, population mixing rates, and other variables. These data help managers make decisions about which populations to preserve, whether to move individuals from one site to another, how to breed species most effectively in captivity, and even, in some cases, what taxonomic classification is most appropriate. Many U.S. Geological Survey (USGS) Science Centers and Cooperative Fish and Wildlife Research Units have developed capabilities in genetics research. The two case studies that follow illustrate how USGS geneticists are assisting managers in recovering species on the brink.

Key Largo Woodrat

The Key Largo woodrat (*Neotoma floridana smalli*) is confined to a single small population in less than 2,225 acres (900 hectares) of tropical hardwood forest in southern Florida. Listed as endangered since 1984, the survival of the Key Largo woodrat is threatened by development (it does not do well in urban areas) and predation by feral cats and other animals. Predictions of sea-level rise and storm surges associated with hurricanes suggest that climate change will also challenge the woodrats' survival in its specialized habitat on Key Largo.

The danger to the Key Largo woodrat is so high that managers and scientists settled on captive breeding as the most likely means of preventing extinction and promoting the subspecies' recovery. Geneticists at the Leetown Science Center in West Virginia, working in collaboration with the Fish and Wildlife Service's South Florida Ecological Services Field Office and Walt Disney World's Animal Kingdom, developed a captive breeding program that maximizes genetic diversity, thereby minimizing problems that may arise from inbreeding. A suite of genetic markers was identified and screened, which allowed genetic "fingerprinting" (genotyping) of over 140 wild Key Largo woodrats. The genotypes were then analyzed to identify appropriate paired matings for two captive colonies.

Determining the population size and genetic diversity of wild Key Largo woodrats has not been easy. With any endangered species, developing a non-lethal, minimally invasive method of obtaining DNA is highly desirable, so researchers created a method to extract DNA from woodrat scat, or feces. Because woodrats, like many wild mammals, are infested with ticks, a second method of obtaining DNA involves removing ticks to extract, amplify, and analyze the woodrat DNA contained in their blood meal.

Breeding this mammal in the controlled environment of the Disney Animal Kingdom facility has also presented challenges. Females may or may not accept

Key Largo woodrat

USGS

D. Parsick, USD

***The endangered fairy shrimp* Branchinecta sandiegonensis.**

the male rats that researchers select for them as genetically appropriate mates. On occasion, the females intimidate, injure, or kill the male, and males may injure each other.

Despite these difficulties, 18 offspring resulting from captive breeding have been produced, genotyped, and introduced into the captive breeding program. The unique genotype of each individual will be used to monitor any woodrats returned to the wild gene pool at Key Largo.

Fairy Shrimp in Southern California

Fairy shrimp are small crustaceans that inhabit seasonal wetlands such as vernal pools, desert playas, and wet meadows. Because they are adapted to living in temporary wetlands, many species can complete the aquatic portion of their life cycle in a matter of days or weeks. During the dry season, embryos encapsulated in hard cysts lie dormant in pool sediments for months or even years (Figure 3). Of the approximately 50 species known in the U.S., five that occur in California are federally listed as endangered or threatened, mainly due to habitat loss. This is especially true in southern California, where over 98 percent of historical vernal pool habitat has been lost to urban development.

In southern California, the endangered San Diego fairy shrimp (*Branchinecta sandiegonensis*) and the threatened vernal pool fairy shrimp (*Branchinecta lynchi*) overlap in distribution with a more common species, the versatile fairy shrimp (*Branchinecta lindahli*). These three closely related species can be distinguished by appearance during their adult stage. However, adults are present only when pools have been filled for a sufficient length of time, which, in drought-prone southern California, can happen rarely or in some years not at all.

Developing a method to distinguish *Branchinecta* fairy shrimp species in their cyst stage provides two advantages. First, it allows listed fairy shrimp to be detected over a much wider time frame. Second, sampling cysts from vernal pools during the dormant dry season is less destructive to other species, particularly the specialized plants that characterize these sensitive habitats. (Southern California vernal pools are also home to five federally listed plant species.) Cyst identification may allow listed species to be detected on project sites earlier in the planning process, and cysts may be a better target for surveys and long-term monitoring at protected and restored sites.

Working closely with researchers at San Diego State University and University of San Diego, USGS geneticists at the Western Ecological Research

Obtaining blood from a Key Largo woodrat for DNA research.

Center's San Diego Field Station have developed a genetic assay that can be used to isolate DNA from fairy shrimp cysts and to screen the DNA to distinguish among species. This assay method provides a fast and accurate method of identifying *Branchinecta* cysts from southern California vernal pools. While it was designed to distinguish among the three *Branchinecta* species present in southern California, it could be modified to assay other regional *Branchinecta* species assemblages.

More generally, using genetic methods to differentiate among the fairy shrimp taxa may be appropriate when species that are similar in appearance occur in the same habitats or when physical differences are only apparent in particular life stages. Genetic identification can aid recovery efforts by allowing the presence or absence of listed species to be determined quickly, so that appropriate management actions can be applied in a timely manner.

These examples describe two very different applications of genetic information, yet both apply novel techniques to aspects of endangered species recovery. They represent just a small fraction of the genetic and molecular research ongoing within USGS research centers (http://biology.usgs.gov/genetics_genomics/conservation_genetics.html, and http://fresc.usgs.gov/products/fs/fs-2006-3108.pdf). The field of conservation genetics continues to evolve at a rapid pace. As data collection and analysis methods improve, we are progressing from single gene studies towards more genome-wide approaches, allowing both a deeper understanding of the processes that regulate genetic variation within species and a greater ability to conserve species in peril.

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A vernal pool located on the Miramar Marine Corps Air Base in San Diego County, CA, photographed during the wet and dry seasons.

Meeting Information Needs for Endangered Species

by Jennifer Pollock

The National Biological Information Infrastructure (NBII), a unique resource coordinated by the U.S. Geological Survey (USGS), provides easy access to data and information about the Nation's biological treasures. It links diverse, high-quality biological databases, information products, and analytical tools maintained by NBII partners and other contributors in government agencies, academic institutions, non-governmental organizations, and private industry. The focal points for its biological and technical expertise are "nodes" organized by geographic region or theme. The nodes deliver scientific information to a vast community of users, including resource managers, researchers, academia, and the public.

The NBII supports the conservation of threatened and endangered species through a series of projects and activities. Here are some examples:

Mid-Winter Bald Eagle Survey

Delisted in 2007 as a recovered species over most of its range, the bald eagle (*Haliaeetus leucocephalus*) has been studied extensively for many years. One of the long-term data sets for this species is the Midwinter Bald Eagle Survey. Its purpose is to monitor the status of bald eagle wintering populations in the contiguous United States by estimating national and regional count trends overall and by age class. Each January, several hundred people count bald eagles along standard, non-overlapping survey routes. Since 2005, the NBII has worked with scientists from the USGS and Army Corps of Engineers (which coordinates the survey) and technical experts at Oregon State University to provide a standard method of entering data collected each season. We provide access to the raw data and summary trend information from 1986 to 2005, based on 178,896 observations of eagles during 8,674 surveys of 746 routes in 43 states. This information is on the Web at (http://ocid.nacse.org/nbii/eagles/).[1]

The Oregon silverspot butterfly (*Speyeria zerene hippolyta*) is listed as threatened.

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Butterflies and Moths of North America

Pollinators play a crucial role in sustaining agricultural production and biodiversity around the world by enabling plants to reproduce. Bees, bats, birds, butterflies, moths, and other species perform these economically and ecologically vital functions every day. Unfortunately, many butterfly and moth species have been declining, due in part to the loss of habitat, including migratory pathways and nectar sources. Twenty-four species of butterflies and moths have been listed under the Endangered Species Act (Figures 1 and 2).

Attempts to reverse this trend are underway, but successful butterfly and moth conservation efforts have been limited by access to distribution data and other important information. Information about habitat requirements are scattered in the technical literature, which is difficult and time-consuming to access. In 2006, the Mountain-Prairie node of the NBII (http://mpin.nbii.gov) and the Big Sky Institute at Montana State University (http://bsi.montana.edu) launched the Butterflies and Moths of North America Web site (www.butterfliesandmoths.org), which contains the most comprehensive online distribution record of butterfly and moth species available for this region. [2] More than 225,000 records and 3,600 species are accessible via the Web site through dynamic distribution maps, checklists, images, and species accounts that are generated for users.

Tracking Fish Disease

Along the Pacific Coast of North America, from the Sacramento River in California to Kodiak Island in Alaska, an often fatal disease called the infectious hematopoietic necrosis virus (IHNV) has caused severe outbreaks among stocks of salmon and trout, including those listed as threatened or endangered. The virus has been identified from wild, farmed, and hatchery fish in the last 40 years. Over 600 IHNV isolates (viral particles) from Washington, Oregon, Idaho, California, Alaska, and British Columbia have been genetically analyzed. As a result of this genetic typing, dramatically different patterns of diversity and evolution in IHNV have been observed.

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Another threatened butterfly, the Bay checkerspot (Euphydryas editha bayensis), occurs in San Mateo and Santa Clara counties, California.

For many years, the data and information on IHNV were contained in an independently managed database and in associated paper documents. Each record had to be entered centrally, and managers in the field had to submit requests for data from the repository. To help catalog the data available on these isolates, the NBII Pacific Northwest Information Node and its partners developed the IHNV Fish Virus Database interface. The new interface allows fish health managers and researchers to dynamically access information about strains of IHNV within various watersheds and fish culture facilities. This will assist in comparing emerging strains of IHNV. The database can be accessed at (http://gis.nacse.org/ihnv). [3]

Southern California Data Integration Project

Southern California is one of the most biologically diverse regions of the world. It contains more than 75 federally listed plant and animal species that inhabit a wide variety of habitats from below sea level to more than 10,000 feet (3,050 meters) above sea level. There are also numerous species that are state-listed and many more that are species of concern. In collaboration with the Fish and Wildlife Service and California Department of Fish and Game (CDFG), the NBII has made previously inaccessible species occurrence data -- such as amphibian data collected before and after the 2003 fires -- available via the Internet. The CDFG serves this data on the NBII California Node via the Biogeographic Information and Observation System Web site (http://bios.dfg.ca.gov). This information enables federal and state biologists to make decisions based on the best available information, thus enhancing the conservation mission.[4]

These examples are just a sampling of the many information resources for the public, resource managers, and policy-makers that are just a few keystrokes away through the NBII. Visit us on the Web at (http://www.nbii.gov).

[1] Steenhof, K., L. Bond, and L. L. Dunn. 2008. The midwinter bald eagle survey results and analysis 1986-2005. U.S.Geological Survey, National Biological Information Infrastructure, and Northwest Alliance for Computational Science and Engineering. Available on-line at http://www.nacse.org/nbii/eagles. May 30, 2008.

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[3] Kurath, G., Emmenegger, E. 2006. The Infectious Hematopoietic Necrosis Virus (IHNV) database U.S.Geological Survey, Western Fisheries Research Center and National Biological Information Infrastructure; and Northwest Alliance for Computational Science and Engineering. Available on-line at http://gis.nacse.org/ihnv/ . May 30, 2008.

[4] Calif. Dept. of Fish and Game. 2008. Biogeograpic Information and Observation System (BIOS). Retrieved May 30, 2008 from http://bios.dfg.ca.gov

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BOX SCORE

Listings and Recovery Plans as of November 28, 2008

GROUP	ENDANGERED U.S.	ENDANGERED FOREIGN	THREATENED U.S.	THREATENED FOREIGN	TOTAL LISTINGS	U.S. SPECIES W/ PLANS
MAMMALS	70	256	14	20	360	57
BIRDS	75	179	15	6	275	85
REPTILES	13	66	24	16	119	38
AMPHIBIANS	13	8	11	1	33	17
FISHES	74	11	65	1	151	102
SNAILS	64	1	11	0	76	70
CLAMS	62	2	8	0	72	70
CRUSTACEANS	19	0	3	0	22	18
INSECTS	47	4	10	0	61	39
ARACHNIDS	12	0	0	0	12	12
CORALS	0	0	2	0	2	0
ANIMAL SUBTOTAL	449	527	163	44	1,183	508
FLOWERING PLANTS	572	1	143	0	716	631
CONIFERS	2	0	1	2	5	3
FERNS AND OTHERS	26	0	2	0	28	28
PLANT SUBTOTAL	600	1	146	2	749	662
GRAND TOTAL	1,049	528	309	46	1,932*	1,170

TOTAL U.S. ENDANGERED: 1,049 (449 animals, 600 plants)
TOTAL U.S. THREATENED: 309 (163 animals, 146 plants)
TOTAL U.S. LISTED: 1,358 (612 animals**, 746 plants)

* Separate populations of a species listed both as Endangered and Threatened are tallied once, for the endangered population only. Those species are the argali, chimpanzee, leopard, Stellar sea-lion, gray wolf, piping plover, roseate tern, green sea turtle, saltwater crocodile, and olive ridley sea turtle. For the purposes of the Endangered Species Act, the term "species" can mean a species, subspecies, or distinct vertebrate population. Several foreign entries also represent entire genera or even families.

** Seven U.S. animal species and five foreign species have dual status.

ENDANGERED
Species
BULLETIN

U.S. Department of the Interior
Fish and Wildlife Service
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