August 2013

Stewards of the Natural World:

GIS for National Parks

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Introduction

When man began to understand the devastating effects of human actions on natural earth systems, he reacted with a new concept: conservation. This era began with the preservation of significant, unique examples of ecosystems, perhaps best exemplified by Yellowstone and Yosemite National Parks. This was followed by much preservation of dramatic and remnant pieces of ecosystems.

For all its successes, conservation was not without its problems. We were preserving significant, unique, dramatic, and remnant pieces, but we were still losing ecosystems.

The fragmentation issue is huge in an era where landownership and development preclude us from preserving all the pieces needed to make a complete, natural ecosystem. But humans are incredibly smart and have an amazing array of technologies available to extend their abilities. We may not be able to *restore* complete ecosystems, but we now have the scientific and technical ability to *manage* and *design* them.

"You and I are living in a world where we're going to have to move from simply conserving places to actually being proactive and creating healthy places," says Jack Dangermond, president of Esri. With the help of geographic information system (GIS) technology, we are at the dawn of a new era in man's relationship with the environment. As we move from simply conserving and preserving our natural spaces to actively managing and designing them, we are redefining what it means to be masters of our environment.

—Matt Artz, Esri

Creating a National Park from the Bottom Up

The Democratic Republic of Congo's Lomami National Park and GIS

Three rivers surround 40,000 square kilometers of mysterious forest in the heart of the Democratic Republic of Congo (DR Congo). Until very recently, it was unexplored. It has no airstrips; its paths are without bridges. No four-wheel vehicles can come even to the sparse settlements, which are limited to the area's periphery. In 2007, an expedition—made up of conservationists with experience from exploration and wildlife inventory in other parts of DR Congo—entered this forest situated between the basins of the Tshuapa, Lomami, and Lualaba Rivers. The TL2 project, as it is now known, was led by Lukuru Foundation researchers John and Terese Hart, who set out to survey large mammals and human activity and now are promoting the creation of a protected area in this, one of the world's last unexplored tropical forests.

The TL2 project mission is to build effective conservation, from a village base to national administration. It is a locally based project, built on the diplomatic and field experience of the Harts and a cadre of Congolese field biologists with whom they had worked on previous projects. More and more local people have joined the project, bringing the advantage of long experience in the forests, languages, and cultures of the TL2. Their combined observation and diplomatic skills are critical for the scale of coverage and tying results together to give the products needed for enduring conservation. Since 2007, these teams have

The lesula monkey (*Cercopithecus lomamiensis*), a new species of monkey documented by TL2 project researchers in the middle of Lomami National Park.

surveyed the forest by walking over 5,000 kilometers of compass-directed inventory tracks.

From the beginning of their surveys, the Harts sought GIS support to explore; document; and, eventually, define the area for conservation. An innovative partnership was developed in 2007 with Canadian Ape Alliance, a nongovernmental organization based in Toronto, Canada. Nick January, a volunteer GIS application specialist with the alliance, directs the collaboration with Lukuru's TL2 project through an Esri Conservation Grant, which has been generously supported since 2005. Fully equipped with multiple ArcGIS for Desktop, ArcGIS Spatial Analyst extension, and ArcPad licenses, the Harts are now able to capitalize on an existing mapping system that documents, stores, analyzes, and provides end products in support of their conservation efforts.

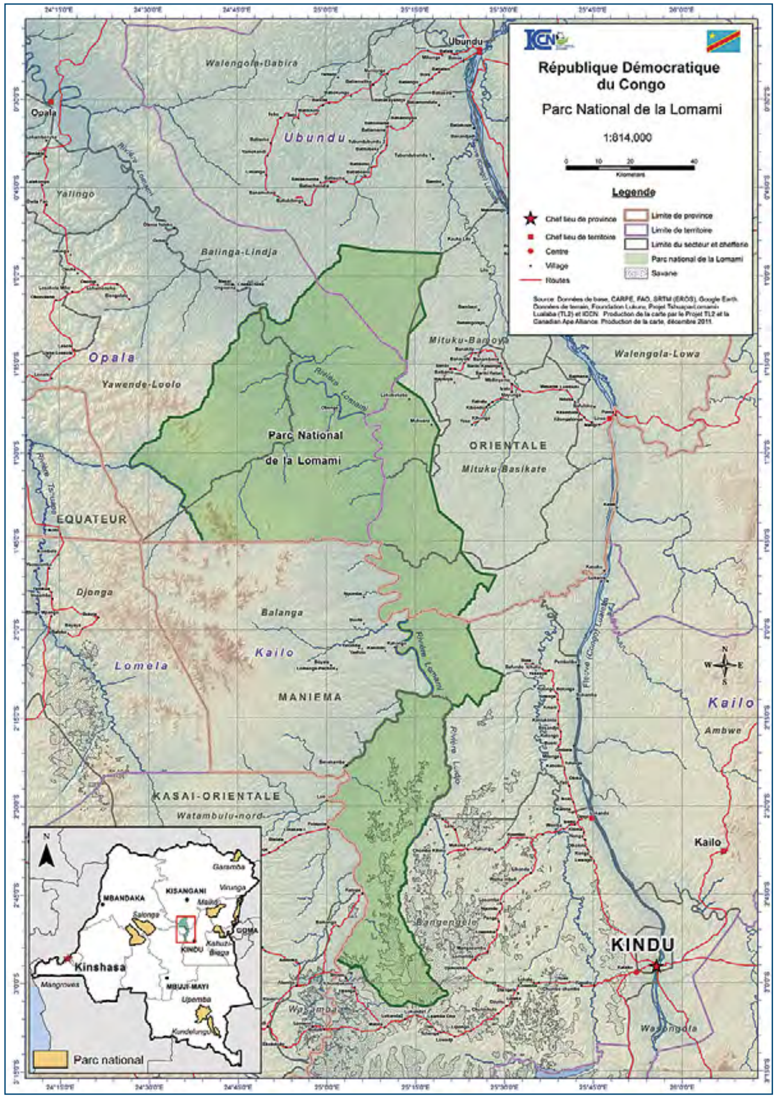
The development of an accurate and comprehensive basemap—an essential tool—was a daunting challenge. How could the TL2 teams accurately map a proposed protected area in such a remote and inaccessible region of central Africa?

It quickly became apparent that the available data was inaccurate and would have limited use for the scale of the TL2 project. For DR Congo, digital basemap data was restricted to widely distributed, publicly available national shapefiles (including transport, vegetation cover, river networks, political boundaries, protected areas, and elevation data). To successfully delimit the newly explored area, an early focus for the TL2 GIS was a complete overhaul of local geospatial data for the basemap.

GPS field data from multiple reconnaissance surveys was being rapidly collected and added to a growing volume of TL2 data (spreadsheets, databases, KML files, field notes). This stream of invaluable data was collected on the comprehensive and collaborative Lukuru/Canadian Ape Alliance GIS platform for TL2. The TL2 contributors learned a routine for documenting, storing, maintaining, editing, and analyzing the geospatial data so that final cartographic products would become more sophisticated and precise for what had recently been unexplored, inaccessible forest.

As TL2 field data became available, January worked on creating a more reliable basemap. To eventually get a delimited map of the proposed protected area, all map features needed to be digitized, including river networks, villages, and roads that had long since turned into footpaths. These were logical park boundaries. This background work included the use of Arc Hydro to create watersheds and drainage patterns, the incorporation of GPS field data to accurately map settlements, and the use of satellite imagery to further confirm location accuracy and content. Older maps and legal documents were used to correctly lay out internal political boundaries.

The Esri Conservation Grant expanded as the TL2 project added staff and ArcGIS expertise. Esri's technical and administrative



Proposed Lomami National Park, Democratic Republic of Congo.

support from both US and Canadian offices became critical to the GIS operation. Not only was a smooth integration and analysis of volumes of field data from a variety of sources possible but so too was a seamless transfer to web-based platforms, such as ArcGIS Online. With Esri software licenses and training materials, it was possible to have multiple installations under dispersed field working environments despite many hardware malfunctions.

In five years, the TL2 project has made important progress toward establishment of Lomami National Park. Exploration has led to the definition of boundaries for the remote park; these are delimited through the incorporation of GIS technology and Esri support. Surveys have resulted in previously undocumented populations of bonobo chimpanzees, okapis, elephants, monkeys, and Congo peacocks. One of the most important discoveries of the TL2 project has been the documentation and confirmation of a new monkey species living in the park area, the lesula monkey (*Cercopithecus lomamiensis*), an event that garnered international attention for the species, as well as Lomami National Park.

Once the park is officially established, the TL2 project will continue to monitor wildlife populations and hunting in the region. It will conduct conservation outreach programs in town centers, villages, and state capitals. The project will also train local people and students to protect, monitor, and promote conservation in Lomami National Park and in the DR Congo overall. With collaboration from the Congolese parks authority, outside experts will be able to visit and experience this extraordinary region and continue its exploration, documentation, and preservation.

For more information, visit bonoboincongo.com or www.great-apes.com.

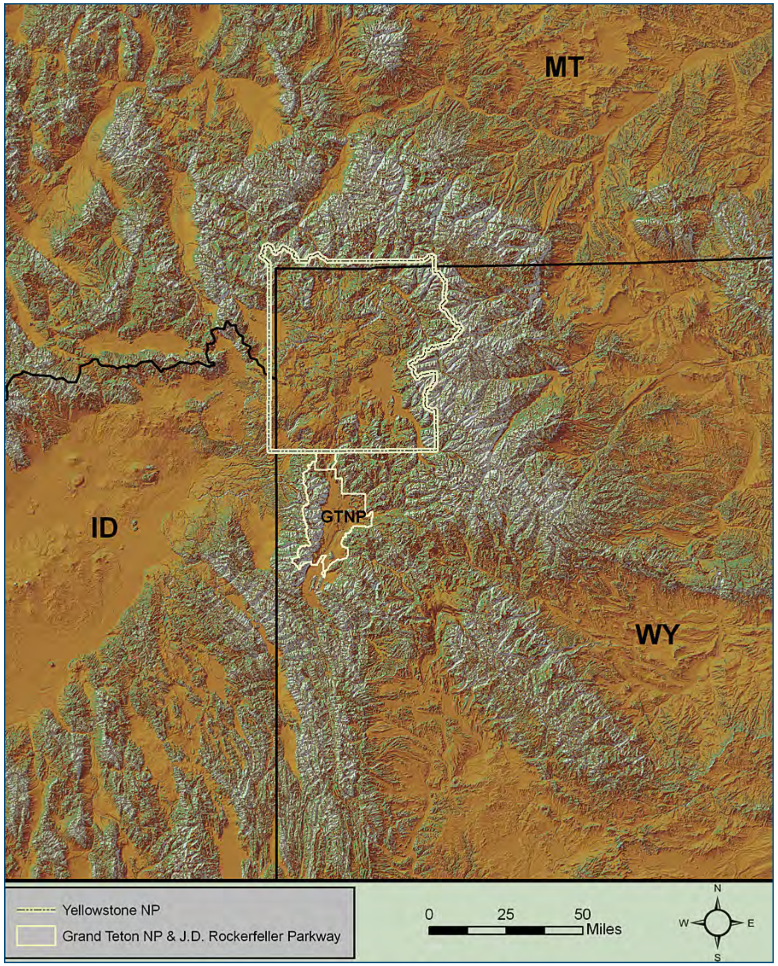
(This article originally appeared in the Winter 2012/2013 issue of *ArcNews*.)

Where the Wild Things Are in Yellowstone Park

A Science-Based Approach to Collaborative Decision Making at Ecosystem Scales

The human history of the Yellowstone region can be traced back to an undesignated time in tribal oral history more than 11,000 years ago, when many groups of Native Americans used the park as their home, hunting ground, and source for gathering medicinal plants. These traditional uses of Yellowstone lands continued until the first explorers and trappers of European descent found their way into the region, recounting tales of a bountiful land full of natural wonders where "fire and brimstone" gushed up from the ground. In March 1872, President Ulysses S. Grant signed into law a congressional act making Yellowstone the first national park in the world, an area so extraordinary that it was set aside and protected in perpetuity for the enjoyment of future generations. Thanks to its early designation and protection, Yellowstone is one of the few remaining intact large ecosystems in the northern temperate zone of the earth.

In recent years, managing these ecosystems has become increasingly challenging. Drought, wildfire, habitat fragmentation, contaminants, invasive species, disease, and a rapidly changing climate have begun to threaten human populations, as well as native species and their habitats. To plan for this uncertainty, a dedicated group of ecologists is using ArcGIS, statistical analyses,



The greater Yellowstone ecosystem.

and a GeoDesign workflow to measure the impact of potential land-use change before it happens.

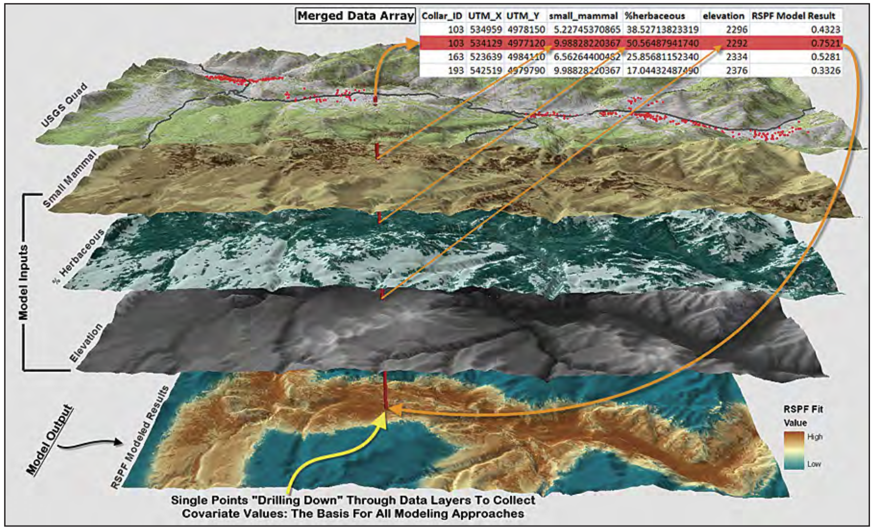
Ecological Forecasting

The Yellowstone Ecological Research Center (YERC), a private, nonprofit organization located in Montana, spends much of its time conducting long-term, large-scale, collaborative ecological research and education in concert with both public and private organizations. Historically, that work has relied heavily on ArcGIS to help organize, analyze, and visualize data on the health and status of native species and the land and water that sustain them.

Simulating ecological system dynamics is a complex undertaking. The sheer volume, variety, and complexity of geospatial data have grown exponentially in recent years, requiring the development of new tools and efficient workflows to help decision makers spend more time on the issues without having to sort through data. More importantly, decision makers need to be able to synthesize this data into standardized, transparent, and defensible information to support the management needs of today while preparing for the needs of tomorrow. And that means having a repeatable process, a core tenet of scientific inquiry.

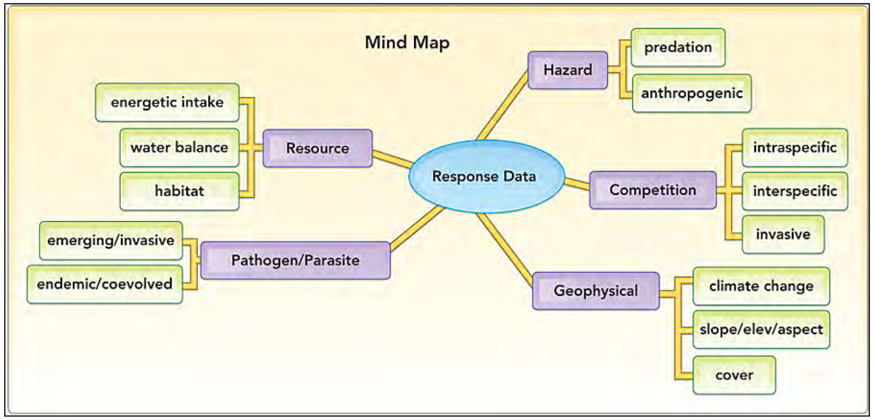
To support the entire process of ecological forecasting, YERC ecologists, statisticians, and GIS analysts created the Ecosystem Assessment, Geospatial Analysis and Landscape Evaluation System, known as EAGLES, which is essentially GeoDesign at an ecosystem scale. EAGLES is an integrative workflow architecture that organizes vast amounts of historic spatial data, some covering the entire United States, with modeling routines to create predictive ecosystem and species models. ArcGIS is a key component of EAGLES, providing a mapping platform to make the data easily understandable to decision makers.

The workflow begins with the assembly of experts having a strong knowledge of the organism of interest, including physiological drivers, feeding habits, predator/prey relationships, competitive interactions, and habitat. Additionally, this effort can integrate pathogens, parasites, or other hazards. These experts



When all data is referenced in a common coordinate system, the referential link gives the scientist or manager the ability to investigate all the various interdependencies of a single point to all other data, increasing the efficiency and quality of the inquiry.

help develop a conceptual model of key issues and management objectives. The conceptual modeling process begins with a verbal description of important relationships between the species of interest and its environment. The verbal description is then used to help select a set of hypothetical drivers to be considered for inclusion in the model. The environmental variables (i.e., covariates) and their relationship to the species of interest (i.e., response data) are referred to as a narrative model using a mind map.



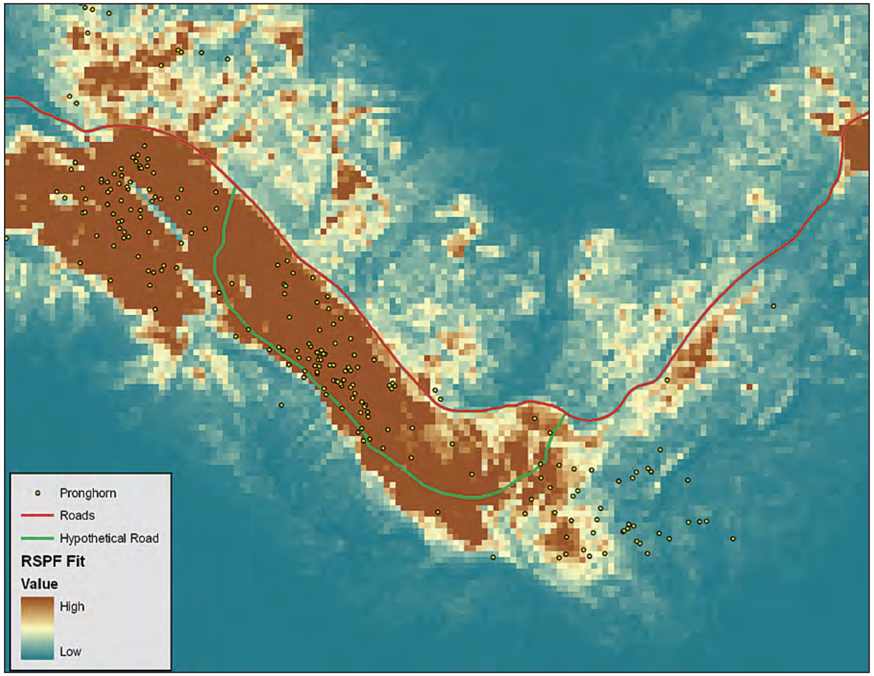
A mind map is a quick way to display potential factors affecting variation in a focal species response, for example, the health and vitality of a population. The mind map could be based on present-day data or legacy datasets, either of which helps visualize the narrative model, which can get rather complex. The narrative model will eventually be used to create a quantitative model to support statistical analytics, which occur later in the workflow.

One of the park's pronghorn antelope.
(Photo courtesy of Hamilton Greenwood.)

The Case of the Pronghorn Antelope

For example, the Yellowstone pronghorn antelope (*Antilocapra americana*) faces a suite of risks characteristic of small populations with geographic/demographic isolation, low abundance, and low recruitment. Decision makers need a management plan based on demographic monitoring of abundance, especially species vitality rates. This study focused on demographic monitoring, especially recruitment and survival; ecological interactions, especially predation rates and recruitment; and habitat assessment.

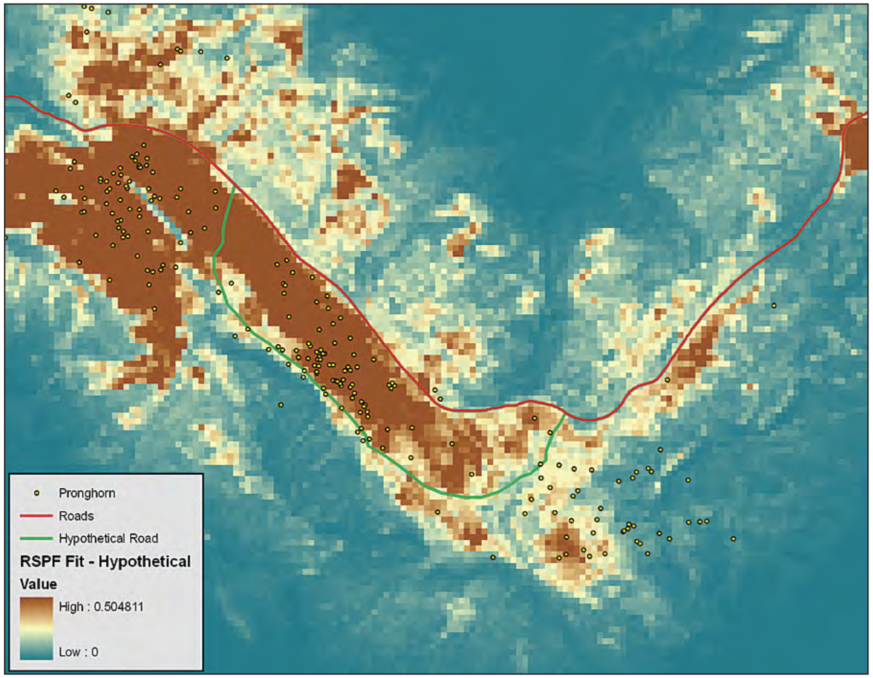
The issue assessment resulted in the creation of two narrative models, one representing birthing arenas and another for resource selection (involving the identification and use of viable habitats). In this case, species vitality could be explained by forage availability, predator intensity, geophysical context, and climatic variables. For example, the more rain, the more food, and the more newborns, the healthier the population might become.



The map displays a portion of the original resource (RSPF) model showing predicted habitat use for pronghorn in Yellowstone National Park. The Swap tool was used to apply the resource model to a hypothetical road addition (shown in green).

Information Needs

Once the narrative models have been created, the next step is the identification and gathering of relevant datasets that could answer questions regarding road impacts, predator impacts, and range condition impacts on pronghorn antelope. A few of these datasets are elevation, topographic complexity, land cover, predation, and distance to roads.



The new prognostic RSPF model output for pronghorn indicates that pronghorn would be excluded from portions of their original selected habitats.

In the case of the pronghorn antelope study, the species observations included 762 telemetry fixes from 26 collared animals from May to July of 2005. The spatial extent of the analysis was defined by this data in combination with expert knowledge of known habitat use. The spatial resolution for all environmental data was a 100-meter grid produced by resampling the data as appropriate.

Analysts used various modeling techniques to create forage, herbaceous, sage, soil, and cumulative net primary production (NPP) layers (i.e., process models). Additional models using empirical field data created coyote and wolf intensity of use and small mammal biomass layers. Finally, available space layers were created using one-kilometer buffers around each pronghorn location in which points were randomly generated over that space to simulate potential habitat use. Since the spatial scale at which pronghorn select their habitat was unknown, this process was repeated at three kilometers and five kilometers for comparative analysis.

Examining Alternative Futures—Ecological Forecasting

EAGLES has a tool called the Swap tool that enables users to build alternative scenarios (i.e., change models) using an already constructed model and change only one attribute while holding all else constant to examine the effects of that change on the model. This approach allows a transparent investigation of the changes in levels of treatments, such as geophysical layer alterations, changes in forage availability, or more sophisticated modeled input layer substitutions. The goal is to apply a model that previously "fit" to observed data for a potential scenario in an effort to make projections about the ecological ramifications of a given landscape change (i.e., impact models).

For example, a forecast about the impact of building a new road through a habitat would rely on the input of a new layer that contains the proposed road. The user can then apply the fitted resource model to the new road layer (instead of the original layer) and view the response surface under the changed landscape. Such projections allow a measured assessment of habitat change. Visualization of the resultant surface occurs in GIS, and the resultant equations and models can be examined statistically, as well. The intent is to provide a utility for planning for landscape change.

Humans with Nature

The benefit of the EAGLES toolset is that it streamlines the finding, compilation, and integration of data by allowing the user to identify the geospatial data inputs, region of interest, scale, and a common data resolution—even a temporal resolution—to make it easier to assemble available national datasets into a common georeferenced coordinate system using ArcGIS. Applying such a workflow to standardized datasets across the United States would help propel the adoption of GeoDesign.

Finding solutions to major ecological challenges will require new ways of thinking. It is no longer humans against nature or humans in nature—it is humans *with* nature. Whether it's Yellowstone's pronghorn antelope, grizzly bear populations, or the collapse of Pacific Northwest salmon runs, science and GIS have lifted each of these issues—and many others like them—from subjective opinion and polarization to a place where decisions can be made based on facts.

For more information about the Yellowstone Ecological Research Center, visit www.yellowstoneresearch.org.

For more information on how to put GeoDesign into practice, visit esri.com/products/technology-topics/geodesign.

(This article originally appeared in the Winter 2011/2012 issue of *ArcNews*.)

Afghans Work to Preserve Band-e-Amir National Park Habitats

GIS Technology Plays a Role in the Conservation Quest

Maps created using GIS technology are being used to identify wildlife habitats to protect and other sensitive areas to conserve in Afghanistan, including places such as Band-e-Amir, the country's first national park.

Band-e-Amir is a chain of six deep lakes, situated in a desert area high in the Hindu Kush mountains. They are separated by mineral deposits of white travertine limestone and lie like a jeweled necklace on a woven rug.

Six deep lakes comprise Band-e-Amir, which became Afghanistan's first protected national park on Earth Day in 2009.

With the changing light and moving mountain shadows, these lakes range in color from faint turquoise to intense shades of blue, and their placid glass surfaces mirror the surrounding peaks. Ibex (wild goats) and urial (wild sheep) can be seen roaming along the red cliffs. Afghan snow finches also make the area their home.

Afghanistan's government declared Band-e-Amir, which is one of the most spectacular travertine systems in the world, a national park on Earth Day in 2009. The Wildlife Conservation Society (WCS), funded by the United States Agency for International Development (USAID), played a strategic role in working with Afghanistan's citizens and agencies to open the park, which draws Afghan tourists who swim in the lakes and rent paddleboats. WCS uses ArcGIS for Desktop to develop sustainable resource management plans for the park and other areas throughout the country.

For example, ArcGIS was used to create maps of habitats for ibex, wild cats, and snow leopards. The technology was also used to create a map of biologically significant wetlands and important bird habitats, including proposed protected areas. One of the important bird areas that was identified and mapped was Band-e-Amir.

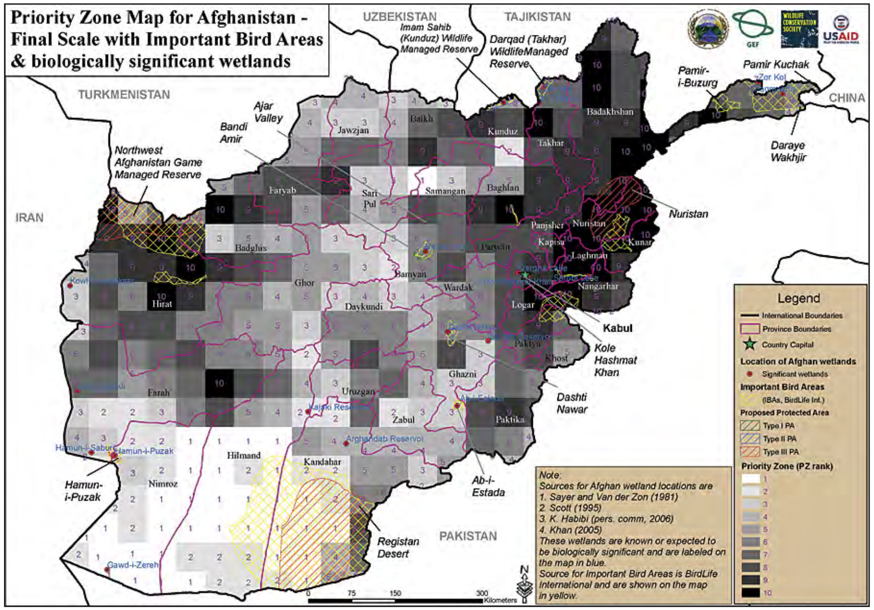
A Hard Sell

In 2011, the country continued expanding its environmental protection policies, which is extraordinary because conservation has not been part of Afghan cultural thinking. This foreign concept has been a hard sell, especially when 80 percent of the population's livelihood is tied to natural resources, such as rangeland, which is used for pasture, and shrubs and timber, which are used for fuel. War has made matters worse by displacing millions of people who have been forced to find shelter, fuel, and food while on the move. Forests have been cut down to obtain wood for fuel, grasslands have been degraded, and soils have blown away. In a country fraught with so many problems, the establishment of a national park is phenomenal.

Building a GIS

WCS consults with Afghanistan's National Environmental Protection Agency, central and local governments, and communities to brainstorm about issues, develop concepts, and build the country's capacity to protect and restore the environment.

In 2006, WCS worked with a team of local citizens to gather terrain, habitat, and species data for a database; process that data in GIS; and create maps to help them better understand and address the country's environmental needs.



Habitat maps, such as this one that shows the location of important bird areas and biologically significant wetlands in Afghanistan, are used by the Wildlife Conservation Society to prioritize the entire surface of Afghanistan and designate areas that should be protected.

(Photos and map courtesy Muhammad Ayub Alavi.)

Muhammad Ayub Alavi, a geologist born in Bamyan Province who works as a WCS conservation specialist in Band-e-Amir, explains how GIS supports conservation plans for his country. "We are using GIS to analyze habitat, ecoregions, and wildlife populations. The government sanctioned us to create the first protected area system plan for the country. GIS shows information that lays the general foundation for our work for the next 25 years, which is outlined in our system plan. We have used it to prioritize the entire country's surface and designate areas that should be protected."

To do this, the GIS team developed and ran different types of models to show where goats and large cats live and migrate and the land that Afghans use for farming and grazing their animals. This helped policy makers and scientists better understand the needs of both humans and wildlife.

Conservation projects are limited by resources, ownership, and government goals, so WCS needed to focus its efforts, taking on one project at a time. Therefore, WCS and scientists assigned values to criteria that helped them decide where to concentrate their efforts. The most important criterion was the variety of species an area could support. Each ecoregion has a distinctive composition and pattern of species distribution because of the area's soil, water, climate, and landforms.

Elevations in the Afghan landscape change rapidly, and that affects water, soil, land, and climate. Therefore, the habitats in the country's ecoregions can contain a wider range of vegetation and wildlife species than, say, a flat expanse of desert. The team assigned priority ratings to the areas that had the widest ranges of biodiversity within the ecoregions of high mountain desert, plain desert, or alpine and sabal pine forest land cover.

Another prioritizing criterion was the endangerment categories assigned to certain animals that roam Afghanistan. At the top of the list is the Marco Polo sheep (*Ovis ammon polii*), which is the

The Eastern Forest Complex, home to snow leopards and several other wild cat species, is a conservation priority.

largest mountain sheep in the world. The snow leopard was also high on the WCS priority list.

WCS used ArcGIS for Desktop to calculate and rank ecosystems and show these areas on maps. Because the maps were going to be used as the foundation for discussing with stakeholders what areas to conserve, WCS experts also factored in security, logistics, budget, and history.

When government policy makers were presented with these findings, they agreed to implement conservation plans at three major sites. First was the Wakhan Corridor, which is part of the Silk Road network between Afghanistan and China. Second was the Hazarajat Plateau, where Band-e-Amir National Park is located. Third was the Eastern Forest Complex, which contains some of the last temperate coniferous forest in the Greater Himalayan mountain range. It is home to the snow leopard and at least five other wild cat species. GIS was extensively used by researchers to analyze change, classify forest cover, and demonstrate forest degradation in that area.

The national government sanctioned Band-e-Amir as a national park, but it is up to the local people to manage it. With funding from USAID, WCS is working with citizens to develop the park's management plan and train rangers and game wardens. WCS has also implemented an environmental education program for schools and works with local communities and central and provincial governments to ensure that wildlife and forestry protection policies are being developed and enforced.

For more information about Esri technology for managing, analyzing, and mapping wildlife data, visit esri.com/conservation.

(This article originally appeared in the Spring 2012 issue of *ArcNews*.)

When Every Second Counts

Yosemite Uses GIS for Coordinating Search and Rescue Operations

By Jesse Theodore, Esri Writer

The Yosemite Search and Rescue team and Chief Ranger Steve Shackelton of Yosemite National Park were selected to receive a Special Achievement in GIS award this year.

GIS has helped the Yosemite Search and Rescue (YOSAR) team improve its methods of operation and has been used successfully in searches for missing persons in Yosemite National Park.

Every year, three million visitors come to Yosemite National Park to enjoy the outdoors. One of the nation's greatest travel destinations, Yosemite provides camping, fishing, hiking, and other activities for guests to enjoy. While most visitors have the time of their lives, a few face the frightening prospect of becoming disoriented or getting injured while hiking the park's many trails.

Each year, Yosemite National Park responds to hundreds of calls reporting missing persons. Most often, a lost hiker or vacationer is found during the first 24 hours. However, when someone is missing for more than 24 hours, multiple search teams are dispatched. Search and rescue operations require a significant, coordinated effort on the ground and in the air. For these incidents, the National Park Service calls on YOSAR, a team of specialists.

YOSAR's skilled search and rescue operators are reknown for their ability to make backcountry extractions of injured hikers and perform climbing rescues off of "big walls," such as El Capitan. In this photo, a rescuer and the partner of a rescued climber are pulled from Big Sandy Ledge on the face of Half Dome.

(Photo by David Pope.)

YOSAR is a group of park rangers, technical climbers, helicopter pilots, and incident management staff who are directed by Keith Lober, the emergency services coordinator for Yosemite National Park.

These skilled search and rescue operators are known around the world for their ability to make backcountry extractions of injured hikers; perform climbing rescues off of "big walls," such as El Capitan; search for missing hikers; and respond to multi-casualty incidents. They work primarily in the park, but are requested by mutual aid management teams throughout the country.

Once activated, YOSAR assembles and deploys ground, technical, canine, and air units and manages the entire incident response process. Managing complex emergency situations requires rapid response capability that ensures a comprehensive, coordinated search is carried out in the fastest possible time frame.

Expanding GIS at Yosemite

Paul Doherty, a park ranger and GIS specialist for the National Park Service, was hired in May 2008 to establish GIS support specifically for search and rescue operations.

"Once I settled in and started working, the GIS needs in the Protection Division were evident and the opportunity to get involved was very exciting," said Doherty.

The National Park Service has successfully used GIS in its Resource Management and Science Division, as well as in its response to wildland fires. Protection Division chief Steve Shackelton envisions applying the same technology and services to all branches of emergency response (i.e., search and

A helicopter rescue technician rappels from Yosemite's contract helicopter H-551.

(Photo by David Pope.)

rescue, law enforcement, disaster management, and structural fire) in the park.

Managing a Complex Operation

Missing person incidents are common in Yosemite. When a hiker is missing or overdue, it requires an initial response known as a "hasty search." These searches are carried out in the first 24 hours in the immediate vicinity where the lost person was last seen. Trail blocks are established to interview possible witnesses and gather information on hiking conditions.

Rescuers carry an injured climber to an awaiting helicopter.

(Photo by David Pope.)

If the person is not found quickly, a large search area of 1–40 square miles is drawn on a map. This area is segmented to create smaller search assignments, and a comprehensive search and rescue case is created.

Finding a missing person in the wilderness is a complex process. Maps are at the core of this process. Incident managers and field teams want to know the coordinates where the person was last seen to determine where they should begin the search. They also want to know about the surrounding landscape so they can safely and efficiently locate, stabilize, and extract victims as quickly as possible.

These search and rescue operations, managed under the Incident Command System, can increase in complexity very quickly. YOSAR members are adept at implementing modern search theory as well as using lessons learned from previous searches.

In 2008, YOSAR wanted to use GIS to quickly and easily print accurate assignment maps that teams would use in the field. To provide more information about the landscape before teams go into the field, these maps use vector layers and raster imagery. In the past, the mapping component of a search required using hard-copy, outdated 7.5-minute quadrangle (quad) maps, transparent Mylars, erasable markers, and—on occasion—limited mapping software.

"It was difficult to keep things organized," said Doherty. "Hard-copy maps and forms are difficult to update and properly archive."

Search teams would sketch their assignments on their maps using erasable markers, a process that had the potential to increase error. Because YOSAR staff members were open to innovation, Doherty could implement novel GIS techniques that have changed how YOSAR operates.

Maps, Data, and Accountability

Doherty built a solid GIS platform for preparation, response, and the postevent analysis of rescue operations, employing ArcGIS Desktop (specifically ArcInfo and the ArcGIS 3D Analyst and ArcGIS Network Analyst extensions). The first priority was coordinating existing GIS resources at the park to build databases and processes that could be activated at a moment's notice.

With GIS in place at YOSAR, Doherty and staff can now

- Supply accurate field maps with search segments outlined.
- Provide aerial imagery and elevation data.
- Show hazards and terrain patterns.
- Record GPS tracks from field teams.
- Load search assignments onto GPS units.
- Build an assignment database to track team deployments.
- Show probability of detection (POD) *[the probability of the missing person being detected, assuming that person was present in the segment searched]*.
- Depict probability of person in area (POA) *[chances that the missing person is in the area being searched]*.
- Plot the locations of known helicopter landing zones.
- Plot the locations of clues as they are discovered.
- Determine observer/communication tower line of sight.
- Generate briefing maps.

A myriad of data is built and maintained by the National Park Service and the YOSAR GIS team. This includes vector data for roads, streams, trails, park buildings, vegetation, and helispot locations. Raster data includes digital elevation models (DEMs), which supply a three-dimensional surface with topographic features; digital raster graphics (DRGs), which are high-quality scanned images of U.S. Geological Survey quad maps that provide contour lines and detailed terrain information; and 2005 National Agriculture Imagery Program (NAIP) aerial imagery.

During a search incident, Doherty works with YOSAR search incident data to generate additional data such as search area polygons; search segments/assignments; clues (i.e., point last seen, footprints, litter, and trail interviews); viewshed analyses; and GPS tracks from helicopters, ground crews, and dog teams.

GIS Gets the Job Done

With each new search operation carried out by YOSAR since the adoption of GIS in 2008, GIS has become more of a key component.

Paul Doherty, a park ranger and GIS specialist for the National Park Service, was hired in May 2008 to establish GIS support specifically for search and rescue operations.

(Photo by Tom Patterson.)

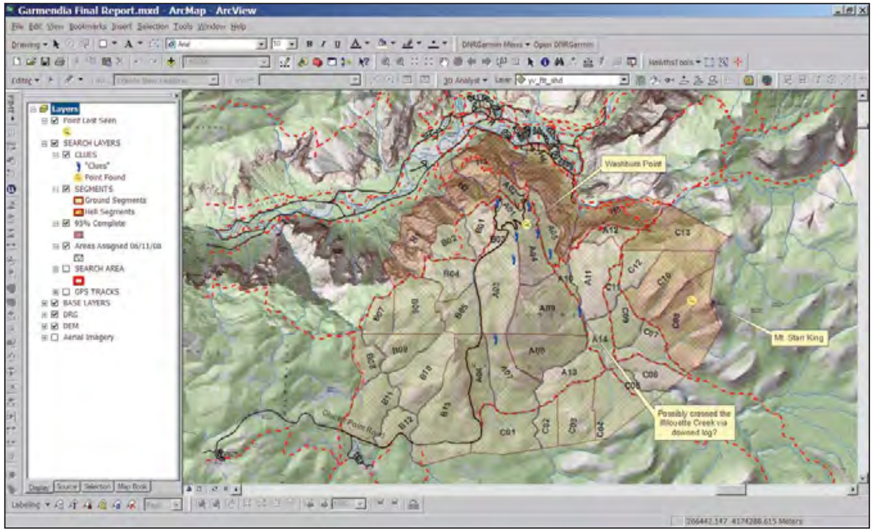
The successful search for Esmin Garmendia illustrates the many uses of GIS by YOSAR. Garmendia, a 23-year-old man who had visited the park with friends, left the parking area and ventured into the woods alone. He was last seen by his friends at about 3:00 p.m. on June 8, 2008. Garmendia's friends returned from their hike, but when he did not appear after some time, he was reported as a missing person. Soon a full YOSAR operation was under way.

At a planning meeting, searchers examined where Garmendia was last seen and where he might have gone. DEM, trail, stream, and vegetation data, as well as local knowledge, was used to generate an appropriate search area. The search area was segmented into manageable and clearly identifiable subsections to ensure a new search area would be covered by ground teams, dog teams, and helicopters each day.

GIS was used to determine where to place teams in the field. Using the same layers that were used to predict Garmendia's travel, teams were strategically placed to best cover their assigned terrain and ensure that the maximum search area was sufficiently covered.

For example, YOSAR used slope data from a DEM of the park to assign technical teams to areas having a slope of more than 45 degrees and dog-assisted ground teams to safer, flatter terrain. In the past, YOSAR staff read the contours on standard quadrangle maps and estimated slope of the terrain. However, with this objective tool for determining slope, decision makers could spend time on other operational, planning, and logistical functions.

Next, a briefing was held to communicate search and rescue operation plans to all teams and individuals involved. Incident action plan (IAP) maps were generated to show possible search areas and list objectives. These 8.5" x 11" maps contain metadata such as map scale, title, author, and the date the data was generated. These maps included the point location where Garmendia was last seen; search buffer zones (created using GIS analysis); and topography generated by overlaying DRGs, DEMs, and imagery layers.



ArcMap project screen shot of the Garmendia search segments, a "clue" database, status of search segments, and Yosemite National Park base data used to create search assignments.

(Map by Paul Doherty.)

Search teams were then deployed. GPS and other data was captured in the field and sent back to the incident command post. Updated maps were generated to reflect where resources were sent, how the search was progressing, and what evidence (if any) was collected and where it was found. Previous manual tracking methods using paper maps lacked any type of objective data capture and required scanning to archive the information in a digital format.

Incident briefing maps were used during daily meetings. These paper maps were 24" x 36" and included data from debriefing forms as well as any significant clues from the clue log. The maps showed hazards for new searches in the field, such as cliffs and steep drainages and dense vegetation, and any updates from the previous day's operations. Numerically labeled polygons showed areas that had yet to be searched. These polygons were overlaid with data on trails, rivers, and other physical features.

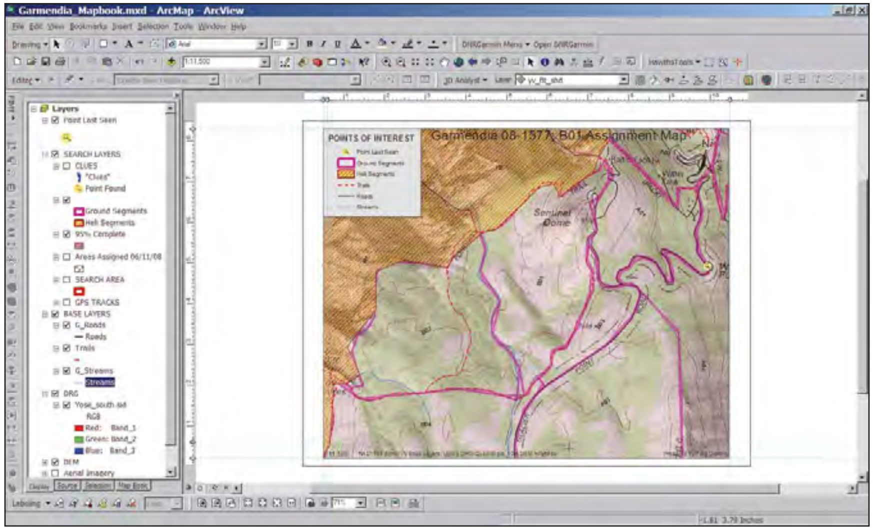
The incident command staff were briefed with maps that showed all areas that were actually searched the previous day and where the new search teams would operate over the next 24 hours. Field teams were provided with new IAPs and 8.5" x 11" assignment maps the next day. These maps included additional information such as declination, a Universal Transverse Mercator (UTM) grid in the correct local datum (North American Datum of 1983), significant landmarks, hazards, and search segment boundaries.

GIS helped during all phases of the Garmendia search operation, which encompassed nearly 23 square miles. It helped coordinate more than 190 ground, helicopter, and dog teams. Fortunately for this hiker, Yosemite had a helicopter available for aerial observation throughout the entire operation. After three days of search and rescue operations, a helicopter located Garmendia from the air. He was found safe and healthy, despite his arduous ordeal.

GIS provided an information platform to map operations, update information, and improve decision making. GIS methods enhanced YOSAR operations through

- Supplanting old paper maps and hand-written notes with digital data capture, management, analysis, and dissemination
- Supplying a standard for measuring or quantifying search variables versus simply supplying map images or approximating map polygons
- Helping document exactly where resources were directed and where to change actions as needed in a real-time search

"GIS supplies powerful tools, but it will not direct a search," said Doherty. "It does not replace the institutional knowledge of veteran search managers and never will. It does, however, allow us to take advantage of analyses that are far more useful than simple hard-copy maps. It helps us perform a search more efficiently, with enhanced team safety, and with a greater probability of returning victims to their loved ones."



ArcMap project screen shot of the Garmendia search segments, a "clue" database, status of search segments, and Yosemite National Park base data used to create search assignments.

(Map by Paul Doherty.)

Doherty is looking forward to continually expanding the use of GIS in search and rescue during his career with YOSAR and collaborating with incident management teams around the globe who are interested in utilizing GIS.

In less than a year, YOSAR's geospatial platform has been used successfully in half a dozen searches. From the peak visitor season in summer to the cold and icy conditions in winter, this platform provides an information-based method for outlining initial search strategies, helps refine the exploration as time progresses, and keeps information continuously flowing from the field to the incident command post and back again. Everyone operates using the same accurate data, which helps find the missing person as quickly as possible. In search and rescue operations, this can mean the difference between life and death.

(This article originally appeared in the Summer 2009 issue of *ArcUser Online*.)

From Maps to GeoDesign

Conserving Great Ape Landscapes in Africa

By Lilian Pintea, Africa Programs, The Jane Goodall Institute

The Jane Goodall Institute (JGI) has been very interested in the evolution of the new field of GeoDesign, which offers the vision and the infrastructure to bring people, disciplines, data, and technology together to not only better describe landscapes but also develop more successful conservation strategies and actions.

One practical application of GeoDesign has been the successful use of geospatial and conservation sciences to inform decisions in the Greater Gombe Ecosystem in Tanzania. JGI greatly improved village land use in this very sociopolitically difficult and historic setting. We were successful not only because of the technology we employed but also because the JGI staff understood human values and decision-making processes that influence landscape change in that particular region. We learned that helping develop the region (e.g., through working together to provide clean water sources, among many projects) opened the door to communities and motivated them to "buy in" to our efforts, creating a window of opportunity to apply conservation science to threatened ecological systems. Some of these programs are discussed in detail below.

At the core of JGI's applied conservation science program is using geography as a common framework to support our projects in Africa by connecting people, their values and activities, and conservation data and developing a shared understanding and vision of landscapes and how they should be changed. This in turn enables us to implement, monitor, and measure the success of those changes for both human and chimpanzee livelihoods.

Jane Goodall with Freud.
(Courtesy of The Jane Goodall Institute.)

We Need to Make More Enlightened Decisions

Time is running out for many endangered species, including our closest living relatives, chimpanzees. Chimpanzee and human populations are part of the same life support system, embedded in ecological systems that are intimately linked and dependent upon ecosystem services to survive. Unsustainable uses of natural resources by humans result in loss of those ecosystem services, with negative consequences for both chimpanzee and human livelihoods. The fundamental problem is that, despite advances in science and technology, we have not yet developed the methodologies to apply these to conservation and make more enlightened decisions about how to achieve a better balance between environmental and economic results.

Fifty years ago, on July 14, 1960, Jane Goodall stepped for the first time onto the shores of Lake Tanganyika and, through her groundbreaking discoveries about chimpanzees in what is now Gombe National Park in Tanzania, opened a new window to the natural world and to ourselves. This unique long-term research continues today with daily chimpanzee data collected by the JGI Gombe Stream Research Center and digitized, stored, and analyzed at the Jane Goodall Center at Duke University.

GIS and Imagery for Clearer Understanding

GIS has been used to georeference and digitize hundreds of thousands of chimpanzee behavior locations and analyze ranging and feeding patterns and relations with habitat characteristics as detected by remote-sensing and field surveys. The use of geospatial data for chimpanzee research was straightforward. Spatial tools and variables derived from GIS and remote sensing were directly used as part of research collaborations to test hypotheses. For example, a vegetation map derived from 4-meter IKONOS imagery helped demonstrate that chimpanzee hunts on colobus monkeys are more likely to occur and succeed in woodland and semideciduous forest than in evergreen forest, emphasizing the importance of visibility and prey mobility. JGI also worked with the Tanzania National Parks to improve the management of the park by using geospatial technology to visualize habitat change, map the park boundary, and support the development of the Gombe National Park Management Plan.

In addition to continuing Jane Goodall's pioneering research, JGI has been accumulating decades of experience and practical knowledge outside protected areas on how to successfully engage local communities and decision makers in the sustainable use of their natural resources. While the technology to map land cover inside and outside Gombe National Park was mostly the same, the way geospatial information was used to inform decisions was very different.

The use of geospatial information to inform decisions outside the park has been more complex. Gombe National Park was created in 1968. The park inherited a history of conflict with the local communities that started in 1943 when the colonial government established for the first time Gombe Stream Game Reserve. In 1994, JGI began working with the local communities outside Gombe through the Lake Tanganyika Catchment Reforestation and Education (TACARE, pronounced "take care") project to seek ways of arresting the rapid degradation of natural resources. TACARE project staff quickly learned that community buy-in was essential for success. Therefore, the TACARE project added agriculture, health, social infrastructure, community development, and clean water components to the range of interventions it employed. These interventions initially focused mostly on areas close to village centers.

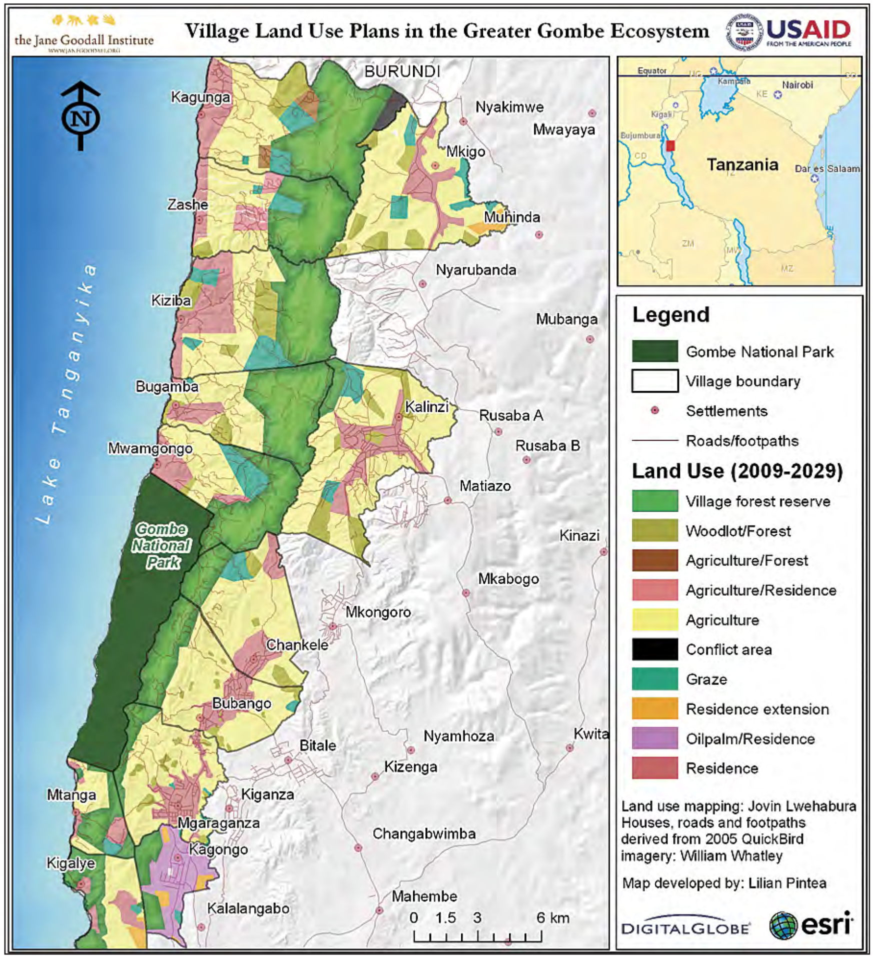
However, forest change detection using Landsat imagery from 1972 and 1999 showed that most chimpanzee habitats outside the park had been in areas away from the village centers and almost 80 percent of it converted to farmland and oil palm plantations. Remote-sensing and GIS analysis led to a landscape approach by focusing conservation efforts geographically on areas away from village centers and on forest patches with the most benefits to chimpanzees. In 2005, adopting the recommendations obtained through analysis of satellite imagery and with funds from the US Agency for International Development (USAID) and other donors, JGI and its partners embarked on a five-year Greater Gombe Ecosystem (GGE) project.

A Conservation Action Plan approach was developed to identify and prioritize conservation strategies. Village land-use planning was identified as one of the top strategies. GIS was used to overlay deforestation layers, historic distribution of chimpanzees and habitats, slope, footpaths, roads, streams, watersheds, density of human structures, and 60-centimeter QuickBird imagery to prioritize a conservation area that, if protected, would substantially increase the viability of chimpanzees inside and outside the park and stabilize the watersheds to support human livelihoods.

Participatory village land-use plans were prepared by the communities according to Tanzanian laws and with full involvement of government and community stakeholders. JGI facilitated the process and provided technical support, including maps and geospatial tools to record and manage spatial data. The planning process followed seven steps and required villagers to settle any existing land disagreements and agree on village boundaries and how land resources located within the villages should be used to meet specific human livelihood needs and environmental objectives.

At the end of the project in 2009, 13 villages within GGE completed their participatory village land-use plans, which became ratified by the Tanzanian government. Local communities voluntarily assigned 9,690 hectares, or 26 percent, of their village lands as Village Forest Reserves. These reserves are interconnected across village boundaries to minimize fragmentation and cover 68 percent of the priority conservation area identified by the GGE Conservation Action Plan.

With renewed financial support from USAID, JGI and partners are now engaged in facilitating community-based organizations, developing bylaws and building local capacity to implement these village land-use plans and restore and manage newly established Village Forest Reserves. The plan is



Participatory village land-use plans were prepared by the communities according to Tanzanian laws.

(Courtesy of The Jane Goodall Institute.)

to use DigitalGlobe imagery continuously to provide detailed information on village land-cover change, such as increases in forest cover in Kigalye Village Forest Reserve, and monitor both new threats and conservation successes.

About the Author

Dr. Lilian Pintea brings more than 15 years of experience in applying remote sensing and GIS to the job of protecting chimpanzees and their vanishing habitats in Africa. As vice president of conservation science at JGI, Pintea directs the scientific department at the institute and conducts applied conservation research in Tanzania, Uganda, the Democratic Republic of the Congo, and the Republic of the Congo.

See also "Harnessing the Power of Our GeoDesign Vision."

(This article originally appeared in the Summer 2011 issue of *ArcNews*.)

A Decade of Success

Combining Geospatial Technology and Problem-Solving Skills

By Michael Winston, Shelley School District

A program developed by an Idaho school district encourages students to use GIS skills to solve real-world problems. Teachers in the Shelley School District have been using GIS technology for a decade. The Solutions program developed by the district exposes students to new technologies and skills that are valuable in the problem-solving process.

A consortium of government agencies, weed control entities, watershed organizations, and interested citizens banded together to stop the spread of leafy spurge (*Euphorbia esula*) to Yellowstone Park.

Shelley School District is located about 20 miles from the Idaho National Laboratory (INL), a national science laboratory. The district's teachers were first introduced to GIS technology at INL, and GIS was a natural fit for the Solutions program. Some of the GIS projects students have worked on over the years include using current census data to redistrict the school board zones, creating maps for the City of Shelley showing fire hydrant locations, and mapping noxious weeds for county and state weed agencies.

Teachers like to involve students in both short-term projects and longer-term projects. Short-term projects help students gain an initial sense of accomplishment, which instills the confidence that will be required for longer-term projects. Long-term projects generally require higher skill levels but can be rewarding for students who persevere.

As successful as these GIS projects have been, teachers were concerned that too many students were passing up opportunities to work with GIS projects, and many students involved in GIS projects were learning advanced computer skills but lacked basic map-reading skills. As a result, the program was restructured. Students are now introduced to mapmaking/map-reading skills at a younger age. For example, students learn how to make simple compasses, how to make maps, how to read topographic maps, and how to use GPS technology in geocaching activities. This introduction exposes more students to GIS and helps them pick up basic skills.

One project, Holding the Line, is a capstone effort that exemplifies the aspirations teachers have for effectively incorporating GIS in the classroom. This project addressed the slow spread of noxious weeds toward Yellowstone National Park. Current weed control measures had not been effective in preventing the spread of one weed in particular: leafy spurge (*Euphorbia esula*). A consortium of government agencies, weed control entities, watershed organizations, and interested citizens banded together to stop the spread of leafy spurge to Yellowstone Park.

Stopping the slow spread of leafy spurge toward Yellowstone National Park.

Rebecca Schneiderhan, who has since graduated and has her own GIS consulting business, was contracted to oversee the distribution of four million beetles as part of a biological control effort started more than 10 years ago. The beetles are effective in controlling leafy spurge but harmless to native flora and fauna. They are released at marked sites that have been studied for years to determine how effective the beetles are in controlling spurge. Schneiderhan was tasked with collecting two million beetles from previous release sites, purchasing two million additional beetles, then releasing all four million beetles in areas adjacent to the Yellowstone Park boundaries. The beetles were successfully collected, and released at target sites, and those sites were mapped.

Much of the beetle collecting and mapping was done using the services of Paul Muirbrook, an individual who established a business that hires high school students and high school graduates to perform various GIS/GPS tasks for local government agencies. Schneiderhan was also assisted by a second grade student who helped collect beetles and map the sites. These sites will be monitored for the next five years to determine the effectiveness of the effort in preventing the spread of leafy spurge.

This project is considered a capstone project for Shelley District's GIS efforts because it provides opportunities to help solve real-world problems and helps students of all ages develop multiple skills. For example, students involved in this project learned about plants (weeds), insects, Yellowstone Park, government agency interactions, and how GPS and GIS technologies can be used. It also provided employment opportunities for both entrepreneurs and summer hires and helped build partnerships between government agencies and schools.

In summary, Shelley School District's efforts to expose students to GIS/GPS technologies have evolved over the years. The district's teachers now attempt to introduce students to mapmaking fundamentals at an early age and seek projects that involve solving real-world problems, encouraging students to use their skills in the solutions of those problems.

(This article originally appeared in *ArcUser Online*.)

National Park Service Follows the Modern Lewis and Clark Trail

Historic Trail Auto Route Road Signs Inventoried with GIS and GPS

By William J. Gribb, Geography Department, University of Wyoming

The courage, determination, and adventure of the Lewis and Clark Corps of Discovery have inspired many to follow its pathway, just not in the same arduous way. Congress recognized the importance of preserving the historic and nation-building significance of the Lewis and Clark Corps of Discovery journey.

The Lewis and Clark National Historic Trail auto route extends from the plains to the Pacific.

In a series of legislative actions, Congress created the Lewis and Clark National Historic Trail, an auto route that follows as closely as possible the water route that the Corps of Discovery traveled in 1804–1806. The 11 states, which Lewis and Clark traversed, designated roads that parallel the actual route taken as the auto route roads. The National Park Service (NPS) worked with the individual states and made available the official signage designating the auto route. Lewis and Clark followed one route on their westward journey and slightly different routes on their eastward return journey, thus creating routes that can be followed with several different roads representing the westbound and eastbound pathways.

In an effort to update, integrate, and computerize the auto route and signage, as well as link the auto route to significant historic, cultural, and landscape features, the National Park Service's Lewis and Clark National Historic Trail group formed a partnership with the Wyoming Geographic Information Science Center (WyGISC) at the University of Wyoming to create a GIS database. The objectives of the project were to construct an accurate location of the auto route; locate and inventory existing Lewis and Clark auto route signs; locate and categorize the significant historic, cultural, and landscape features in close proximity to the auto route; and assess the way-finding capabilities of existing signage. To meet these objectives and create a database that integrates with the current NPS GIS configuration, a combination of ArcGIS Desktop, Wind Image software, and Trimble's Pathfinder Office was used.

Working with the Lewis and Clark NPS group, the WyGISC team identified initial U.S. Geological Survey 1:100,000-scale digital line graph databases that could be incorporated to provide the initial road and hydrology datasets. Census Bureau TIGER files were included for state and county boundaries and the location of the 1,431 places, towns, and cities the auto route crosses. Four states had already produced accurate ArcGIS Desktop compatible shapefiles; the remaining seven states provided only hard-copy maps of the auto route. In the effort to provide one consistent road base file, the Esri StreetMap dataset was incorporated into the project and the auto route layer adjusted to it. The project objective, however, was to locate and inventory the road signs designating the route and signs directing travelers along the route. To accomplish this objective, the team completed a combination of location and data coding using Trimble Pathfinder Pro XRS receivers with data logger and a Ricoh Caplio 500SE GPS camera. The location of each sign was recorded with the XRS unit along with 13 characteristics of the sign, including number and condition of panels, and road characteristics. In addition, the team captured high-resolution digital images of the sign and the surrounding landscape with the Ricoh camera. To assist NPS with integrating the auto route with significant cultural, historic, and landscape features complementary to the Lewis and Clark journey, a total of 607 sites were also recorded using the GPS and digital images.

After 42 days of field data collection, the team needed several months to edit the data and create a system to integrate the auto route with the corrected sign locations and the digital images. With Visual Basic for Applications, a script was developed that created an identification system that linked the sign to the digital image using a combination of route designation, date, and time. This ID system allows NPS researchers to select a sign along the auto route and access the attribute database about the sign, its location, and condition and the digital images of the sign. The same potential is available for all the cultural/historic/landscape sites along the route. Overall, researchers will have access to 1,817 signs, 607 sites, and 10,295 images along the 6,885 miles (11,080 km) of the Lewis and Clark National Historic Trail auto route.

As part of the field collection data, the team captured the types of signs and their conditions and effectiveness characteristics. This allows NPS to not only create descriptive information about all the signs but also provide the ability to query and produce maps of the location of signs based on any of the attributes. For instance, NPS can now determine which signs need repair or maintenance because of vandalism or excessive wear or which signs are obstructed by vegetation overgrowth or some other barrier. This information provides a very cost-efficient means to determine the number of signs needing repair and their location so the appropriate repair teams can schedule the needed action. The digital imagery of the signs provides a mechanism to assess the repairs without going into the field.

As part of the project, NPS wanted the capability to examine and assess the distribution of the auto route signs. Using ArcGIS Desktop analytic capabilities, the clustering of route signs at road intersections and route turns can be examined to determine if the correct combination of signs, densities, and distances is available to direct the traveler along the auto route. In addition, the ability to view the digital images allows NPS staff to assess the signage along the route at potentially hazardous locations.

About the Author

William Gribb, Ph.D., is an associate professor and director of the Graduate Program in Planning at the University of Wyoming and an affiliate researcher at the university's Geographic Information Science Center.

More Information

For more information, visit the Lewis and Clark National Historic Trail Headquarters site at www.nps.gov/lecl/index.htm. Key personnel for this project at the University of Wyoming's Wyoming Geographic Information Science Cenater were William J. Gribb, Scott Lieske, and Phil Polzer.

(This article originally appeared in the Fall 2010 issue of *ArcNews*.)

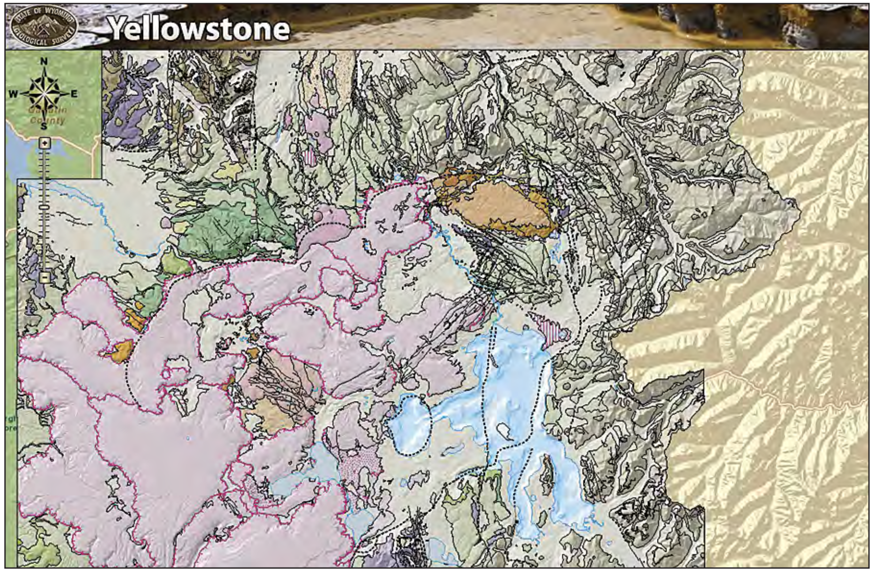
New Yellowstone Website Provides Interactive Maps on Volcanic Activity

By Chamois Andersen, Communications and Public Outreach, Wyoming State Geological Survey

The Yellowstone Plateau in northwestern Wyoming has a long geologic history—earthquakes; expanding and retreating glaciers; rising mountains; powerful geothermal explosions; and cataclysmic volcanic eruptions, the most recent of which was the Yellowstone Supervolcano, which erupted 640,000 years ago. Today, the region is a geologic marvel, with one of the largest remaining ecosystems in North America and the world's largest concentration of geysers. More than six million visitors each year travel to Yellowstone to experience its geologic forces. But how can the Wyoming State Geological Survey (WSGS), charged with providing knowledge on geology and energy resources in the state, and with such an incredible testing ground like Yellowstone, better reach a broad audience interested in learning about the park's geologic past? How can the public better appreciate this geologic wonderland? And what innovative web-based tools can be used to showcase the park and provide knowledge on its geologic history, a story so important to the creation of the Greater Yellowstone Ecosystem?

WSGS created the Yellowstone Geologic GIS Database as an interactive website, providing researchers and students alike with a look into Yellowstone's geologic past and present.

GIS experts and geologists with WSGS and the United States Geological Survey (USGS) collaborated to create a central portal, or clearinghouse, of information on the volcanic eruptions and



The map illustrates the geology, earthquakes, and hydrothermal areas that make up Yellowstone National Park. The website allows users to view layers ranging from past geologic events to satellite imagery, lake bathymetry, and volcano monitoring equipment in the park.

earthquakes that have created the Yellowstone landscape that continues to evolve today.

This project involved first collecting and compiling data related to Yellowstone's geologic past, including GIS datasets; unpublished bedrock and surficial datasets and maps; and seismic catalogs, field data, hydrologic data, and relevant earth science or cultural datasets. These were provided by a variety of state and federal entities and converted into standardized file types and common databases, including shapefiles and KML files, as well as for a geodatabase. The final step for implementation was to provide the public with access to the data via the WSGS website, which includes multiple downloadable formats for a wide array of users. The GIS applications were created using the ArcGIS for Server Web Application Developer Framework (ADF). This application allows USGS and WSGS staff to update maps, graphs, and charts with near real-time data. Scientists can use the data to create figures and plots of real-time information on dynamic hazardous conditions.

"The past and present geologic activity that continues to shape and form Yellowstone is of great importance and interest to scientists, policy makers, and the public," says Tom Drean, state geologist and director of WSGS. "By creating and updating this interactive website, we are providing past knowledge and current information that can be easily accessed by anyone with an interest in this geologic wonderland," he continues.

Norris Geyser Basin is the hottest geyser basin in Yellowstone

Interactive maps illustrate the geology, earthquakes, and hydrothermal areas that make up Yellowstone National Park. The site includes downloadable GIS datasets that allow students and researchers to view layers ranging from past geologic events to satellite imagery, lake bathymetry, and volcano monitoring equipment in the park. The data can also be viewed via Google Earth with 3D visualizations of the area.

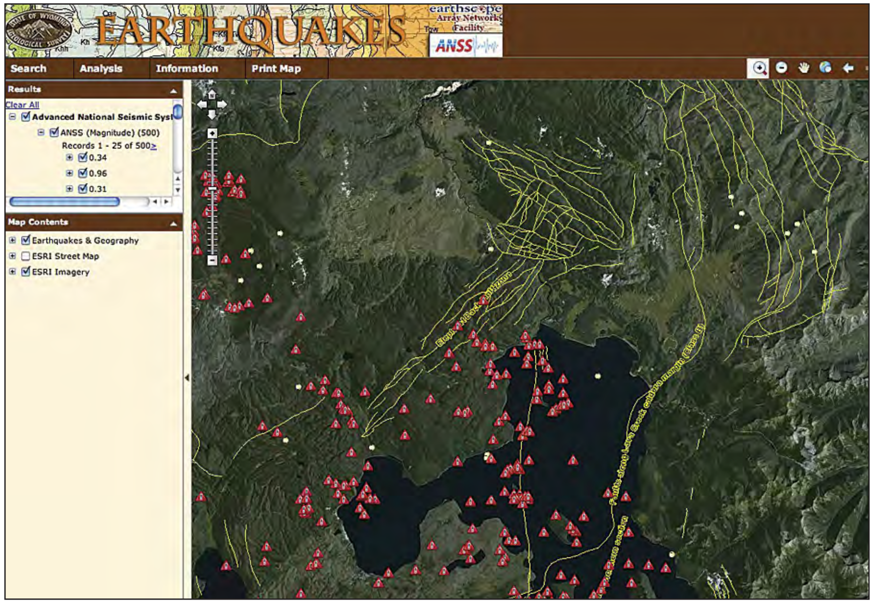
WSGS created the website as an educational information portal, representing a major collaboration between WSGS and USGS staff. "This product is a good example of what can be accomplished when agencies cooperate and work toward a common goal," Drean says.

The WSGS Yellowstone Geologic GIS Database website includes the following:

- More than 20 datasets available to download (individually or combined)
  - High-resolution lidar and digital elevation models
  - Earthquake data (historical and current)
  - Geology (bedrock, surface, geothermal, etc.)
  - Hydrography (bathymetry of Yellowstone Lake)
  - Other information (trails, place-names, boundaries)
- Interactive mapping application
  - Live webcams
  - USGS live earthquake feed
  - Ability to search earthquakes in the park by magnitude and date
  - Print map feature
- Media gallery
  - High-resolution photos of the park
  - USGS videos of the Yellowstone Caldera

The website's main feature is a searchable map of Yellowstone that was created by combining data from a variety of state and federal sources into a single GIS database. The interactive map includes an overlay of colors representing different types and ages of rock. A user can then add various layers to the map, such as topography and imagery (with zoom capability), and even search for earthquakes in the area by typing in a minimum and/or maximum magnitude and the years of interest.

"The flexibility and breadth of information contained on the website allows people to quickly review information that is of greatest interest and use to them," Drean adds.



The Wyoming Earthquake Database allows users to search earthquakes in the park by magnitude and date.

The present Yellowstone Plateau developed through volcanic cycles spanning 2 million years that included some of the world's largest known eruptions. The Yellowstone region includes three calderas: the first cycle caldera formed 2.1 million years ago during the eruption of the Huckleberry Ridge Tuff; the Henry's Fork Caldera formed 1.3 million years ago near the present location of the town of Island Park; and the Yellowstone Caldera formed 640,000 years ago during the eruption of the Lava Creek Tuff—an event that spread ash over much of the North American continent. Since that time, there have been approximately 80 additional but smaller eruptions, such as lava flows. The youngest of these range from 70,000 to 160,000 years old.

"The volcanic events that formed Yellowstone were not the products of many millions of years of geologic change ending many millions of years ago. We are seeing a time scale compressed into only the last 2.1 million years," Drean says. For the Greater Yellowstone Ecosystem, geologists and volcanologists study in detail the latest periods of geologic time, the Pliocene and the Quaternary, covering the last 5 million years out of 4,500 million.

Yellowstone's geologic story also includes earthquakes, such as the Hebgen Lake earthquake of 1959 near West Yellowstone (magnitude 7.5). "This was a major earthquake," says Jacob Lowenstern, scientist in charge of the USGS Yellowstone Volcano Observatory. "It fractured geothermal reservoirs in Yellowstone, creating new geysers and destroying others. Flow rates and temperatures of hundreds of hot springs changed overnight," he said.

Data collection, the use of Esri software and other applications, and the mapping efforts of WSGS are intended to further research on Yellowstone's geologic past and future. "With this web-based tool, we have assembled data from a host of research entities into a single searchable format," Drean says. "This website will be continually updated, providing us with the opportunity to interpret the past and plan for the future of Yellowstone. And if the past gives us a glimpse for what is to come, we know the Yellowstone landscape will continue to change."

About the Author

Chamois Andersen writes and publishes reports for a broad audience concerned about the environment and natural resources. In her current role, she serves as head of Communications and Public Outreach for WSGS. Previously, she worked as a public information officer for the University of Wyoming's Environment and Natural Resources Program, as well as for the California Department of Fish and Game and the Colorado Division of Wildlife.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

Conserving Earth's Gentle Giants

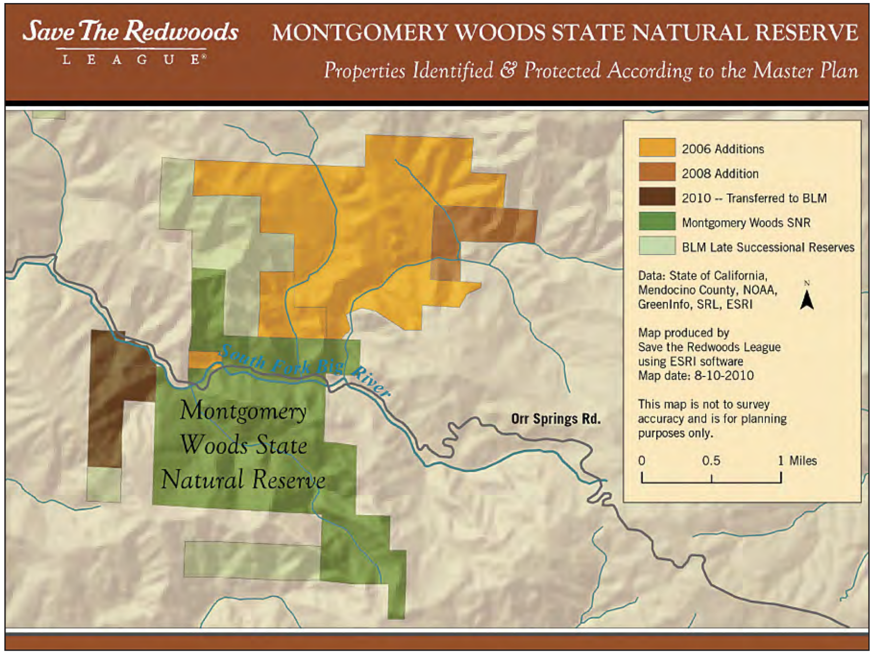
Save the Redwoods League Maps the Future of Important Ecosystem

The logger's saw. Real estate development. Vineyard plantation. Climate change.

All pose threats to California's giant redwood trees, according to the Save the Redwoods League. In 1850, there were two million acres of ancient coast redwood forests in California. Today, fewer than 120,000 acres of these old-growth forests remain, having fallen victim for years to unsustainable logging practices, urbanization, poorly planned development, and road building. Climate change is another concern, and the Save the Redwoods League hopes to answer how it might affect the health of redwood forests and giant sequoias through its $2.5 million research project called the Redwoods and Climate Change Initiative.

To help protect these majestic trees, the oldest of which dates back 2,200 years, the Save the Redwoods League buys land in northern and central California, where the coast redwoods grow. Since forming in 1918, the California-based nonprofit organization has purchased more than 189,000 acres for preservation. Some of the land also includes giant sequoias, as well as upstream acreage of coast redwood forests, which is important to preserve from a watershed standpoint.

In the past, the League bought land based in part on recommendations from concerned citizens who wanted a



In 2006, the Save the Redwoods League doubled the size of the Montgomery Woods State Natural Reserve by purchasing and adding parcels with old-growth Douglas-fir forests and rare oak woodland habitats on them, as shown on this map.

(Courtesy of Save the Redwoods League.)

particular piece of land protected, but it was hard to know the entire picture based solely on word of mouth.

Today, the Save the Redwoods League uses maps, scientific knowledge, more than 90 years of experience, and the latest technology—including GIS—to create detailed regional conservation strategies for redwood forests, parks, and connecting landscapes. Much of the land purchased and protected now lies in Humboldt Redwoods State Park and Redwood National and State Parks, along the coast of Northern California. Many of the League's conservation efforts would not have been possible without GIS, which is used to analyze data about the redwoods, development, nearby watersheds, and rare plants and endangered animals in those areas.

To strategically guide, prioritize, and focus its land protection efforts, the Save the Redwoods League launched the Master Plan for the Redwoods in the late 1990s. As part of this plan, the League used GIS models to identify areas that are important to protect. The models incorporated data on the locations of

- Trails
- Ancient redwoods
- Existing parks
- Habitat for imperiled and sensitive species, such as the coho salmon, northern spotted owl, and marbled murrelet
- Threats to the forest, including residential development, land conversion to vineyards, road building, and incompatible forestry practices, plus many other dangers

The League wants people to experience the redwoods, so if an area contains features that encourage people to visit the majestic trees—such as good hiking trails or beautiful scenery—the area is given a higher rank and has a better chance of receiving public support to protect it. Based on these conservation models, the data is then analyzed using ArcGIS Desktop software, and maps are created and used throughout the organization for deciding what parcels of land to try and acquire, fund-raising appeals, outreach, and resource management.

Access to accurate data is crucial for the League's GIS analysis and mapping. Data comes from public agencies, such as the California Department of Fish and Game, California State Parks, the National Park Service, and the U.S. Forest Service.

Laura Kindsvater, senior conservation planner at the Save the Redwoods League, says the GIS data used in analyses includes

- Rare and sensitive species, such as the northern spotted owl, Pacific giant salamander, Sonoma tree vole, and Humboldt milk vetch
- Fish streams that provide habitat to the threatened or endangered coho and Chinook

- The U.S. Forest Service's existing vegetation data depicting where mature, second-growth forests occur Habitat model data for wide-ranging species, such as the mountain lion, Pacific fisher, and other forest carnivores
- Projected development, roads, and timber harvest plan boundaries

"Combining and analyzing this data using GIS allows us to visually determine which areas are most important for protection," Kindsvater says, "and we can then act on this newfound knowledge."

Old-growth coast redwood forest.
(Photo by Howard King.)

By using GIS to assist in creating the master plan, the Save the Redwoods League has identified land across the entire range of coast redwood forests in California, down to the property level, that rank highly for protection. Based on GIS analyses, the League has created detailed regional strategies that outline land acquisition goals. Now that the League has completed the detailed regional strategies, the organization will implement the master plan and contact owners of higher-ranked land in areas such as the Santa Cruz Mountains, Humboldt and Del Norte counties, coastal Mendocino and Sonoma counties, and the San Francisco Bay area to find out if they are willing to sell their land or work together on a conservation agreement. (An example of a conservation agreement is when a landowner donates or sells the right to develop land to the Save the Redwoods League while continuing to own the property.)

ArcGIS is also helping the League discover more about important ecological characteristics specific to the site of the lands it is working to protect so that it can build a case for the property.

For example, when the League was raising funds to purchase land to add to Montgomery Woods State Natural Reserve in Mendocino County, it used GIS in combination with fieldwork to find out what types of vegetation grew on each piece of property and which of these were rare and targeted for conservation at the statewide level. Several of the properties have native grasslands and Oregon white oak forests on them, which are both a high priority for acquisition by state natural resource agencies. GIS was also used to better understand how each parcel contributes to increased protection of the surrounding Big River watershed, as well as the good health of specific fish populations within the watershed and downstream of the parcels. Since the 1960s, when several large floods in Humboldt County caused massive erosion from logged areas upstream that then inflicted heavy damage to old-growth forests downstream, the League has had a commitment to protecting redwood ecosystems at a watershed scale.

"In addition," says Kindsvater, "we have been able to identify, using GIS, 35 project areas across the state of California that are a priority for protection. Focusing on these project areas allows us to be much more effective as an organization in protecting the last remaining groves of old-growth redwoods, building the viability of parks and reserves, and maintaining and restoring connecting landscapes."

Sixteen of the 35 project areas have been identified as high priority to purchase and protect, allowing the League to further focus its energy. For example, the Coastal Sonoma project area in Sonoma County, located to the west and northwest of Santa Rosa, has been identified as high priority. Sonoma County has a wealth of incredibly beautiful redwood forests, a low percentage of currently protected lands, significant groves of old growth that remain unprotected, and a high potential to provide inspiration and recreation for millions of people who live less than two hours away. Yet these old-growth stands are also threatened by a rapid growth rate in population throughout Sonoma County. Through the master plan, the Save the Redwoods League has learned that there are important lands in the coastal Sonoma region to protect and that the organization must act now to conserve them. It has therefore been investing a great amount of time, energy, and resources in increasing land protection in this region over the last several years, culminating in several large land purchases, such as the Jenner Headlands and Stewarts Point acquisitions.

More Information

For more information, visit SaveTheRedwoods.org.

(This article originally appeared in the Fall 2010 issue of *ArcNews*.)

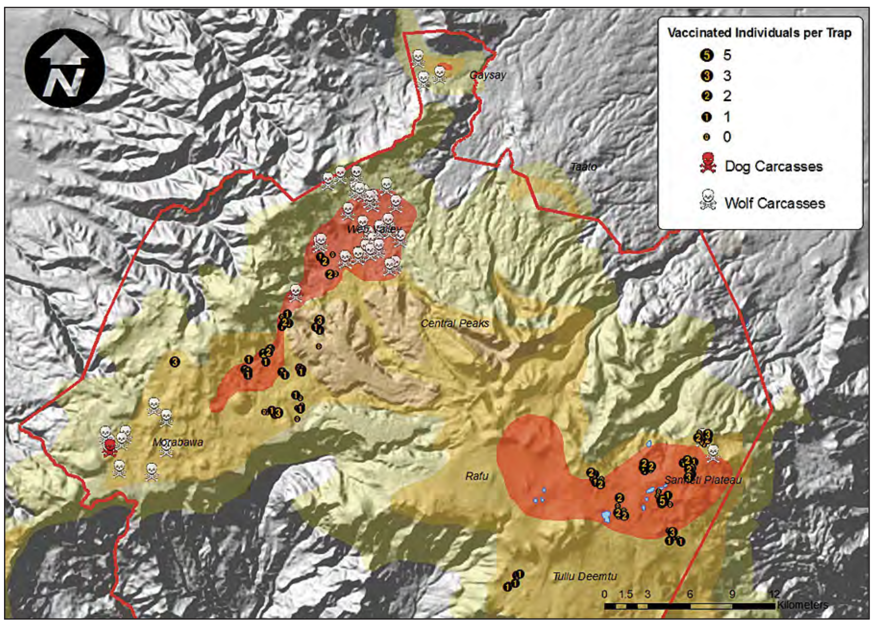
Conservation Group Seeks to Save Rare Ethiopian Wolves

Rabies Threatens Endangered Species in Africa

By Christopher H. Gordon, Graham Hemson, and Anne-Marie E. Stewart, Ethiopian Wolf Conservation Programme

Ethiopian wolves, the rarest canids in the world, face many threats to their survival. One of the most serious comes from rabies, transmitted to the animals from domestic dogs.

To protect the wolves, the Ethiopian Wolf Conservation Programme (EWCP) (www.ethiopianwolf.org), with help from other organizations, operates a rabies vaccination program that uses GIS technology to target the best locations to vaccinate the dogs and wolves that will prevent the spread of the virus.



Overview of BMNP showing all dog and wolf carcasses found.

The Danger the Wolves Face

Fewer than 450 Ethiopian wolves still roam the mountainous regions of Ethiopia, Africa. They live at altitudes of more than 9,800 feet and are only found in seven isolated populations. The largest comprises 250 wolves that make their home in the protected area of the Bale Mountains National Park (BMNP) in south central Ethiopia.

EWCP was founded in 1995 to promote sustainable solutions for protecting the Ethiopian wolf. The organization mainly focuses its efforts in and around BMNP.

EWCP takes a three-pronged approach to saving the wolves: Educating people about the importance of protecting the wolves, monitoring the wolf populations, and vaccinating the wolves and local dogs against diseases.

The Ethiopian highlands, where the wolves reside, have become some of the most densely populated agricultural areas within

Africa. With human development surrounding and encroaching on the animals' habitat, the wolves are confined to small areas and isolated from other wolf populations.

The majority of people living here are pastoralists, and their livestock overgraze and trample the natural Afro-alpine habitat. With the climate warming, the cultivation of crops at high altitudes is becoming more viable and results in the loss of indigenous plant species. This leads to the destruction of habitat for rodents, which are the wolves' main prey.

While the Ethiopian wolf is threatened by habitat loss, and thus prey reduction, persecution, and hybridization, diseases transmitted from the local domestic dog population remain the primary threat to the species. There were rabies outbreaks in Ethiopian wolves in BMNP in 1991–92 and again in 2003–04. This disease is fatal, and in past known cases, it has killed at least 70 percent of wolves in the core infection area. This is obviously a significant threat to an already critically endangered species.

Vaccination Program Gets Under Way

In 1996, EWCP launched a domestic dog vaccination program, aiming to vaccinate 70 percent of the 20,000 dogs living in and around the national park. Theoretically, such vaccinations would curtail the disease and stop it from spreading to the wolves. However, dogs have a tough life and a short lifespan in Ethiopia, with many vaccinated dogs dying young and puppies constantly being born that need to be inoculated. Furthermore, during the dry season, herders and their livestock and dogs travel into wolf range from many miles away to take advantage of the grazing still available within the park. This increased contact with the Ethiopian wolves raises the risk of rabies spreading to the wolves.

Currently, EWCP can only afford to vaccinate 7,000 dogs per year (at a cost of $6 per dog). All these factors combine to make it extremely difficult to vaccinate 70 percent of the local domestic dog population and ensure the wolves will be protected.

A wolf released after a vaccination.
(Photo copyright © Anne-Marie E. Stewart.)

Dr. Jorgelina Marino, EWCP's ecologist, first began implementing ArcGIS software in 2005 with support from the Society for Conservation GIS (SCGIS). ArcGIS was used to collate data collected by the organization's wolf monitoring team on wolf distribution, individual pack territories, and habitat availability. Using GIS, EWCP mapped where vaccinations were concentrated from year to year and more efficiently planned where to target vaccinations in the future.

Understanding a Rabies Outbreak

During a recent rabies outbreak among Ethiopian wolves, ArcGIS software helped EWCP stop the disease from spreading.

Most wolves in BMNP are split into three linked subpopulations: Sanetti Plateau, Morebawa, and the Web Valley. In late August 2008, EWCP researchers in the Web Valley found a dead Ethiopian wolf. The monitoring team regularly discovered more carcasses from early October 2008 onward, with laboratory testing confirming seven rabies cases. As each case was discovered, it was added to a rapidly growing GIS layer of the area, helping EWCP better understand the likely origin of the outbreak and which direction it was spreading through the population. The rabies had been carried into the wolf range by a rabid dog, which must have bitten a wolf. Wolves are social pack animals (once one has rabies, the disease spreads quite rapidly).

Thirty-nine carcasses were recovered from the Web Valley between August 28, 2008, and January 15, 2009. Because EWCP researchers are so familiar with the wolf population there, they knew 13 more wolves were missing from the area.

Due in part to the information gained from mapping the outbreak, EWCP received permission from Ethiopian conservation authorities to vaccinate 50 wolves against rabies. Permission for vaccinating wolves is only granted by the authorities once a rabies outbreak has occurred.

The intervention began on October 20, 2008. The objectives were to contain the rabies virus within the Web Valley and reduce the probability of BMNP wolves becoming extinct by protecting wolf packs in other key adjacent subpopulations.

Effective planning for such an endeavor is critical, and ArcGIS Desktop ArcView excelled in this task. The locations of discovered carcasses were mapped, along with previous data on pack locations and viable habitats.

Based on the maps and EWCP's understanding of the two previous rabies epidemics, the disease's potential spread was estimated. Decisions about where to set the live traps for the wolves were also made before mobilizing the vaccination team. Since restrictions exist on the number of wolves that can be vaccinated, it was crucial to ensure that every vaccination was utilized to maximum effect.

As Morebawa was the most immediately threatened subpopulation, trapping the wolves for vaccination was focused on the Web Valley, East Morebawa, and the Web Isthmus (a small corridor) between these two populations.

During more than 1,200 hours of trapping, 50 wolves were vaccinated from 11 packs. Vaccination efforts were based on population viability modeling outcomes showing that, if 40 percent of the wolves in each pack were vaccinated, the probability of that pack's survival would increase from 54 percent to 90 percent.

But despite wolf vaccinations conducted in October, rabies was spreading swiftly through the domestic dog population around the national park. The EWCP team began to find wolf carcasses from West Morebawa in early May 2009. In total, 11 carcasses were found, while the monitors only identified 32 live wolves in a population that should have numbered closer to 90. Samples were collected from one wolf, and it tested positive for rabies.

Authorities again granted EWCP permission to vaccinate 50 wolves. By the time the outbreak was discovered, however, it was considered too far advanced to protect the remaining wolves from the West Morebawa area. Fortunately, 8 of the 32 remaining wolves had been vaccinated against rabies during the 2003 epidemic. EWCP focused the second intervention effort on the third major subpopulation, the wolves on the Sanetti Plateau, and vaccinated 48 wolves from nine packs in fewer than 700 hours of trapping. During the second trapping effort, two more carcasses were discovered on the Sanetti Plateau. Both were juveniles, found dead at a time when mortality would be naturally high in individuals of that age due to their recent independence and inexperience in finding food. They tested negative for rabies.

Benefits of Long-Term Monitoring

The swift response to outbreaks such as these could not be possible without EWCP's long-term population monitoring program. Strategic decisions were made based on in-depth demographic knowledge about the carcasses discovered and wolves that were missing. This knowledge was also integral for implementing the rabies vaccination program and postintervention monitoring. Combined with new technologies such as GIS, EWCP launched rapid and effective intervention procedures. Reactive intervention campaigns are costly, both financially and in terms of potential loss of population size and viability. Careful planning helps reduce the costs somewhat while increasing the effectiveness of any action taken.

The constant threat of rabies and the past history of two previous known outbreaks combined with this current epidemic suggest that this problem is not solved yet. Despite the early detection, a significant number of wolves in BMNP still died.

An estimated 67 percent of wolves from six unvaccinated packs in Web Valley and 73 percent of wolves in West Morebawa were lost. In all, the 50 carcasses and 66 missing wolves represent approximately 36 percent of BMNP's wolf population and possibly more than 25 percent of the global population, (a worrisome and real threat to a wonderful species).

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More Information

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