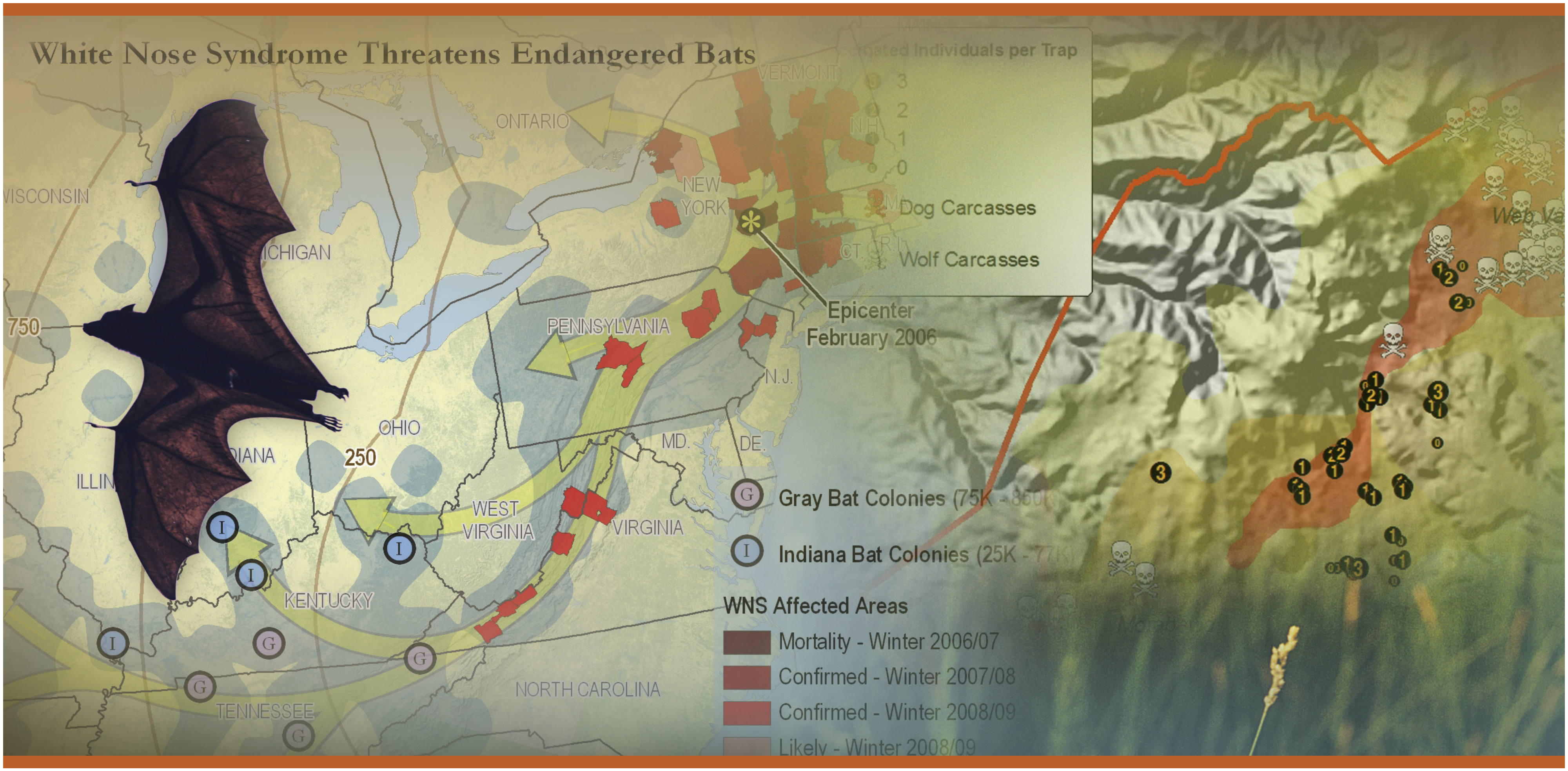
GIS Best Practices

Wildlife Management



October 2010

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS for Wildlife Management

Human-caused disruptions, such as habitat loss, pollution, invasive species introduction, and climate change, are all threats to wildlife health and biodiversity. GIS technology is an effective tool for managing, analyzing, and visualizing wildlife data to target areas where interventional management practices are needed and to monitor their effectiveness. GIS helps wildlife management professionals examine and envision

- Habitat requirements and ranges
- Population patches and linkages
- Disease levels within populations
- Progress of management activities
- Historical and present wildlife densities

Understanding the specific needs of wildlife populations is key to preventing local or global extinctions, rehabilitating populations, and restoring habitat. In the following case studies, you will learn how wildlife management professionals around the world have successfully implemented GIS to respond to invasive species, manage and facilitate disease prevention, minimize mortality, and determine wildlife movement and habitat ranges.

Learn more about GIS for the environment at www.esri.com/industries/environment/business/wildlife.html.

Conservation Group Uses GIS to Help Save Rare Ethiopian Wolves

Rabies Threatens This Endangered Species in Africa

By Christopher H. Gordon, Graham Hemson, and Anne-Marie E. Stewart
Ethiopian Wolf Conservation Programme, Robe, Bale, Ethiopia
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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 geographic information system (GIS) technology to target the best locations to vaccinate the dogs and wolves that will prevent the spread of the virus.

A wolf released after a vaccination.
© Anne-Marie E. Stewart

The Danger the Wolves Face

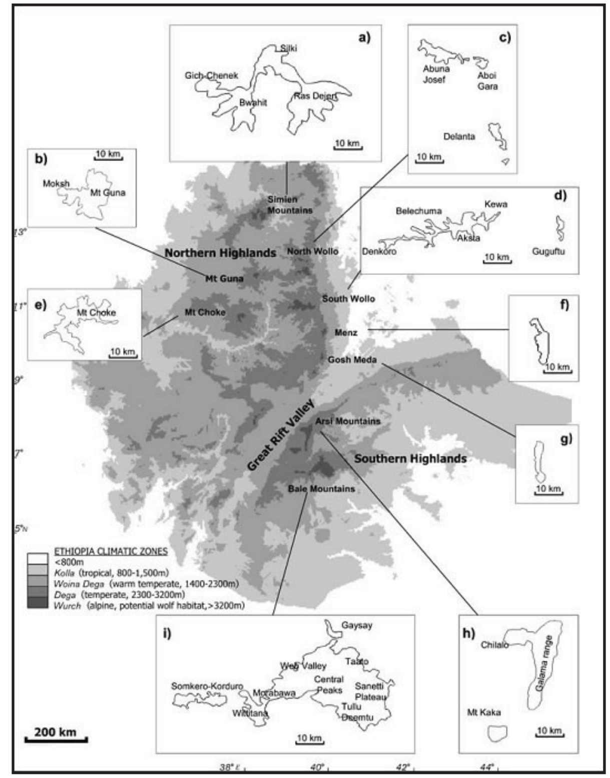
Fewer than 450 Ethiopian wolves still roam the mountainous regions of Ethiopia, Africa. They live at altitudes of more than 9,800 feet and are only found in seven isolated populations. The largest comprises 250 wolves that make their home in the protected area of the Bale Mountains National Park (BMNP)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

The 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 of 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.



Afro-alpine ranges and remaining wolf habitats in Ethiopia. Climatic zones are illustrated in a gradient of gray. The detailed maps, A through I, illustrate the current distribution of suitable wolf habitats. The Ethiopian wolf is now extinct from Mount Choke and Gosh Meda.

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 the 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.

Dr. Jorgelina Marino, the 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. The software was also used in several other projects.

ArcGIS software from Esri played an important role in the domestic dog vaccination program. Using the technology, EWCP mapped where vaccinations were concentrated from year to year and more efficiently planned where to target vaccinations in the future.

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

Understanding a Rabies Outbreak

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, the 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 the 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. The potential significance of this natural bottleneck to wolf distribution was highlighted by the GIS analysis.

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.

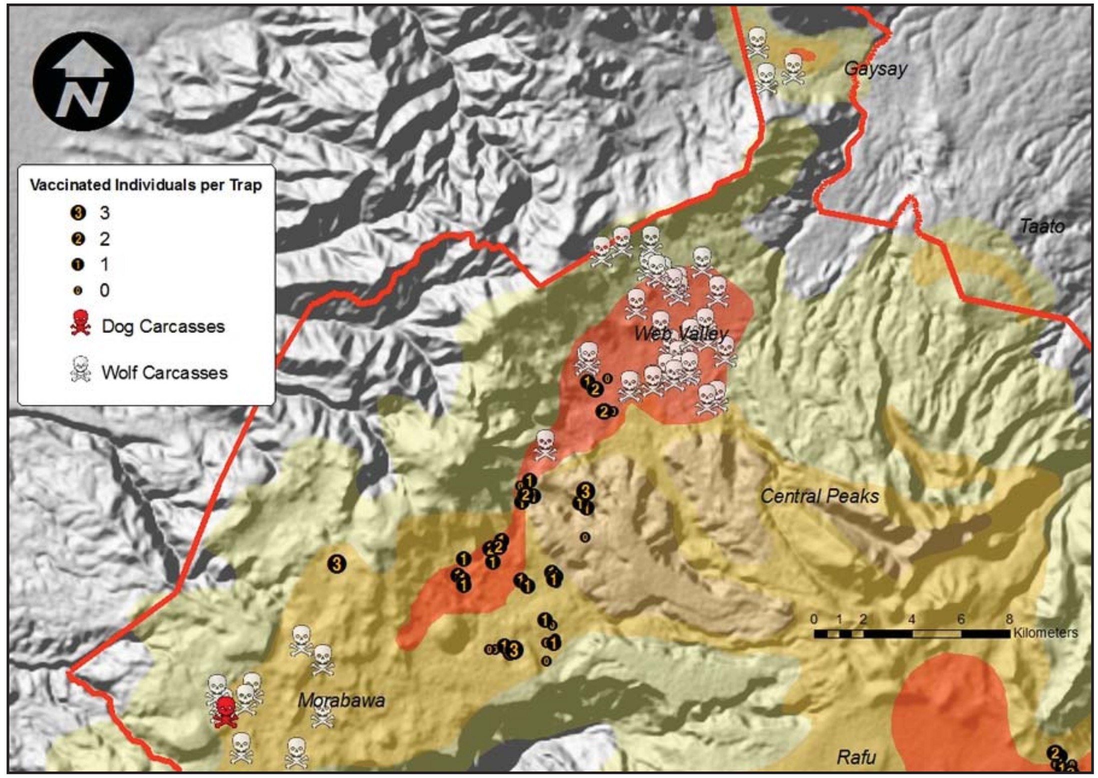


Figure 1: An overview of the Web Valley and Morebawa, showing wolf deaths caused by rabies, and the ensuing vaccination effort. The circled numbers represent the number of wolves vaccinated at each trapping location. The carcasses found to the south of the vaccination points were caused by a second rabies outbreak.

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 the 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.

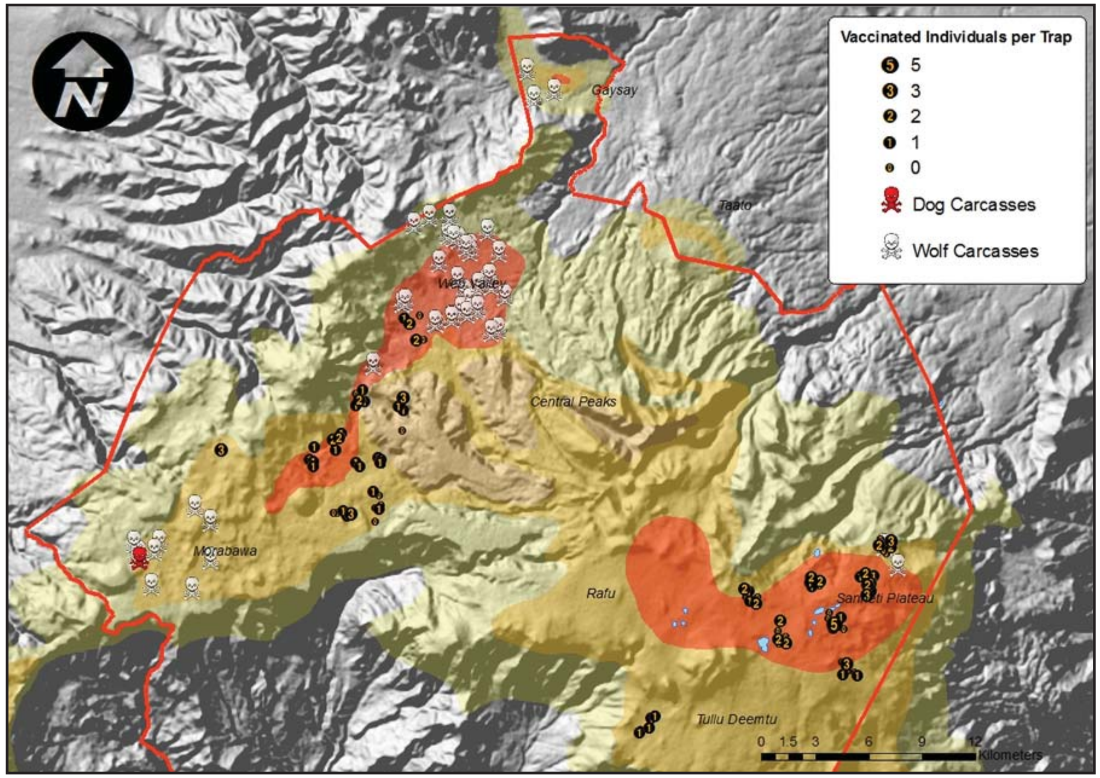


Figure 2: Overview of BMNP showing all dog and wolf carcasses found and the trapping effort.

Benefits of Long-Term Monitoring

The swift response to outbreaks such as these could not be possible without the 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, the 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 the BMNP still died.

An estimated 67 percent of wolves from six unvaccinated packs in Web 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.

Acknowledgments

This intervention to help save the wolves would not have been possible without the assistance and support provided by the Ethiopian Wildlife Conservation Authority. We thank Dr. Fekadu Shiferaw, Dr. Fekade Ragasa, Leta Edea, Edriss Ebu, Dr. Claudio Sillero, and the rest of the EWCP team for their hard work and dedication. EWCP is a partnership of the WildCRU at the University of Oxford with Ethiopia's Wildlife Conservation Authority and Regional Governments. It is chiefly funded by the Born Free Foundation and Wildlife Conservation Network, with additional financial support from the Frankfurt Zoological Society and many others. We thank the International Union for the Conservation of Nature/Species Survival Commission (IUCN/SSC) Canid and Veterinary Specialist Groups for their advice and endorsement of the intervention.

(Reprinted from the May 2010 issue of *ArcWatch* magazine)

Eradicating Rats on Lehua Island, Hawaii, with the Help of GIS and GPS

By Justin W. Fischer and Peter Dunlevy, U.S. Department of Agriculture

Highlights

- Wildlife Services used GIS and GPS to document and track bait distribution during each bait drop.
- GIS and GPS were critical in making this eradication project effective and environmentally safe.
- Use of the technologies ensured the coverage necessary for the project's goals.

Lehua Island is an uninhabited, 290-acre crescent-shaped volcanic cone located approximately 150 miles north-northwest of Honolulu, Hawaii, or approximately 20 miles west of the island of Kauai. Lehua is a state-designated seabird sanctuary managed by the Hawaii Department of Land and Natural Resources (HIDLNR) and federally owned by the U.S. Coast Guard. Renowned for its diversity of nesting seabirds, it is home to at least 17 recorded species of seabirds, including, but not limited to, colonies of Laysan and black-footed albatross, red-footed and brown boobies, black noddies, and Newell's shearwaters. Lehua is also home to several species of native coastal plants and insects.

However, invasive rats are also flourishing on the island. Early biological surveys (1931) of Lehua discovered the presence of Polynesian rats. Polynesian rats are slightly smaller than their more common cousin, the Norway rat, but are still effective predators of native island flora and fauna. Rats eat a wide variety of foods, including fleshy fruits, seeds, flowers, and other plant parts and many species of insect; they also prey on birds and their eggs. Invasive rats have eliminated seabird species and suppressed or eliminated native plant and insect populations from islands around the world.

Lehua Island (photo credit: Steve Ebbert, U.S. FWS).

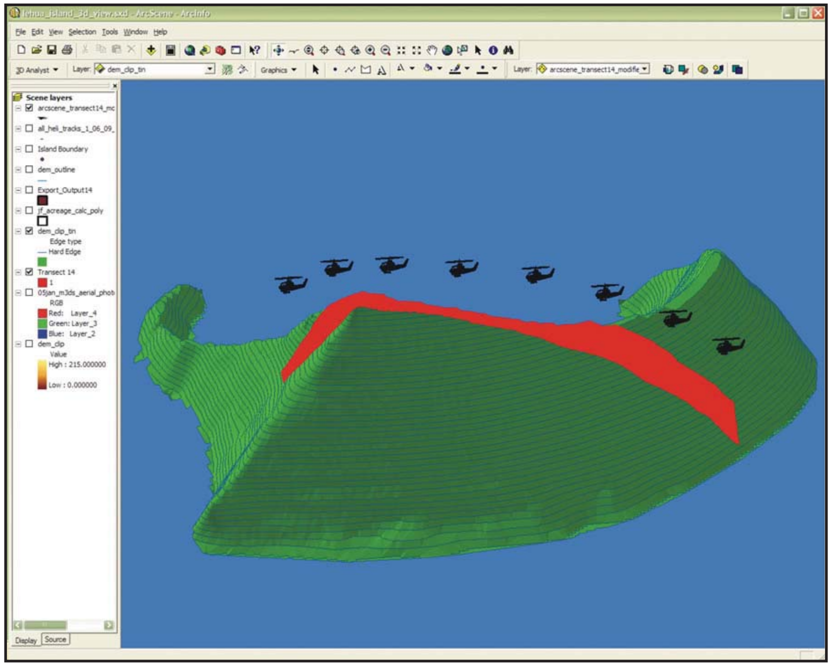
In addition to rats, nonnative European rabbits were documented on Lehua in 1931. These rabbits have also altered the island ecosystem by competing with seabirds for use of burrows and decimating native plant communities. The combination of nonnative rats and rabbits depredating plant and animal communities for decades has dramatically reduced or eliminated many native species found on Lehua.

Biological surveys were again conducted on Lehua in the late 1990s, and the impact of rats and rabbits on the island ecosystem were well documented. After consultation between HIDLNR and Fish and Wildlife Service (FWS) biologists, it was decided that eradicating the rats and rabbits would be the prudent management action. The Lehua Island Ecosystem Restoration Project was founded for this purpose. This project also focused on restoring native plant communities and allowing recolonization of the island by seabirds. The original Environmental Assessment (EA) and Final Supplemental EA were approved in September 2005 and October 2008, respectively.

This shows environmental monitoring plot GPS data collection.

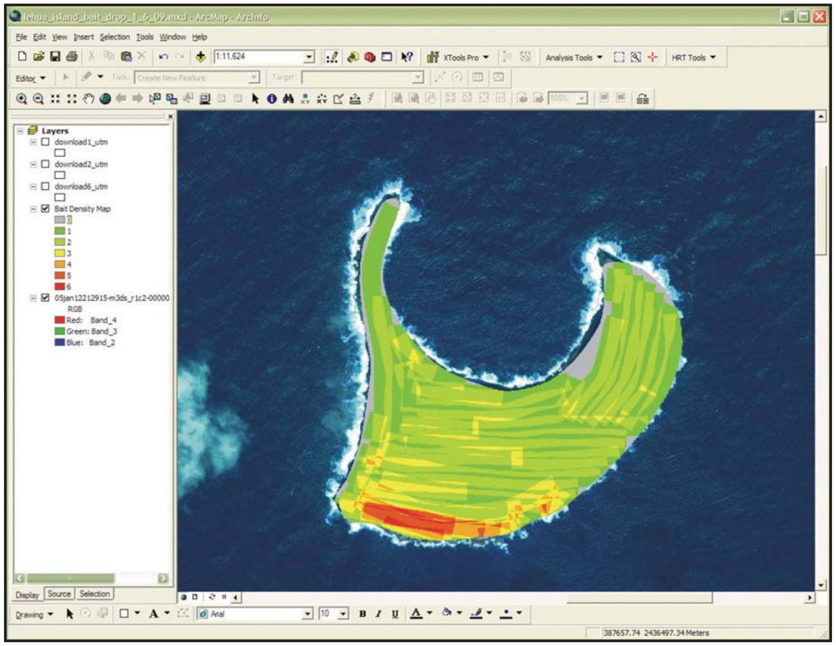
The EA proposed broadcasting bait pellets containing diphacinone over Lehua using a helicopter. Diphacinone is an anticoagulant rodenticide that causes internal hemorrhaging, resulting in death, and has been used throughout the world. This method of aerially broadcasting rodenticide to remove rats was recently conducted on Mokapu Island, just off the north shore of Molokai, Hawaii, in February 2008. The EA also stated that the eradication would occur during winter months (December through February). Based on recent trapping on the island, this is when the rat population is at its lowest. This is also when migratory bird species are lowest in numbers, thereby reducing any chance of hatchlings accidentally eating bait pellets and the helicopter colliding with flying seabirds.

On January 6, 2009, the FWS, HIDLNR, and United States Department of Agriculture-Animal and Plant Health Inspection Service (USDA-APHIS)-Wildlife Services conducted the initial bait drop involving the broadcast of 3,900 pounds of rodenticide on Lehua Island. To ensure the bait was spread uniformly over the entire island, they used a Trimble AgGPS Trimflight 3 System to accurately map the island boundary and record every flight path for each application.



This is a 3D view of helicopter broadcasting bait. The transects (see red area) were 80 meters wide.

All data was stored in ESRI shapefile format on a removable compact flash (CF) card. The AgGPS Trimflight 3 System in-cockpit display and lightbar provided the pilot with instantaneous guidance along flight lines. The team downloaded GPS data from the CF card during bait reloading and helicopter refueling. Once downloaded, GIS and GPS data was imported into ArcGIS to track and document bait distribution. The team used ArcGIS ArcInfo ModelBuilder and scripting to quickly and efficiently transform downloaded AgGPS Trimflight 3 System data to highlight areas on the island where the helicopter may have failed to broadcast bait and where swaths had overlapped. In a nutshell, this entailed splitting the multipolygon transect layer into individual polygons, converting all polygons to raster files, then overlaying the raster files to create a bait distribution density map. The goal of the bait drop was to broadcast bait uniformly over the entire island. ArcInfo was also used to calculate the three-dimensional surface area of the island. The topography of Lehua is very steep, so the 3D surface area is much more than the 2D planimetric area of the island. Determining correct surface area of the island was very important, because all rats must be exposed to lethal dosages of bait to achieve eradication, and the Environmental Protection Agency label determines the maximum amount (kg) of bait that can be broadcast per unit area (ha).



This is a bait distribution density map for the first broadcast.

A second bait broadcast occurred on January 13, 2009, to ensure an adequate exposure period. Anticoagulants are far more effective when ingested in small doses over multiple days. This also circumvents the rodents' ability to detect toxins in their food because symptoms are delayed for days after a lethal dose is consumed. Environmental monitoring of the fate of bait pellets occurred after each bait drop. The team mapped terrestrial and marine plots with a Trimble GPS unit prior to the first bait broadcast. Bait pellets were counted within plots to confirm spread rates on the ground and measure bait disappearance by rats after each drop. Intertidal invertebrate, fish, soil, and seawater samples were also collected 24 hours later and again seven days after each bait broadcast to determine if diphacinone residue was present in any nontarget organisms or the environment.

The presence of rats will be determined over the next two breeding seasons (2009 and 2010) to assess whether the eradication effort was a success. The team will use night vision, snap traps, and tracking tunnels to determine whether rats were eradicated. The use of GIS and GPS technology was critical during each bait broadcast for documenting bait distribution and identifying areas of the island that had been missed.

"Wildlife Services in Hawaii has conducted rat eradications on remote islands since 1991," explains Mike Pitzler, Hawaii, Guam, and Pacific Islands Wildlife Services state director, "but Lehua is the first project in the world to use these safer methods developed here in Hawaii over the last 15 years."

In 2005 and 2006, all rabbits were removed from the island through intensive hunting efforts. With the rabbits already gone and the rats hopefully eradicated, plant communities and seabirds are expected to recover quickly on their own. Following verification of rat elimination on the island, restoration of several native plant and invertebrate species will begin. Eradication of rats and rabbits from Lehua Island should increase the populations of threatened and endangered seabirds using the island and also give all native species a better chance of survival.

About the Authors

Justin W. Fischer is a GIS specialist/wildlife biologist with USDA-APHIS-Wildlife Services-National Wildlife Research Center's Chronic Wasting Disease Project and Invasive Species and Technology Development Research Program. His current position involves devising means to reduce chronic wasting disease transmission, spatial analysis using GIS and remote-sensing techniques, and database design and maintenance. Peter Dunlevy is a project manager/supervisory wildlife biologist with USDA-APHIS-Wildlife Services in Hawaii, Guam, and the Pacific islands. He is currently involved in development, planning, and implementation of invasive species eradications for native species and ecosystem restoration.

(Reprinted from the Spring 2010 issue of *ArcNews* Online)

Disease Causing Steep Decline of Bats

Mapping the Spread of White-Nose Syndrome with GIS

By Mylea Bayless, Bat Conservation International, and Zachary Wilson

Highlights

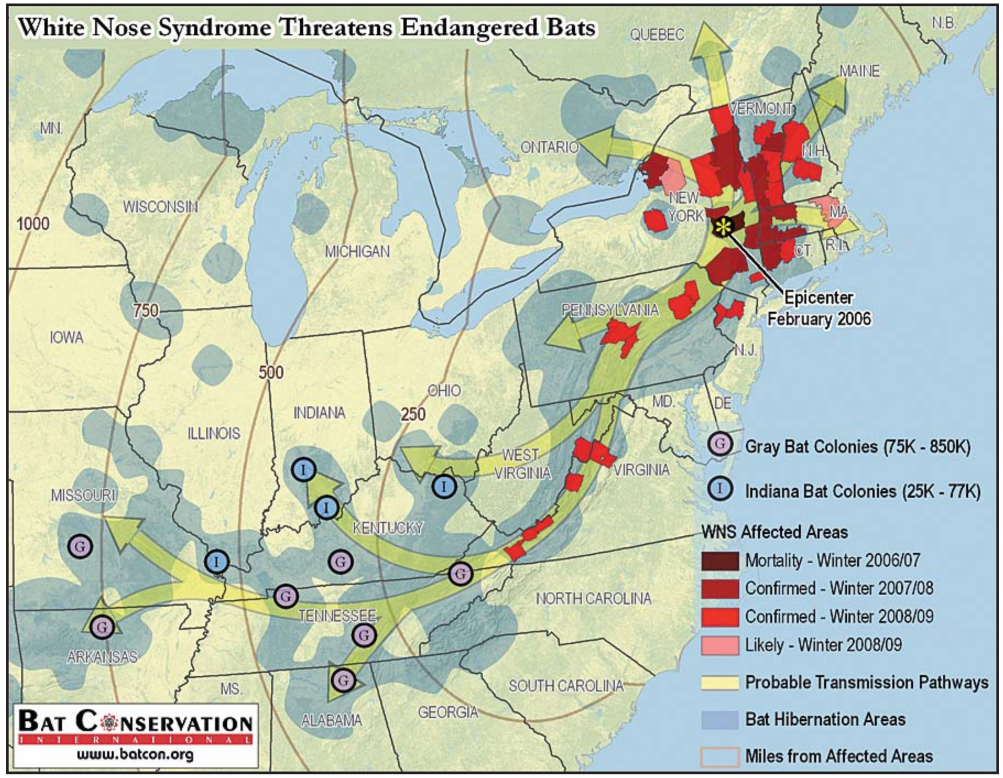
- Using ArcGIS, BCI created an integrated geodatabase of critical hibernation sites.
- BCI created maps based on georeferenced band recapture and radio telemetry studies.
- The maps have been widely distributed and were used in the congressional joint oversight hearing.

Caves have become graveyards for what biologists estimate as more than one million bats, the victims of a devastating disease known as white-nose syndrome (WNS).

Building on the work of its partners, Bat Conservation International (BCI) is using GIS to create a geodatabase of critical hibernation sites and map the probable spread of the disease. Understanding how WNS has spread and is expected to spread in the future will help biologists respond to the disease using surveillance and conservation actions.

The first case of WNS in hibernating bats was discovered in a cave near Albany, New York, in February 2006. Since then, the disease is known to have killed bats in Connecticut, Massachusetts, New Hampshire, New Jersey, Pennsylvania, Vermont, Virginia, and West Virginia.

Named after a cold-loving white fungus found on bats' muzzles and wings, WNS is linked to damage on wing membranes, excessive loss of limited fat reserves during winter, and death from starvation before spring. Since the disease was first discovered, WNS has spread rapidly across the eastern United States and affected six species of insect-eating bats (one of which, the Indiana bat, is federally endangered), causing mortality approaching 100 percent at some hibernation sites. The current losses are staggering, but biologists believe even larger numbers of bats and additional endangered species are at significant risk in the path of WNS.



The future spread of WNS could impact the most important hibernation sites for the endangered Indiana and gray bats. Map sources: Bat Conservation International, National Atlas, Natural Earth, North American Atlas, Ontario Ministry of Natural Resources, Pennsylvania Game Commission, U.S. Fish and Wildlife Service, and West Virginia Division of Natural Resources.

Why We Need to Protect Bats

BCI, a nonprofit organization based in Austin, Texas, is committed to conserving bats and their ecosystems through worldwide partnerships, research, management, education, and outreach. Most North American bat species feed on night-flying insect pests that impact forests, agriculture, and human health. Globally, bats provide countless millions of dollars of ecosystem services, including insect/pest management, pollination, seed dispersal, and growing ecotourism appeal. Bats exist in every biome on earth except the extreme Arctic and Antarctic regions and are vital to maintaining balance in ecosystems. More than 1,100 species of bats worldwide account for nearly 20 percent of all mammal species, yet they are poorly studied and often neglected in conservation planning, leaving many bat species endangered or threatened with extinction. Now bats face another threat, WNS, which is causing the most precipitous decline of North American wildlife in recorded history. Such losses alone are expected to have unprecedented consequences on ecosystem health throughout North America, with unknown economic consequences.

GIS—An Essential Tool for Understanding WNS

GIS technology is helping biologists better understand the spread of WNS. Spatial analysis of currently affected areas and potential future spread is necessary for focusing efforts to raise awareness and promote preparedness. For example, states within the path of WNS will likely develop WNS surveillance plans and adjust their budgets to plan for the cost of a WNS response. BCI has a long history of working with state and federal agencies planning bat conservation activities but has never had in-house GIS capabilities. A few past projects have focused on developing geospatial datasets, but no long-term plan was in place for establishing GIS as part of day-to-day operations. In October 2008, BCI applied for and received an ESRI conservation grant for ArcGIS software to support its new strategic plan to spatially enable the organization.

As WNS has progressed, Cal Butchkowski of the Pennsylvania Game Commission has used GIS to compile reports into a comprehensive map showing WNS-affected counties across the northeastern United States. Affected sites have been aggregated at the county level to protect sensitive cave and mine location information. Butchkowski's maps clearly show the spread of WNS across the landscape.

BCI's conservation mission led to additional questions about the future spread of WNS and the threat it posed. BCI became concerned that WNS could reach hibernation sites housing the largest numbers of endangered Indiana *(Myotis sodalis)* and gray *(Myotis grisescens)* bats in the United States, but the organization did not have the data necessary to visualize the potential risk. Colleagues at the Pennsylvania Game Commission, U.S. Fish and Wildlife Service, West Virginia Department of Natural Resources, and others, provided data on the hibernation sites that housed the largest numbers of endangered bats. Using ArcGIS, BCI created an integrated geodatabase of critical hibernation sites and mapped the probable routes of future transmission of WNS based on georeferenced band recapture and radio telemetry studies. The resultant maps of the spread of WNS—created entirely using ArcGIS Desktop software's ArcMap application—have been widely distributed and were used in the congressional joint oversight hearing on WNS held June 4, 2009, which focused on increasing awareness about the current status of WNS and threats posed by its future spread. The maps helped illustrate that WNS is no longer a regional issue but has quickly become a national crisis and has the potential to affect bats internationally. Based on the testimony of bat experts during the hearing, it became apparent that current funding for WNS research and monitoring is inadequate.

Jim Kennedy of BCI (left) and Chester Martin observe a colony of gray bats (photo by Merlin D. Tuttle, BCI).

GIS capabilities at BCI enabled researchers to clearly articulate the urgency and ecological risk of WNS. GIS will also help BCI raise money to achieve its conservation mission. Geospatial data and maps have a growing value in securing funding for nonprofit conservation work. Proposal applications are often limited to one or two pages of narrative to capture the need and planned use of potential grants. The addition of maps allows BCI to convey the scope of the problem and work area at a glance without exceeding space constraints for the proposal text. The future opportunities GIS will bring to BCI are exciting, both to explore conservation issues and articulate BCI's mission.

About the Authors

Mylea Bayless is a conservation biologist who focuses on white-nose syndrome, southeastern rare bats, and bats in bridges. Zachary Wilson is an independent GIS consultant.

More Information

BCI graciously acknowledges the support and investment of its many partners and funders—including the Beneficia Foundation, the Department of Defense Legacy Program, Disney's Rapid Response Fund, the Kabcenell Foundation, the National Fish and Wildlife Foundation, the National Park Service, the Nina Mason Pulliam Charitable Trust, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the Wallace Global Fund, ESRI, and other numerous state and federal agencies responsible for managing our nation's wildlife. The following links provide the latest information on white-nose syndrome: www.batcon.org/wns, www.fws.gov/northeast/white_nose.html, www.nwhc.usgs.gov/disease_information/white-nose_syndrome, and www.fort.usgs.gov/WNS.

(Reprinted from the Winter 2009/2010 issue of *ArcNews* magazine)

Habitat Maps Created with GIS Aid Alberta with Grizzly Conservation

By Maggie Jones, ESRI Writer

The ferocious and majestic grizzly bear is made feeble and meek from habitat degradation and stress caused by urban development, natural resource extraction projects, and illegal hunting in the areas where it roams.

Veterinarians and researchers from the Grizzly Bear Research Project place GPS collars on the bears, monitor the animals' vital signs, and draw blood to check for stress hormones. Photo/Gord Stenhouse.

The powerful grizzly bear, with a range spanning across northwestern North America, can grow to well over 1,000 pounds—appointing it the king of the forest. However, the grizzly population has started to decrease rapidly because of habitat encroachment such as urbanization and the harvest of natural resources. In the wilderness of Alberta, Canada, the population of more than 1,000 roaming grizzlies has been reduced to fewer than 500 in just a few years.

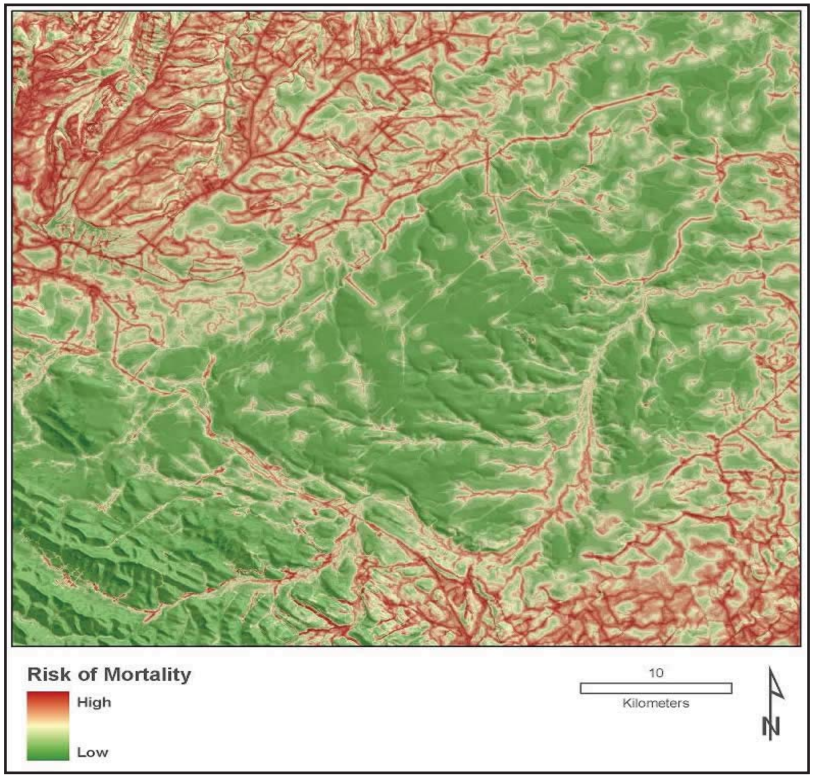
Enter the Grizzly Bear Research Project (GBRP), a Foothills Research Institute (FRI) program dedicated to improving grizzly conservation in Alberta. The GBRP provides knowledge and planning tools, such as habitat maps, to land and resource managers who want to harvest timber, conduct mining operations, and drill for oil within the province. These maps, created using geographic information system (GIS) software, help decision makers better manage and safeguard the grizzly bears' habitat and educate the public about the bears.

Researchers record important bear habitat information and locations on handheld GPS units. Photo by David Laskin.

"Considering that there were thousands of grizzlies in the region when it was settled over a hundred years ago, the dwindling numbers today make the future of Alberta's grizzly bears look particularly bleak," said David Laskin, a GIS analyst on the project. "Grizzlies are an iconic symbol of the Canadian Rockies and the Albertan wilderness; without them, everyone who lives here would be affected in some manner. As a result, there has been considerable public support for developing an effective management plan for the remaining bears, and progress has been made."

A Plan for Habitat Conservation

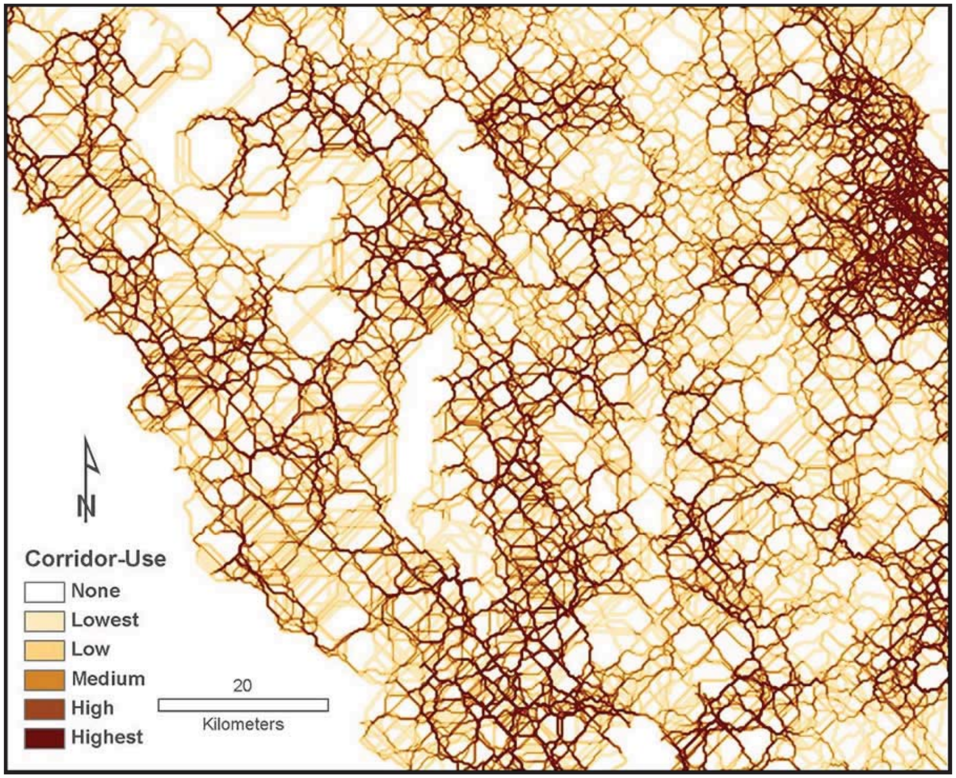
The GBRP team of researchers and scientists devised a strategy in 1999 to monitor the health and population of the grizzlies for scientific purposes. When the grizzly population declined, the team changed its focus to a conservationist mission.



A GIS map shows the areas in Alberta where grizzly bears suffer a high mortality rate.

The concerned members now seek to provide bear health, habitat, and range information to businesses, government officials, scientists, and conservationists. FRI works directly with industry managers and planners to mitigate the negative effects caused by development and public access to forested areas, working to find simple solutions such as rerouting roads or planning new roads for the least possible impact on bear habitat.

GIS analysts use GIS technology to produce habitat, probability of bear habitation, and bear travel corridor maps. The reports and maps provide an understanding of grizzly bear health and how it relates to the landscape and environment. GIS allows people to view data as maps rather than columns of numbers, making it easier to read and understand. GIS can layer different types of point information on top of a basemap. Point data collected with GPS that shows the location of bears enables the team to identify areas at risk of human-caused mortality.

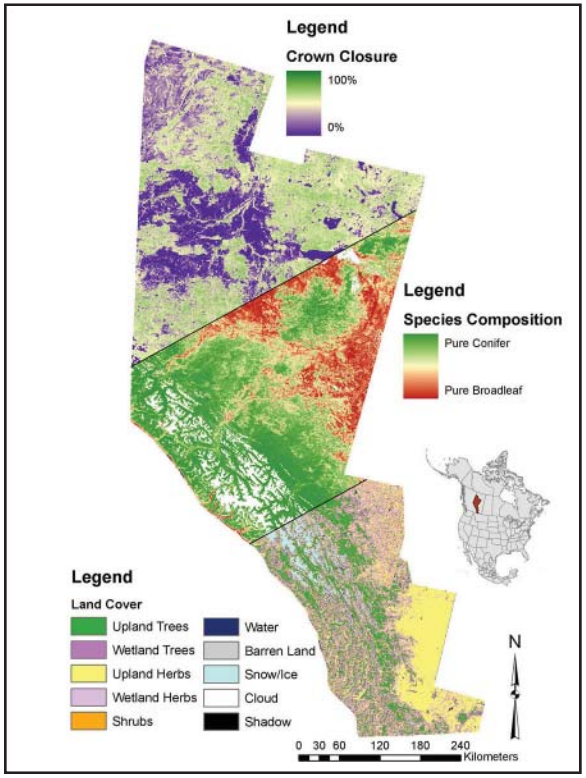


Bear corridors are mapped using GIS.

"The reasons for population decline in Alberta are manifold," said Laskin. "However, the dominant factors impacting grizzly mortality are human caused. As development increases and encroaches on grizzly habitat, the number of animals getting hit by cars increases significantly. Furthermore, these roads, trails, and cut-lines provide access for illegal hunting." Laskin added that these direct threats are compounded by the bears already having particularly low reproductive rates when compared with other grizzly populations in North America. This may be due to the bears experiencing more stress because they have to share prime habitat with human activities such as natural resource extraction, recreation, and urban growth. The more resources FRI can use to educate Albertans about what affects grizzly health, the safer the bears will be—this is where the habitat maps come in.

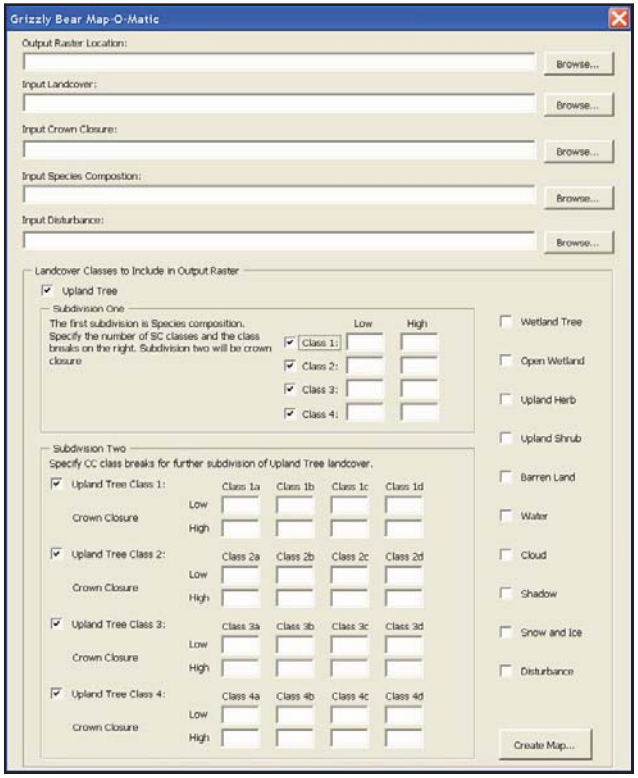
Mapping the Grizzlies in the Field

People constantly change the landscape by building houses and roads as well as harvesting natural resources. GIS technology offers a way to make dynamic maps that are able to keep up with those changes. The GBRP team members create grizzly bear habitat maps that display data layers of land cover, tree canopy cover, and tree species, then plot grizzly movement data on top of this vegetation data. First, the landscape data for the habitat maps is derived from Landsat satellite images; then, each summer, field crews visit hundreds of locations within the extent of the satellite images and record the land-cover type and forest characteristics with handheld GPS and PDA devices. ESRI's suite of GIS products was selected for this project because they can be used on handheld devices, personal computers, and server networks. The team uses ESRI's ArcPad, a mobile GIS product that enables easy on-site data collection and analysis. The data collected in the field is brought to the lab and converted to shapefiles. These shapefiles are



This habitat basemap combines a variety of data layers including trees and shrubs.

then used in ArcGIS Desktop (ArcInfo) software to create the three main raster map products: land cover, crown closure (the density of the forest canopy), and tree species composition, which are combined to derive grizzly habitat-use models.



The Map-O-Matic tool inputs basemaps and outputs a composite map that contains user-defined classes.

Landscape structure is important when defining grizzly habitat. Forest canopy information can reveal to researchers where grizzlies are likely to be found. Grizzly bears prefer to use open forests and meadows to forage for berries and vegetation; however, proximity to dense forest is crucial to provide a safe retreat from potential threats. When mapping land cover—the trees, shrubs, wetlands, water, or barren regions of a study area—the satellite images are "stitched" together using the Mosaic tool, which is one of the many tools ArcGIS users can apply to their projects. Because the openness of a region affects whether a grizzly will want to forage there, the density of the crown closure across the study area is examined. The crown closure is derived using a multitude of digital hemispherical photos taken within a study plot below the canopy. A plot is the forest area beneath a single image pixel in the satellite imagery. The photos are processed in the lab and converted into measurements of crown closure for each plot. The results are compared with other environmental, topographic, and spectral information used to derive a linear statistical model.

Next, researchers apply the calculated results to other image pixels, and GIS estimates the raster values (geographic feature cells) for the entire crown closure map. The tree species composition map shows the proportion of conifers within the forested habitat area. This map is derived from random samples of tree species in each study plot. Back in the lab, the ratio of broadleaf to needle-leaf trees is entered into a statistical model and correlated with underlying environmental, topographic, and spectral information. Similar to the crown closure maps, this relationship is applied to every pixel in the satellite image to create the tree species composition map.

Grizzly bear range and study area in Alberta, Canada.

Researchers needed to ensure that they would be able to combine the basemaps in a variety of ways. "Because ecosystems are very complex and dynamic entities, static land-cover maps are limited in their use due to the wide range of queries researchers have about bears and their habitats," Laskin said. Questions about grizzly ecology are constantly being answered, which opens the door for new questions to be asked. Laskin also said that combining basemaps in a customized manner allows researchers to have a suite of maps that is as flexible as the ever-evolving research focus.

To give them this flexibility, project technicians developed a Microsoft Visual Basic tool called Map-O-Matic. This tool inputs basemaps and outputs a composite map that contains user-defined classes. Obviously, researchers need to go into the forest to obtain the grizzly location data. They tag bears with GPS collars that will transmit bear locations via radio waves to the base station. To do this, team members tranquilize the bears—from a great distance, of course. Then, while the bear is in a sleep state, scientists record its vital signs, take DNA samples, and document other characteristic data. For example, wildlife veterinarians monitor the stress of the bears they collar by identifying certain long-term stress hormones in their blood. The collar is released remotely and falls off after about a year so that no harm comes to the grizzly.

The location data collected by the GPS and sent to the base station is stored in the database and combined with the basemaps by GIS technicians to create habitat-use maps that show the grizzly range and the probability of risk. The team performs a landscape change analysis that monitors annual appearances of clear-cutting, fires, oil well sites, roads, and pipelines across the study area. This change information, combined with GIS habitat basemaps and grizzly location points collected with GPS, enables conservationists to monitor bear health and the effects of changing landscapes on bear habitat.

Results of the Research

The preliminary results of combining basemaps and landscape change, bear location, and bear health data suggest that grizzlies in areas of increased road density experience the highest levels of long-term stress. This type of stress could potentially impact their ability to forage or reproduce and therefore harm the overall well-being of the local bears. Habitat maps also help researchers analyze various land-cover classes and their changes, the probability of a bear being in a certain area, bear movement corridors, and areas of mortality risk. GIS gives researchers and managers a better perception of data for improved decision making and planning for grizzly conservation.

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A grizzly bear hugs a tree in Canada. Photo/Gord Stenhouse.

California Lake Threatened by Pike

Geospatial technologies aid response to invasive species

By Will Patterson and Ken DeVore, California Department of Fish and Game

Summary

The introduction of nonnative species can be beneficial. However, when nonnative species spread quickly and threaten the abundance and diversity of native plants and animals, they are considered invasive. Northern pike (*Esox lucius*), an extremely aggressive predatory fish, can seriously affect aquatic ecosystems by eating fish such as trout and salmon. Pike have adversely affected both trout fishing and the local economy at Lake Davis in California.

In September 2007, the California Department of Fish and Game (DFG) completed a chemical treatment project to eradicate the invasive northern pike from Lake Davis and its tributary streams. Unlike an eradication effort in 1997, the 2007 project included significant use of GIS and GPS to improve the likelihood of success.

Northern pike.
Photographs courtesy of the California Department of Fish and Game.

Lake Davis is a large reservoir located in the Sierra Nevada mountains about 90 miles northwest of Lake Tahoe. Pike were illegally introduced to Lake Davis and nearby Frenchman Reservoir and Sierra Valley streams. In the early 1990s, DFG successfully eradicated pike from Frenchman Reservoir and Sierra Valley streams. In 1997, a treatment using a piscicide *[a chemical poisonous to fish]* appeared to have successfully eradicated pike from Lake Davis. However, pike were rediscovered in 1999. It is not known whether some pike survived the 1997 treatment or were illegally reintroduced to the reservoir.

The saga of Lake Davis has been a high profile and controversial issue. Since 1999, DFG has tried to control and contain pike in Lake Davis using many techniques including trapping, electrofishing, and even explosives. Although more than 66,000 pike were removed between 2000 and 2007, the pike population continued to grow and spread further upstream into tributaries. If pike escape or are moved from the reservoir and become established in other waters, they could endanger other fish populations. Pike could negatively and irreversibly impact portions of the Sacramento-San Joaquin Delta, Feather, Sacramento, and San Joaquin river systems and other waters in California.

DFG conducted a joint environmental review process with the U.S. Forest Service in accordance with the California Environmental Quality Act and National Environmental Policy Act. The purpose of the 2007 project was the eradication of pike from Lake Davis and its tributaries in a way that minimized impacts to the environment and local community. After extensive public outreach and input, several pike elimination alternatives were evaluated. DFG determined that treating the reservoir and its tributaries with a rotenone piscicide had the fewest environmental and economic impacts.

Lake Davis is a large reservoir located in the Sierra Nevada mountains about 90 miles northwest of Lake Tahoe.

Rotenone is a naturally occurring compound derived from the roots of a tropical plant in the bean family. A new commercial formulation of rotenone, CFT Legumine, was selected for the 2007 treatment. Rotenone has been approved for fishery management use by the U.S. Environmental Protection Agency and California Department of Pesticide Regulation and is the only group of piscicides registered in California for this use.

The project was extensively covered by numerous media sources. Many reporters were on-site to witness treatments. Following the treatment, the reservoir will be restocked so that it will again be the trophy trout fishing destination it was before the introduction of pike.

Using GIS and GPS in the Pike Eradication

GIS and GPS were involved from early project planning through implementation and will also be employed for posttreatment monitoring. The project used ArcGIS Desktop (both ArcInfo and ArcView), ArcGIS Explorer, and ArcView 3.x. Three Trimble GeoXM units, 80 new Garmin GPSMAP 60Cx and GPSMAP 76Cx units, and several older Garmin units of various models were used for data collection. The new Garmin units included SiRF high-sensitivity architecture and Wide Area Augmentation System (WAAS) differential capability, which allowed for high-quality data collection even under riparian canopy conditions. GIS and GPS were used on the 2007 project for

- Project area boundary definition
- Grid referencing system creation
- GPS basemap development
- Aerial survey registration
- Interactive map viewing
- Map atlas creation
- Field surveys and navigation
- Bathymetric data analysis
- Treatment status maps

Treatment of the waters of Lake Davis began on September 25, 2007.

Project Area Boundary

The project area boundary was defined using GIS. The 44-square-mile project area included the reservoir and the tributaries leading into it. The California Interagency Watershed Map, a subset of the most current and official California GIS layer for watershed boundaries, was used to represent the project area boundary.

Grid Referencing System

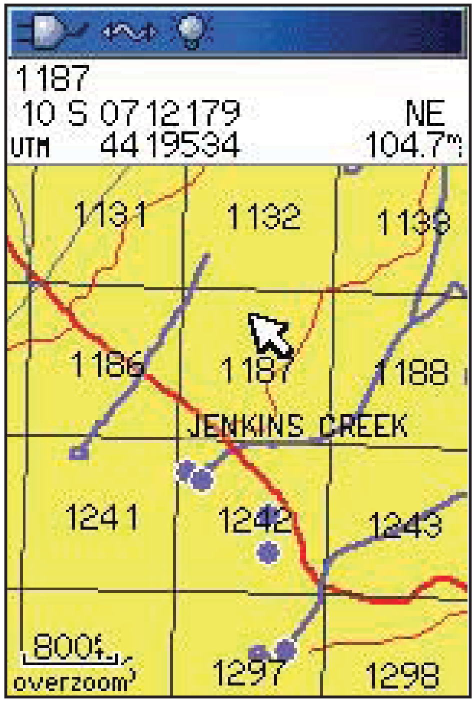
To geographically organize project resources, a grid of quarter-mile square cells was created to cover the entire project area. Each grid cell had a unique identification number. The grid was used for many spatial referencing aspects of project management including deployment of stream and reservoir treatment crews, chemical treatment calculations, communications, and emergency response. The grid was developed as a vector GIS layer using the ArcInfo Workstation Generate command with the Fishnet subcommand. (This operation can also be accomplished with ArcToolbox using the Create Fishnet tool in the Feature Class toolset in the Data Management tools.)

GPS Basemap

A project area basemap was developed using GIS shapefiles that were symbolized and loaded into the Garmin GPS units using Garmin's MapSource Product Creator software. The GPS basemap included the same project area boundary, quarter-mile grid referencing system, and background layers (including the U.S. Geological Survey [USGS] High Resolution National Hydrography Dataset and United States Department of Agriculture Forest Service roads) that were used on other project maps.

Aerial Surveys

Prior to the treatment, DFG conducted digital aerial photography surveys of the project area at key times to evaluate the water levels and habitat conditions of the reservoir and its tributaries. Rather than using traditional orthorectification procedures, the ArcMap georeferencing toolbar was used to save time by quickly bringing the aerial photographs into register with the rest of the project GIS data.



Custom basemaps were created with GIS data and loaded into Garmin GPS units used for field surveys, navigation, and tracking. Streams and springs are shown in blue while roads are shown in red. Also note the grid reference system.

Interactive Map Viewer

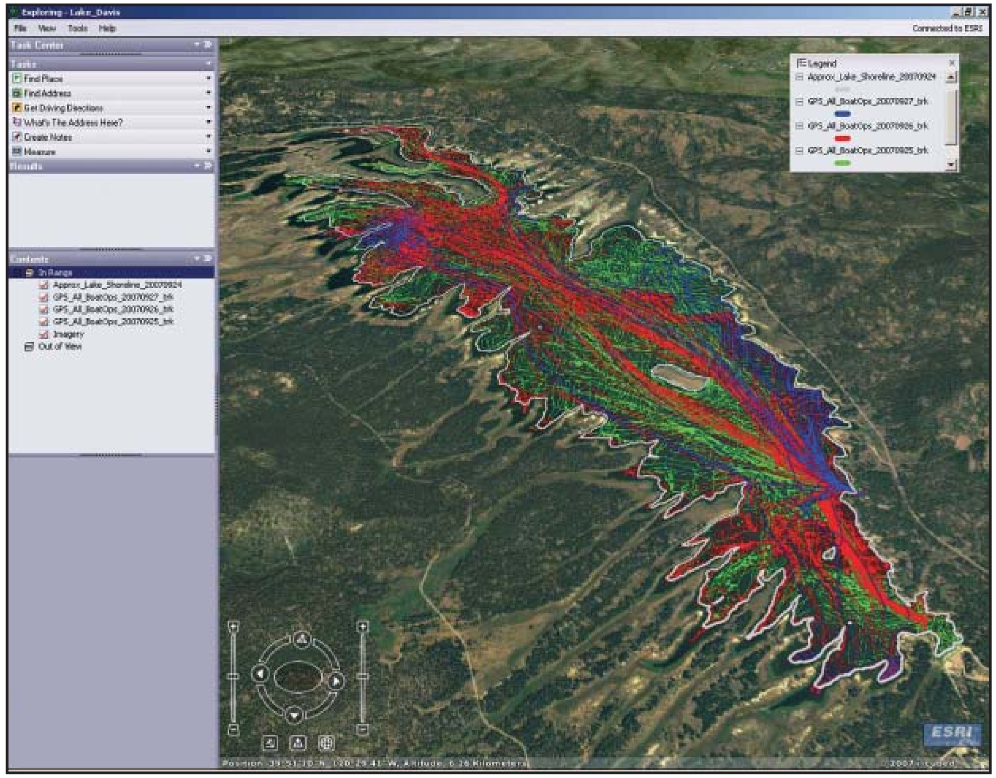
Using ArcIMS and DFG's map viewer template, an online interactive Lake Davis map viewer was set up for project staff and the public. *[DFG's map viewer template has won awards from the Organization of Fish and Wildlife Information Managers in 2005 and a first place in the Internet Mapping contest at the 2003 ESRI International User Conference.]* This made it easy to assess the geography of the project area and particular GIS layers of interest using just a Web browser.

Map Atlases

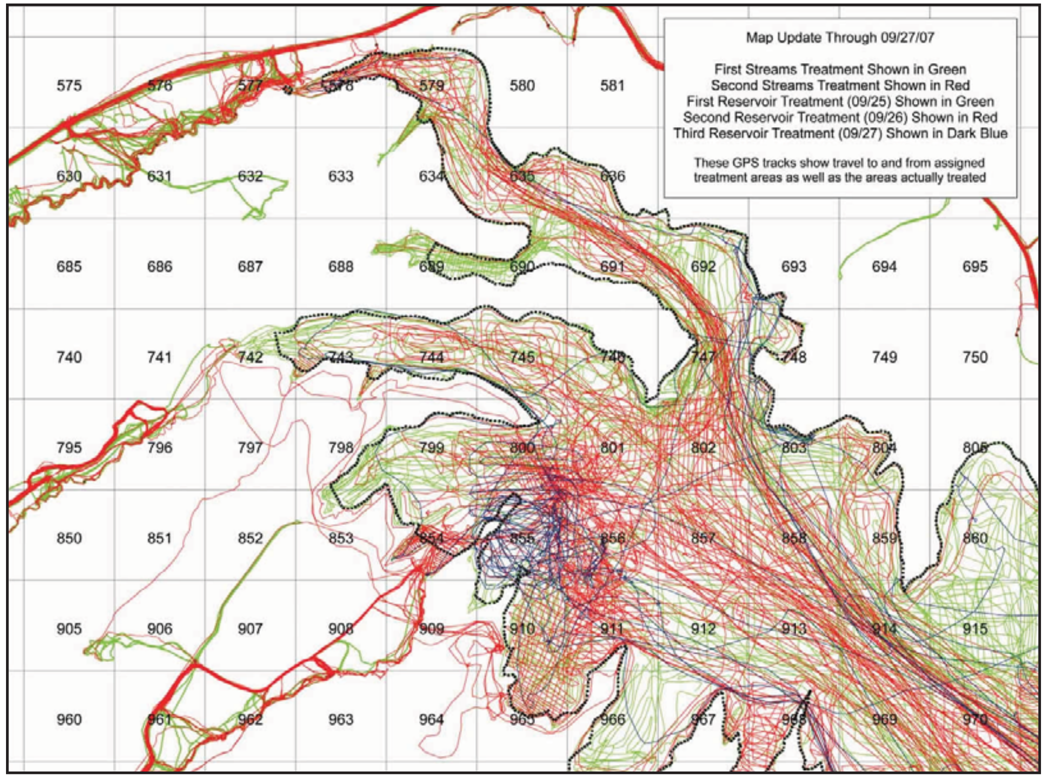
Separate reservoir and tributary stream map atlases were produced in hard-copy format and given to field crews ahead of time so they could become familiar with areas they were assigned to treat. ArcView 3.x was used to create the atlases because it can create multiple map layouts from multiple views. The atlases included area overview maps and individual maps for each quarter-mile grid. Many of the maps used digital raster graphic (DRG) topographic maps draped over current aerial photographs. The ArcView 3.x DRG Tools extension obtained from ArcScripts (www.esri.com/arcscripts) was used to isolate particular topographic map features and make the rest of the map transparent so that the aerial photographs could be seen underneath. In the stream map atlases, the aerial photographs were printed on regular paper, and the topographic map features were printed on transparent overlays. This approach allowed the stream field crews to clearly view the aerial photographs by themselves or in combination with the topographic map features.

Field Surveys and Navigation

For several years prior to the 2007 project, GPS units were used by stream field crews to survey their assigned areas and map existing and potential locations (wet areas) to be revisited for treatment. During the treatment phase, GPS was used by field staff for navigation to assigned treatment areas and by emergency medical technicians, fish disposal crews, and other project staff for general locational reference. Particularly sensitive habitat areas along with potential habitat for threatened species were also identified using GPS and flagged in the field so that they would not be disturbed.



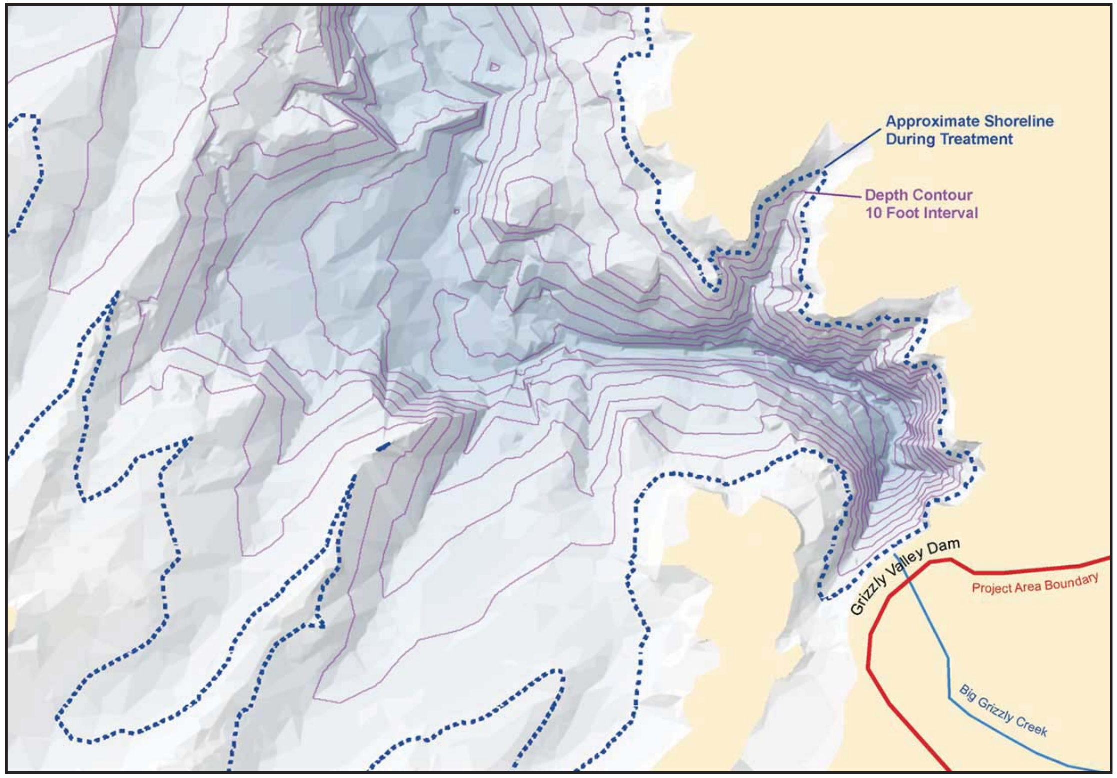
GPS tracks from the reservoir treatment were visualized using ArcGIS Explorer. Green, red, and blue lines each represent a separate day of treatment. The gray outline shows the approximate shoreline.



A section of a combined reservoir and stream treatment status map. GPS tracks within the reservoir often follow the grid reference system as boat crews were assigned to treat particular grid numbers.

Bathymetric Data Analysis

Bathymetric (water depth) contour data for Lake Davis was provided by the California Department of Water Resources (DWR) in CAD format. Using various geoprocessing techniques, DFG GIS staff produced derivative GIS products from the CAD data including bathymetric triangulated irregular networks (TINs), digital elevation models (DEMs), and hillshades. These derivative products were used to help calculate the amount of rotenone needed for the reservoir treatment, including specific amounts to be applied within each quarter-mile grid. Supplemented with daily reservoir-level information provided by DWR's California Data Exchange Center, the bathymetric data was also used to create a GIS layer that estimated the reservoir shoreline location at the time of treatment. While the reservoir has a capacity of about 84,400 acre feet, the storage was around 41,800 acre feet during the treatment.



A visualization of Lake Davis bathymetry.

Treatment Status Maps

During the chemical treatments, stream and reservoir treatment teams carried GPS units that recorded daily travels as track logs. At the end of each day, the teams turned in their GPS units for processing. GIS staff downloaded the track logs from the units and converted them to shapefiles using DNR Garmin software (developed by the Minnesota Department of Natural Resources [DNR]). Using ArcMap and ArcGIS Explorer, status maps were produced using the GPS track log shapefiles to show how the treatment was progressing. Project managers used the maps to determine if all target areas had been visited and to adjust the deployment of treatment crews as necessary.

Conclusion

GIS and GPS proved to be powerful tools critical to the successful implementation of a project of this scope and complexity. GIS provided the means to create needed map-reference products and facilitate geographic analyses. GPS provided necessary tools for surveys, navigation, and tracking. Both technologies were utilized to produce status maps that were invaluable in conducting the 2007 treatment.

For more information, visit the Lake Davis Pike Eradication Project Web site at www.dfg.ca.gov/lakedavis/ or the DFG Web site at www.dfg.ca.gov.

About the Authors

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