**ABSTRACT**

The Sky Island region of the southwestern United States and northern Mexico is a world biological hotspot, where the temperate Rocky Mountains and Colorado Plateau meet the subtropics of the Sierra Madre Occidental and the Sonoran and Chihuahuan Deserts. Within this region, preserving, restoring, and increasing connected landscapes has ever greater urgency. Human population growth, increased urbanization, irresponsible off-road vehicle use and the development of new roads, highways and other infrastructure related to rapid human expansion are the most serious threats to wildlife and their habitats. In the arid southwest, where species survival is already affected by extreme summer temperatures and long distances between water sources, climate change is adding another layer of difficulty. The ability of wildlife to adapt and respond to a changing climate will depend on their ability to move freely across the landscape.

Sky Island Alliance’s Wildlife Linkages Program strives to protect and restore the movement and dispersal of native plants and animals, and to reduce threats and barriers to landscape permeability, using education, science and advocacy to achieve conservation action. The Program’s vision is of an interconnected landscape where wildlife, based on their ecological needs, can move easily between core habitats, the Sky Island mountain ranges. This is achieved by connecting people, policy, and conservation at many levels, and by linking citizen involvement and science and field expertise with policy change and conservation action. We have accomplished a new kind of sustainability in motion, in which citizens sustain the conservation movement by engaging in the collection of data, gaining expertise, becoming advocates for regional conservation.

In 2001 Sky Island Alliance developed a citizen science protocol requiring volunteer participation in a five-day training workshop on GPS, photo documentation, natural history and conservation of regional species, and track identification in the field. Eight focal species were identified for study: jaguar, bobcat, mountain lion, ocelot, gray wolf, black bear, white-nosed coati, and the ornate box turtle. Strategic 1.5 mile transects were established in potential linkages and surveyed every 6 weeks. Tracks are photographed, measured, and geo-referenced, and ATV/ORV tracks or other disturbances documented. Remote-sensing cameras were placed at select transects to provide comparative data. Verified data is analyzed using GIS, trend and presence/absence analysis.

To date we have conducted a total of 16 tracking workshops and trained 249 tracking volunteers, monitored 49 transects, and walked over 2,800 miles to gather information on wildlife movement in known or suspected linkages. Data gathered in the past ten years have contributed to the development of Arizona’s Missing Linkages Assessment and a refined Pima County Wildlife Corridor Assessment, two comprehensive mapping projects that identify at-risk wildlife corridors and recommendations for transportation planners and engineers; and to a wildlife crossing overpass project on Arizona State Route 77, approved for construction in 2013. These data have also contributed to the first photograph ever taken of a live ocelot in Arizona.

**INTRODUCTION**

**An International Corridor**

The Sky Island region is a 70,000 square mile world biodiversity hotspot – a biological bridge where the temperate Rocky Mountains and Colorado Plateau meet the subtropics of the Sierra Madre Occidental, and the Sonoran and the Chihuahuan Deserts (Fig. 1).
Figure 1. The Sky Island region is an international corridor and biodiversity hotspot that encompasses southeastern Arizona, southwestern New Mexico, and northern Mexico. Created by Sky Jacobs © Sky Island Alliance.

This landscape harbors a huge slice of America’s natural heritage – well over half the bird species of North America, 29 bat species, over 4,000 species of plants, and 120 species of mammals – and is the most biologically diverse region in the United States. This biodiversity is augmented by a unique topography of forested mountains surrounded by desert and grassland valleys. The resulting chain of “Sky Islands” acts as a major geographical link for temperate and tropical species, making it the only place in the world where black bear and jaguar meet, and where wild grape grows alongside chiletpin and coral bean. The Sky Islands, within southern Arizona, northern Mexico, and the boot heel of New Mexico, are equally rich in human culture – contemporary, historic, and prehistoric.

Within this region, preserving, restoring, and increasing connected ecosystems has ever greater urgency. Habitat fragmentation and destruction of open space caused by irresponsible off-road vehicle use and the development of new roads and highways, transmission lines, border infrastructure, and other infrastructure related to rapid human expansion are the most serious short-term threats to Sky Island species and their habitats. Division of otherwise continuous habitat will block natural movements of some species whose distribution in the U.S is already limited, confining them to isolation and potential extinction. In an elevational gradient, limiting wildlife migration movements from lower desert regions to higher elevations could be devastating. This would also have far-reaching effects on other, interconnected species, such as prey. In the arid southwest, where species survival is already affected by extreme summer temperatures and long distances between water sources, climate change is adding another layer of difficulty. The ability of species to adapt and respond to a changing climate will depend on their ability to move freely across the landscape.

Sky Island Alliance

In the mid-1990s, Sky Island Alliance pioneered landscape-level conservation planning by integrating the science of conservation biology with grassroots organizing and on-the-ground restoration. With our partners, we put together the first comprehensive regional conservation plan for this magnificent landscape: the Sky Island Wildlands Network. Since 1991, we have engaged a wide range of partners, creating alliances and collaborating with scientists, landowners, agency personnel, planners, conservation organizations, volunteers, individuals, decision makers and foundations. We
understand the Sky Islands from a biological perspective, where species and habitats do not recognize political boundaries, reinforcing the importance of ecoregional conservation.

Due to this vision, we engage in an integrated approach to conservation: we protect and restore native species, healthy and diverse ecosystems, and natural evolutionary processes; safeguard and improve wildlife movement across the landscape (connectivity) and reduce barriers to wildlife migration (landscape permeability); increase public understanding and appreciation of the Sky Island region and importance for sustainable human activities; guide land planning processes to ensure conservation based land management; and promote Wilderness, National Conservation Area, and other protective designations by federal, state, and local governments.

For almost 20 years, Sky Island Alliance has been working with numerous partners to build resilience in the region’s wildlands, protecting and restoring cores and corridors, through five areas of work: landscape restoration, protected lands, conservation policy and planning, northern Mexico conservation, and wildlife linkages.

Wildlife Linkages

Sky Island Alliance’s Wildlife Linkages Program strives to protect and restore the movement and dispersal of native plants and animals, and to reduce threats and barriers to landscape permeability, using education, science and advocacy to achieve conservation action. The Program’s vision is of an interconnected landscape where wildlife, based on their ecological needs, can move easily between core habitats, the Sky Island mountain ranges. This is achieved by connecting people, policy, and conservation at many levels, and linking citizen involvement and science and field expertise with policy change and conservation action. Volunteers sustain the connectivity movement by engaging in the collection of data, gaining expertise, becoming advocates for regional conservation, affecting policies, and playing a role in providing direct benefits to the general public in the form of improved eco-tourism, road safety, and standard of living.

STUDY AREA

Southern Arizona Linkages

The Wildlife linkages Program currently trains and engages volunteers in the monitoring of seven priority linkages within the Arizona and New Mexico portion of the Sky Island region: 1. Catalina – Tortolita mountains north of Tucson; 2. Santa Rita – Santa Cruz River – Tumacacori (too-ma-caH-core-E) mountains north of Nogales spanning Interstate-19; 3. Las Ciénegas watershed corridor between the Rincon, Santa Rita and Whetstone mountains and spanning Interstate-10; 4. Huachuca – Whetstone mountain linkage within Fort Huachuca, west of Sierra Vista; 5. Whetstone – San Pedro River – Dragoon mountains; 6. San Bernardino National Wildlife Refuge – the Sierra Ceniza, Mexico; and 7. Galiuro – Pinaleño – Dos Cabezas mountains of Arizona and New Mexico (Fig. 2). The majority of these study areas are located in southern Arizona on public lands, where even the most remote transect locations are accessible to volunteers.

Sonoran Sky Islands

In Sonora, Mexico, we have conducted regular tracking surveys and tracking training workshops at Rancho el Aribabi, a 10,000-acre conservation ranch designated as a Voluntary Protected Area, located approximately 30 miles south of the international border near the town of Imuris, in the Sierra Azul. El Aribabi hosts over 30 threatened or endangered species of mammals, birds, reptiles, amphibians and plants, including ocelot and jaguar. It is home to the northernmost-known viable ocelot population. Tracking surveys have also been conducted in the mountain corridors of Sierra la Madera, Sierra el Tigre, Sierra San Luis, the Cibuta complex, Sierra Pinito, Sierra San Antonio, and the Ciénega de Saracachi, with the cooperation and participation of Sonora universities and the Comisión Nacional de Áreas Naturales Protegidas (CONANP) as part of our Madrean Archipelago Biological Assessment (MABA) project.
METHODS

Training

The importance of citizen involvement and its connection to conservation action directly contributes to the program’s success. In 2001 Sky Island Alliance developed a citizen science protocol for a wildlife tracking monitoring program (Przybyl 2003), requiring volunteers to participate in a five-day wildlife tracking training workshop and make a one-year commitment to perform eight tracking surveys. Participants in the workshop complete approximately fifty hours of hands-on field instruction and theory in a variety of skills and techniques, including: natural history and conservation of regional Sky Island mammal species; track morphology, structure and terminology; the use of global positioning systems (GPS); photo documentation; track casting and tracing techniques; animal gaits and movement; and track and sign identification in the field. Each workshop is held in the field to provide an outdoor classroom experience and foster a greater connection to the region and between volunteers. In 2009 Sky Island Alliance began offering refresher training for volunteers several times a year, through weekend tracking expeditions and mini-workshops on topics ranging from scat (feces) identification to field photography.

Transect Selection

Transects are established in areas most likely to provide evidence of wildlife activity, primarily in sandy washes, dirt roadways, or riparian edges, where there is suitable substrate for tracking. Study areas are prioritized based on known or suspected wildlife movement corridors, and known or potential threats to wildlife movement, such as highways, or proposed mining or development.
Data Collection Protocol

Six focal species were identified for study in 2001: jaguar (*Panthera onca*), bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), Mexican gray wolf (*Canis lupus*), black bear (*Ursus americanus*), and white-nosed coati (*Nasua narica*). In 2009, two additional focal species were added: ocelot (*Leopardus pardalis*) and the western ornate box turtle (*Terrapene ornata*).

We define focal species as plants or animals whose survival requirements are also required to maintain a healthy ecosystem, therefore making them indicators of ecosystem health (Miller et al. 1999). Sky Island Alliance’s Wildlife Linkages Program focuses on regional animal focal species that can be categorized as a keystone, umbrella, or indicator species, or have an unknown or shifting population or distribution. Threatened or Endangered species often fit many of these categories. We intentionally include both habitat generalists and habitat specialists as focal in order to collect data that will result in a robust wildlife corridor design.

Each occurrence of a focal species or sign is documented on a data collection form, and assigned a data point and photo number. A data point is defined as a sign or set of signs made by a single animal at a single time. Occurrences of non-focal species are not assigned a data point but are recorded with an abundance rating, defined as A (1 to 5 occurrences of sign); B (6 to 10 occurrences of sign); and C (>10 occurrences of sign).

Strategic 1.5 mile long, 60 feet wide transects are established in potential linkages and are surveyed by a volunteer team every 6 weeks, inside a two-week survey window. Surveys are not conducted during rainfall, due to low visibility of tracks and field safety. Teams of 2 to 4 trained tracking volunteers are assigned to each transect, and are provided with datasheets, GPS units, cameras, reference track identification cards and tracking rulers. If the tracking team cannot come to consensus about the identification of a track or sign, the data point is not recorded. At least two trained trackers are required for each survey. For scientifically rigorous data collection, tracking teams are strongly encouraged to survey in early morning, when temperatures are cool, light refraction is optimal for track visibility and photography, and nocturnal species tracks are freshest. Tracking surveys conducted later in the day have a lower chance of detecting nocturnal or crepuscular species and a higher chance of detecting diurnal species, and are therefore slightly biased towards diurnal species detection. Increased human activity during the day can also eliminate tracks that might still be seen in early morning.

Tracks and other sign identified belonging to focal species are photographed with a ruler, measured, and data is collected on direction of travel and GPS location. Details on sex, age, and which foot (left/right, front/rear) is also collected if this information can be determined. A space for additional comments and observations is provided (Fig. 3), and the resulting field notes provide excellent anecdotal information. In addition to track and sign counts, volunteers document changes in transect condition, including evidence of off-road vehicle use or other disturbances. On select transects, remote sensing cameras are also placed to provide comparative data.

![General comments](image)

**Figure 3.** Volunteer trackers document mountain lion tracks in Las Chivas Wash on February 6, 2010 and record general comments from the survey. This right, rear track (pictured left) measured 9 centimeters long, 8 centimeters wide, with a plantar pad width of 5.4 centimeters.
Tracking Surveys in Mexico

Connectivity across the international border is a focus of concern. In Sonora, Mexico, where the majority of lands are privately owned, tracking surveys are restricted by access and travel time, requiring a slightly different monitoring method. Volunteer trackers conduct surveys every 2-3 months accompanied by Sky Island Alliance staff as part of larger biodiversity assessment expeditions and remote camera monitoring projects, and cover multiple transects in the span of several days to a week. Tracking data is otherwise collected following the same protocol as described above.

RESULTS

Summary of Ten Years of Wildlife Tracking in the Sky Islands

To date we have conducted a total of 16 tracking workshops and trained 249 tracking volunteers, monitored 49 transects, and walked over 2,800 miles to gather information on wildlife movement in known or suspected linkages. Half a dozen volunteers trained in 2001 remain active volunteer trackers for Sky Island Alliance today and have consistently and persistently surveyed tracking transects over these years. After the Spring 2010 tracking workshop, our pool of active tracking volunteers reached a record high of 90 individuals and 21 active transects.

Data gathered in the past ten years has contributed to the development of Arizona’s Missing Linkages Assessment and a refined Pima County Wildlife Linkage Assessment, two comprehensive mapping projects that identify at-risk wildlife corridors and recommendations for transportation planners and engineers, created though the Arizona Wildlife Linkages Workgroup. This corridor assessment will be completed this year through the collaboration of scientists and advocates across southern Arizona, including colleagues from state agencies such as the Arizona Game and Fish Department and the Arizona Department of Transportation, effectively connecting volunteer effort with regional agency planning processes. Planning is also underway to create a wildlife linkage assessment for Cochise County, which boasts international corridors for both ocelot and jaguar and connects linkages in both New Mexico and Sonora, Mexico.

Tracking data from the Catalina – Tortolita mountain linkage contributed to the placement of two expanded wildlife underpasses and one wildlife overpass project, the second in the state, on Arizona State Route 77. This project is approved for construction in 2013 and funded by Pima County Regional Transportation Authority dedicated wildlife tax dollars. Volunteers have remained active in monitoring tracking transects and remote cameras in the study area, which will provide baseline monitoring of wildlife pre-construction. The volunteers themselves, as well as the data, are proving excellent catalysts for outreach and they inform community members living near the proposed project.

Tracking has proven to be an excellent method of wildlife monitoring. In March 2008, we documented the first evidence of jaguar on Rancho el Aribabi from tracks. Although remote cameras had monitored the same canyon for nearly a year (where ocelots were photographed in 2007), we continued to find evidence of a young male jaguar’s tracks, scat, and deer kills before he was photographed in 2010 (Fig. 4).

Figure 4. From left to right: jaguar tracks documented in Rancho el Aribabi in 2008; jaguar photographed in same area on remote camera in 2010; potential jaguar corridors and Sky Island Alliance study areas. Map by Louise Misztal © Sky Island Alliance.
However, having both tracking and camera monitoring in place provided the most comprehensive results. A remote camera placed at a tracking transect study site 40 miles north of the international border, in Cochise County, documented an ocelot in November 2009. This was the first verified ocelot record in Arizona since the 1980s (U.S. Fish and Wildlife Service 1990), and the only record of a living individual. The data we have collected from tracks and remote cameras have successfully validated jaguar and ocelot corridor modeling in the region.

Case Study: Las Chivas Wash Transect

The Las Chivas Wash transect (Fig. 5; located in Fig. 2) has been actively monitored since April 2002. The ephemeral drainage runs west to east, along the eastern foothills of Diablo Mountain in the Tumacacori Highlands mountain complex, and feeds into the Santa Cruz River after passing beneath Interstate 19. Connecting sister tributaries to the east of the Santa Cruz River provide an excellent wildlife corridor for species moving between the Santa Rita Mountains and the Tumacacori Highlands. To the south, the Tumacacori Highlands are connected to the Cibuta mountain complex in Sonora, Mexico, making this a small piece of a larger jaguar movement corridor.

![Figure 5. Track detection of bobcat, mountain lion and badger on Las Chivas Wash, 2002-2010. Map by Kenneth Morris © Sky Island Alliance.](image)

Two volunteer trackers from the original tracking team have remained actively involved in monitoring this transect for the last nine years, an example of the success in volunteer dedication and retention. Three of the eight focal species have been recorded on this transect in the last nine years (Table 1). The tracks of white-nosed coati, an important prey species for mountain lion and jaguar (Hass and Valenzuela 2002), were documented for the first time in this location in February 2011.

Track measurements recorded of bobcat and mountain lion in Las Chivas Wash over nine years were each averaged (Fig. 6), and the extremes fall well within the averages established for these species in North America (Elbroch 2003). Track measurements can be used to provide evidence of recruitment. In December 2003, the Las Chivas Wash volunteer trackers noted the presence of a female mountain lion with a single cub: “The female’s track measured length 7.0 cm, width 7.0 cm, with a plantar pad width of 4.8 cm. The cub’s track length was 5.0 cm, width 4.9 cm, plantar pad width 2.2 cm [...] excellent findings of a resident family.”

Wildlife movement and activity patterns can tell a compelling story for wildlife corridors. When comparing seasonality of presence and absence data, we divided seasons into five categories and assigned specific intervals for each, based on the seasons recognized by the Arizona-Sonora Desert Museum for the Arizona Uplands (Arizona-Sonora Desert Museum 2007): Spring (February 1–April 30); Fore-summer (May 1–June 30); Summer monsoon (July 1–September 15); Fall (September 16–November 30); and Winter (December 1–January 31).
Table 1. Species documented by tracks, across all study sites between 2001-2011. Focal species indicated in bold text. *Species identified on the Las Chivas Wash transect.

<table>
<thead>
<tr>
<th>Species Documented by Track Counts, All Study Sites, 2001-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focal species indicated in bold text.</strong></td>
</tr>
<tr>
<td><em><strong>Species identified on the Las Chivas Wash transect.</strong></em></td>
</tr>
<tr>
<td><strong>Badger</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Bighorn sheep</strong></td>
</tr>
<tr>
<td><strong>Black bear</strong></td>
</tr>
<tr>
<td><strong>Bobcat</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Coyote</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Desert cottontail</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Domestic cat</strong></td>
</tr>
<tr>
<td><strong>Domestic cow</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Domestic dog</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Domestic horse</strong></td>
</tr>
<tr>
<td><strong>Gambel’s quail</strong></td>
</tr>
<tr>
<td><strong>Gila monster</strong></td>
</tr>
<tr>
<td><strong>Golden eagle</strong></td>
</tr>
<tr>
<td><strong>Gray fox</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Great blue heron</strong></td>
</tr>
<tr>
<td><strong>Hooded skunk</strong></td>
</tr>
<tr>
<td><strong>Human</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Jackrabbit</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Jaguar</strong></td>
</tr>
<tr>
<td><strong>Javalina</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Kangaroo rat</strong></td>
</tr>
</tbody>
</table>

**Figure 6.** Average bobcat (n=12) and mountain lion (n=34) track sizes, in centimeters, from Las Chivas Wash between 2002 – 2010.
In the Sky Island region, seasons can be variable. Generally, spring is characterized by mild temperatures and little rain, followed by extreme high temperatures and drought during the foresummer season. The monsoon summer season produces the majority of the year’s rainfall and begins plant growth into the fall season, which continues with moderate levels of precipitation and warm temperatures. Winter may include precipitation, and is characterized with the coldest temperatures of the year, reaching below freezing in some areas. These seasonal changes result in different responses by distinct species. When analyzed with local temperature and moisture data, these results can be much more accurate. However, it must be noted that with track counts these results do not accurately depict an analysis of animal activity by season, but rather track detection by season. While they may be correlated, factors such as seasonal changes in rain or wind, which affect track integrity, can play a role.

On the Las Chivas Wash transect, 51 tracking surveys were conducted between 2002 and 2010 and categorized by season. When the data is mapped, there appears to be a significant difference in track detection of focal species during the monsoon summer, with highest occurrence of sign in winter and spring (Fig. 7).

Figure 7. Seasonal track detection of bobcat, mountain lion and badger on Las Chivas Wash, 2002-2010. Maps by Kenneth Morris © Sky Island Alliance.

This could be explained by track deterioration during the rainy season; however, when we compare non-focal, prey species to predator species, it becomes clear that tracks of prey species are detected during the monsoon, whereas mountain lion and bobcat tracks are not (Fig. 8). Based on our remote camera data, we know that regionally, all four species of wild cats show less activity during the hottest part of the year, in the foresummer and monsoon season, and that predator activity patterns mirror prey activity (Yates 2008). Local influences could also be a factor, such as the availability of water.
Conclusion

The Wildlife Linkages Program continues to grow and succeed, largely due to our dedicated grassroots base, our landscape-level planning, and our ability to forge partnerships with diverse stakeholders. This success has proven that we can turn a citizen effort into conservation action, using science and direct engagement by a grassroots citizen base. Janice Przybyl, who saw the birth of the Wildlife Linkages Program and served as Program Coordinator for nine years, noted that “Through the years, the emergence of new technologies [...] has helped make documentation easier and more precise. But all the fancy gadgetry does not substitute for what we learned early on: that the key to success of the tracking program lies with the volunteers. Their enthusiasm for on-the-ground conservation work and our confidence in their abilities as ‘citizen scientists’ is what will sustain the Wildlife Linkages Program through the next decade.”

Protected wildlife linkages are the future of sustainable wildlife conservation in the Sky Island region. Dedicated citizens collecting information and advocating for our wildlife will continue to sustain this vision. We have found success in a model that does not limit “Linkages” to wildlife movement corridors; our Wildlife Linkages Program continues to link people with wildlife with conservation.

Biographical Sketches

Jessica Lamberton, Wildlife Linkages Program Coordinator, has a BS in Natural Resources: Wildlife, Watershed and Rangeland Management from the University of Arizona. Since 2007, she has attained training and experience in wildlife research, particularly with wild cats, using remote camera monitoring and wildlife tracking techniques. Jessica spent four years as the field biologist and Volunteer Coordinator for the University of Arizona Wild Cat Research and Conservation Center, combining citizen science and community outreach with local mountain lion and urban bobcat monitoring projects. With Sky Island Alliance, Jessica has served as a volunteer for ocelot and jaguar monitoring and tracking instruction since 2004, and with grassroots organizing and outreach as the Conservation Associate for Protected Lands. In her role as Sky Island Alliance’s Wildlife Linkage Program Coordinator, Jessica’s focus is the monitoring and protection of the region’s wildlife corridors. Jessica has Tracker I certification through CyberTracker International.

Sergio Avila-Villegas, Northern Mexico Conservation Program Manager, attended the University of Aguascalientes, then University of Baja California for his Master’s degree in Arid Lands Management. Since 1997, Sergio has gained extensive training and experience working in northwest Mexico on wildlife research and conservation projects on species like mountain lions, Cactus ferruginous pygmy-owls, California sea lions, river otters, Santa Catalina rattlesnakes and sea birds. In 2003 he initiated work on jaguar conservation in the Sierra Madre of Sonora where he monitored the northernmost breeding population of jaguars. At Sky Island Alliance, Sergio is taking the lead on research...
and conservation efforts in the Sky Island borderlands, currently filling a critical niche with community outreach, research and conservation in places where no information currently exists regarding the status of the borderland’s cuatro gatos.

Kenneth Morris, Volunteer GIS Assistant, has a BA in Geography and a minor in Latin American Studies with an emphasis on International Development in Latin America from the University of Arizona, and will complete his Masters of Science in Geographic Information Systems Technology at the University of Arizona in December 2011.

ACKNOWLEDGMENTS

This program and its success would not be possible without the dedication and skill of our volunteer trackers. We would also like to thank our tracking instructors over the years: Jack Childs, Harley Shaw, Christine Hass, Cynthia Wolf, Jonathan and Roseann Hansen, Aletris Nells, Lisa Haynes, Sheridan Stone, Steve Bless, and Janay Brun. Alex Smith, Louise Misztal, Sky Jacobs, Christine St. Onge, Melissa Lamberton and Jill Kelleman assisted with data synthesis and editing. Our data collection protocol is based from the Keeping Track © project and data management protocol, with modifications to accommodate the Sky Island region and Sky Island Alliance’s requirements. We appreciate Susan Morse for her assistance in the establishment of the monitoring and training protocol, and Janice Przybyl and Roseann Hansen who were instrumental in the long-term development of the Wildlife Linkage Program. We would also like to thank our funders: anonymous donors, Kresge Foundation, MET Foundation, the Nina Mason Pulliam Charitable Trust, Summerlee Foundation, and TransWild Alliance.

REFERENCES


**BIOTYPE NETWORKS IN GERMANY: THE WILD CAT CORRIDOR MAP – A STRATEGIC INSTRUMENT OF NATURE CONSERVATION**

Dipl.-Biol. Thomas Mölich (++49 36254 / 85962, wildkatze@bund.net), Wildkatzenbüro BUND Thüringen, Haupstrasse 98, 99947 Behringen, Germany  
Dipl.-Biol. Mark Hörstermann (++49 30 2 75 86 - 4 75, mark.hoerstermann@bund.net), Am Kölïnischen Park, 1 D-10179 Berlin, Germany  
Dr. Nina Klar (++49 40 23 81 80 82, ninaklar@gmx.de), ÖKO-LOG Freilandforschung, Ophagen 15, 20257 Hamburg, Germany  
Dr. Burkhard Vogel (++49 361 555 03 12, burkhard.vogel@bund.net), BUND Thüringen, Trommsdorffstrasse 5, 99084 Erfurt, Germany

**ABSTRACT**

On a global level, landscape fragmentation is one of the main reasons for the loss of biological diversity. In Germany, it’s mostly forest habitats which are affected by the increasing intensification of land use. For many forest species, forests become isolated habitats in an ever more intensely used cultivated landscape.

To counteract this process, the BUND (The German League for the Environment and Nature Conservation; Member of the Friends of the Earth network) has developed the wild cat corridor map as an expert plan for the nationwide interconnection of forest habitats for the target species the wild cat. All potential wild cat habitats in Germany with an area of more than 500 km² were determined with the help of a habitat model for the wild cat. Subsequently, by combining the habitat model with a cost-distance analysis it was possible to calculate the most economic corridors between all currently populated wild cat territories in Germany and potential habitats. The result is a map of interconnected wild cat habitats in Germany with a total length for the corridors of approximately 20,000 km. The relevance of the proposed corridors for the distribution of the wild cat is confirmed by the statistical accumulation of dead animals found along potential corridor axes.

The scientifically determined expert planning is available in an interactive form online at www.wildkatzenwegeplan.de. It provides those responsible at federal, state and local level with the opportunity to integrate their planning in a coordinated strategy which aims at interlinking forest habitats in Germany. Since 2004, the BUND is working together with government authorities, landowners and other stakeholders such as hunters and farmers to implement the wild cat corridor map. The broad public is involved by several means of public relations. Three corridors have been planted by the year 2011.

1. **INTRODUCTION**

Landscape fragmentation is one of the main reasons worldwide for the loss of biological diversity (Crooks 2002, Luell et al. 2003). This is nothing new. Already in the 1970s, landscape fragmentation was addressed as a serious environmental problem. So far, however, we have not managed to put a stop to it. There are two different forms of landscape fragmentation: division and isolation of natural habitats.

The increasing trend towards the division of natural habitats by the expansion of transport infrastructure and the increase of settlement areas have been documented by the Federal Agency for Nature Conservation and recently, several federal states. E.g. Jaeger et al. 2001, Roedenbeck et al. 2005). The NABU (Nature and Biodiversity Conservation Union) has identified in its Federal Corridor Map for Wild Animals 125 conflict points where main migration corridors of wild animals are crossed by federal roads (Herrmann et al. 2007).

Germany’s Federal Ministry of Transport reacted to the on-going debate on the separating effect of traffic corridors with a detailed information leaflet on “breaking up” these traffic corridors (Georgii & Wotschikowsky 2008). In the law on securing employment and stability in Germany from February 13, 2009 (so-called economic recovery plan II) the German Bundestag (the lower house of the German parliament) even provided for the first time in the history of the Federal Republic of Germany funds for measures to break up existing federal roads.

Just as serious as the division is the isolation of natural habitats. The increasing intensification of agriculture and forestry leads to suitable habitat structures becoming smaller and smaller until they can no longer meet the space requirements of the affected species. At the same time, because of increasing land use the barrier effect of the surrounding landscape matrix for habitat structures increases. Forest habitats provide a classic example of this. For many species of the forests, forests become habitat islands in an ever more intensely used cultivated landscape. The
negative impacts from fragmentation are proven, e.g. for the badger (Roth et al. 2000), lynx (Schadt et al. 2000) as well as many breeding bird species (Freemark & Merriam 1986, Opdam 1991).

The biotope network concept was developed to counteract the process of isolation of natural habitats (Jedicke 1994). The functioning of corridors has been demonstrated by a variety of studies (Beier 1993, Butterweck 1998, Beier & Noss 1998). Intelligently designed corridors help to interconnect forest biotopes which are isolated from each other (Bennett 1990, Perault & Lomolino 2000, Brotons & Herrando 2001).

As early as the 1980s, there were calls for a country-wide biotope network with a size of 10% to 15% of the land area in Germany. Since 2002 the federal states have been obliged to create a biotope network which makes up 10% of their area (BNatSchG 2002, § 3, Abs). With the initiative draft “Habitat corridors for human beings and nature” the Federal Agency for Nature Conservation drew up an expert basis for the creation of a national biotope network (Reck et al. 2005). However, the implementation of the biotope network concepts is generally only done on a small-scale and medium level. Within the scope of implementing the European network of protected areas “Natura 2000 network” the federal states have only registered isolated habitats as protected areas and have refrained from identifying connecting corridors. Large-scale biotope connection projects such as the project “Ecological Corridor South Brandenburg” from the Naturlandschaften Brandenburg foundation or the GREEN BELT of the BUND have been so far the exception.

Forest ecosystems play a central role in the creation of a nationwide biotope network. Forest species are far more sensitive to landscape fragmentation than species living in the open countryside. Therefore, the BUND as part of the project “Safety net wild cat” created the wild cat corridor map as a strategic instrument for reconnecting forest habitats.

2. MATERIAL AND METHOD

2.1. Area of Investigation and Map Basic

The modeling of the wild cat corridors refers to the Federal Republic of Germany. The data on land use stem from the CORINE Project. Vector data from the year 2000 was used for Germany and grid data with a resolution of 250 meters for neighboring countries. This data represents forest areas, areas with semi-natural vegetation such as heaths and moorland, cultivated areas as well as artificial areas such as settlements and industrial areas. The smallest registered areas have a size of 25 ha. The scale applied is 1:100,000. Linear structures such as water bodies and roads as well as small-scale woodlands or copses are not represented.

2.2. Cost-Distance Models

For modeling wild cat corridors, so-called cost-distance analyses were used. This is a common method in the case of there being little information available on the migration habits of a species (Adriaensen et al. 2003, Kautz et al. 2006, Schadt et al. 2002). This method helps to calculate the most favorable connection between a starting and destination point. Beforehand, resistance values are allocated based on a grid data set of the countryside. These resistance values describe “costs” (e.g. in form of energy) which are accrued when crossing a type of land use (grid cell). To cross, for example, a forest is relatively easy (i.e. cheap) for the wild cat, to cross an agricultural landscape, however, is expensive. Based on a starting point, the cumulated costs can be calculated until any endpoint within the investigation area.

To determine resistance values in the countryside, a statistical habitat model was used for the wild cat (Klar et al. 2008, Klar et al. in preparation). This model was based on radio-telemetric examinations on the land use of the wild cat. The values for habitat suitability resulting from this were directly used as resistance values for the cost-distance analysis. The advantage of such a modeling is that resistance values do not need to be estimated, but are in direct correlation with the actual preference of the species in question for certain habitats.

2.3. Background on the Habitat Models Used

Two different habitat models were used. For the allocation of resistance values of the cost-path modeling a fine-scale model of telemetric data was calculated. A gross-scale model of observation data was established to identify potential wild cat areas for the placing of target points (Klar et al. in preparation).

2.3.1. Statistic Model from Telemetric Data

The wild cat data stem from a four-year telemetric study from the Eifel mountain region (Herrmann & Klar 2007). A generalized linear mixed model (GLMM) was used. Different models were compared with one another and the model which described the wild cat distribution in the area the best was chosen. This so-called best model (following the AIC method) contains the variables “distance to the forest” and “distance to settlements”, whereas a low distance to the
forest was evaluated as positive, a low distance to settlements was consiidered negative. With the help of a logistic equation, a prediction can be made on the wild cat preferences for each individual point in the countryside. The model was checked against independent telemetric data from a lowland forest in the Rhine valley (the forest Bienwald) and from the northern part of the Eifel. In both of these very different landscape types, the model gave reliable information on wild cat occurrences (see also Klar et al. 2008). Therefore, the model can also be applied to areas throughout Germany with historical wild cat occurrences or areas without any information on the wild cats living there.

2.3.2. Statistic Model from Observation Data

In order to determine the potential for spaces suitable for wild cats in Germany, a model was created based on the observation data from Rhineland-Palatinate (Knapp et al. 2000). This involved Rhineland-Palatinate being divided into a grid with 1 km² boxes. The boxes marked as being populated by wild cats were considered to show the presence of wild cats while the remaining boxes were considered to show the absence of wild cats. A logistic regression was created. This involved taking the proportion of forest and settlement areas within a radius of 1, 3 and 5 km into account. The best model contained both the landscape parameters for the proportion of forest within a radius of 5 km and the proportion of settlement area within a radius of 5 km. With help from the Logit-Link formula a forecast for all of Germany was done in a 100 m² grid. Values (p) between 0 and 1 show the likelihood of any given grid box being populated by wild cats (provided wild cats have access to the area). An evaluation of the model showed good predictive power (proportion of correct forecasts (Kappa) = 0.65; AUC = 0.91). A so-called cut-off value of 0.4 was fixed, above which habitats considered to be suitable for wild cats were classified.

2.4. Determining the Starting and Destination Points

A total of 35 starting points and 52 destination points were determined. The best way from each starting point to all other starting points and destination points was calculated. Starting points were placed in such a way that every known occurrence of wild cats in Germany (Büttner et al. 2005) is represented by one. Individual sightings and very small or unconfirmed occurrences were not taken into account. Additionally, starting points were placed on the border with neighboring countries with adjacent wild cat occurrences. As such, starting points are located in areas from which wild cats could migrate. For the border between Baden-Württemberg and France it was presumed that individual wild cats from both the Central Vosges and the Swiss Jura get as far as the Rhine. There exist already accounts of individual wild cats in the Black Forest (Nowak 2009).

The location of the destinations was determined with the help of the habitat model. They are located in areas considered to be suitable for wild cats according to the habitat model, and in which at present there are no occurrences or in which there have only been individual sightings. For this, only connected regions considered to be suitable for wild cats and with an area of more than 500 km² were selected. Areas of this size can accommodate a wild cat population of more than 100 animals. Additionally, destination points were set on the borders with neighboring countries where connections to adjacent forest areas suitable for wild cats are possible. This method allows for the corridors to connect all wild cat occurrences amongst themselves as well as existing wild cat occurrences with potential wild cat areas. The potential wild cat areas without wild cat occurrences do not have to be necessarily connected to one another.

An exception to the rule is a destination point in the north of Mecklenburg-West Pomerania; although there is no connected area of 500 km², owing to the low population density and the expansive wetlands, the conditions are right for a wild cat habitat. Information regarding wild cat occurrences or connection points in neighbouring countries, as well as occurrences in Germany was provided by the following persons: M. Moes (Luxembourg), M. Herdtfelder (Baden-Württemberg), M. Trinzen (Netherlands, Belgium, North Rhine-Westphalia), D. Weber (Switzerland), M. Herrmann (Rhineland-Palatinate, Saarland), T. Mölich and S. Klaus (Thuringia) or taken from the following publications: Herrmann 1990; Libois 1992; Stubbe and Stubbe 2001; Mölich & Klaus 2003; Müller et al. 2003; Pott-Dörfer & Rainer 2004; Büttner et al. 2005; Denk et al. 2004; Simon 2006.

2.5. Allocation of Resistance Values, Sensitivity

The parameter for the resistance of the landscape was derived directly from the fine-scale habitat model. As the determination of the resistance values just as the selection of starting and destination points have a major influence on the result, many so-called cost and resistance grids should always be used to test the sensitivity. Therefore the p-values of the model in 100m-Grid were converted to three types of resistance values:

1. Proportional to the model evaluation: \((0.6-\text{model value (p)})\times100\) (value between 1 and 60).
2. Linear to this: \(\sqrt{\text{model value (p)}}\) (value between 1 and 7).
3. A combination of the two: \(1+\ln(\text{model value (p)})^2\)
Afterwards all settlement areas and water bodies were arbitrarily given the value of 1000, as these constitute absolute barriers. Roads and railroad tracks were not taken into consideration.

3. RESULTS

3.1. Current Distribution of the Wild Cat

![Map of current distribution of wild cats in Germany](image)

Figure 1 shows the current known occupied wild cat areas. The demarcation of the current occupied wild cat areas was done based on consultation with experts (Büttner et al. 2005, Birlenbach & Klar 2009). The regional separation between wild cat occurrences in the west and centre of Germany can be easily seen.
3.2. Starting and Destination Points

Figure 2: Current and potential wild cat habitats in Germany with start and destination points for the corridor modelling.

Figure 2 illustrates the starting and destination points, from which the best connections can be calculated. In total, 35 areas were identified as starting points and 52 destination points were determined. The illustration makes clear the great potential for suitable wild cat habitats in all states in Germany with the exception of city states.
3.3. The Wild Cat Corridor Plan for Germany

In the nationwide wild cat corridor plan, the corridors connect all current wild cat occurrences with one another as well as the present populations with potential distribution areas (Figure 3). The potential wild cat areas without wild cat occurrences do not have to be necessarily connected to one another.

Taken together the combined length of the corridors in the wild cat corridor plan is 20,000 km. As a comparison: The German road network consists of 12,400 km of federal motorway and 41,000 km of federal roads.
Figure 4: Course of the wild cat corridors between the Harz and Hainich woodlands (source: www.wildkatze.info); white hatching: wild cat habitats, black lines: corridors (principal axes)

Figure 4 illustrates a section of the wild cat corridor plan between the woodlands of Harz and Hainich. Between the two woodland areas there are a number of principal axes, orientated according to the existing forest structures. A further principal axis connects the woodland areas of the edge plate north of the Thuringian Basin.

3.4. Comparison Corridors / Number of Animals Found Dead

In Lower Saxony and in Thuringia finds of dead wild cats are relatively speaking well documented (Pott-Dörfer & Raimer 2007, Mölich & Klaus 2003). If you compare the distribution of this certain proof (which had no influence on the creation of the model) with a simulated coincidental distribution within the wild cat inhabited areas in these two federal states, it can be seen that the real proof is statistically significantly stacked along the modelled corridor: in Lower Saxony 35% of the animals found dead at both sides of a corridor model with a 500 m buffer, only 14% of the coincidental points are located within this area (binomial test, chi-square = 9.4534; df = 1; p= 0.002). In Thuringia, 34% of the animals found dead are on the 1 km wide axis of the model, by comparison only 17% of the coincidental points (binomial test, chi-square = 6.9447; df = 1; p= 0.008).

4. DISCUSSION

4.1. Is the Habitat Model Enough to be Able to Accurately Enough Predict Potential Habitats?

The habitat model used for prediction of potential suitable wild cat habitats is relatively crude. The main parameter is the proportion of forest and settlement areas within a radius of 5 km. However, the model achieved a good predictive accuracy when evaluated. That said, it should be remembered that the model was developed in Rhineland-Palatinate and the prevailing habitat conditions there have influenced the model. This leads to parameters such as greater altitude or snowpack in winter not being taken into consideration in the model. High amounts of snowpack and long-lasting snow
coverage are, however, factors which could limit the suitability of forest habitats for the wild cats, as they would be unable to find sufficient supplies of food in winter.

For this reason, it can be presumed that the predictive accuracy of the model declines for potential habitats located at higher altitudes e.g. in Alpine areas. That said, the known incidence/occurrence of wild cats in the Hochharz (Noffke 2008) demonstrate that the animals occupy higher up areas in the low mountain ranges or at the very least use them seasonally.

In total, the predicted potentially suitable wild cat habitats have tallied with expert assessments. Moreover, seeing as only forest areas of 500 km² or more are taken into consideration, the probability of sufficient habitat quality is high. For the larger benchmark level the predictive power of the model can be considered to the adequate.

4.2. How Accurately Do the Corridors Reflect the Current Situation of the Landscape?

As the calculation of the corridors uses CORINE data, linear small-scale structures already present in the landscape (copses, hedgerows, etc.) are not taken into account. Therefore, the calculations for some of the federal states were repeated again using ATKIS data (AKTIS is an abbreviation of ‘Amtlich Topographisch-Kartographisches Informationssystem’ which translates as ‘official topographic-cartographic information system’) (Klar 2007, Klar et al. 2008). They have a higher resolution as well as containing linear small-scale structures. In any case, there was no essential deviation from the corridors drawn up using Corine data discovered. As it makes sense to use the largest possible forest area available as a stepping stone to connect larger forest areas, the course of CORINE based corridors, particularly over great distances, is in many cases preferable to AKTIS based corridors, which are too closely orientated to linear hedge structures (Hänel 2007). As linear structures could be important for wild cats for orientation in the connection between two forest areas, they should be taken into consideration in the actual implementation of the corridors with the course of the safety net corridor being adapted in detail.

The illustration in Figure 4 shows that the corridors calculated using the Corine data are also closely orientated to guiding structures already present in the landscape.

Potential barriers, such as rivers, roads and railroad lines were not taken into consideration in the calculation of optimal corridors. The wild cat corridor map says nothing about the permeability of the corresponding transport axes. In the development of the habitat network it should be noted that for the corresponding intersection points with transport axes suitable crossing options need to be created or used. Roads and railroad lines with lower volumes of traffic are not a problem for the animals, even without any assistance. With higher traffic volumes (>10,000) the creation of the corridor should be combined with the provision of crossing assistance (wildlife crossings) where necessary (Klar et al. 2009). Should there already exist suitable crossing opportunities, such as viaducts or tunnels, close to the course of the corridors, these should be taken into account in the implementation of the corridors.

4.3. Why is the Concept Focused on One Particular Species?

Biotope network systems are most effective when they play the role of a population network system, or create a “viable metapopulation system”. The success of this can hardly be tested without taken into account the needs of the species which should profit from the networking. Henle et al. (1999) require for this reason a “clear definition of target species” for the planning of corresponding network systems. “Target species” are described as species which serve the formulation of verifiable nature conservation goals and promote their political feasibility (Vogel et al. 1996). The habitats of these “target species” should be networked with one another in such a way as to enable unhindered exchange and allow for new habitats to be populated.

The wild cat was selected as a target species which combines the requirements of a number of forest dwelling species as regards a forest corridor – the habitat spectrum of the wild cat encompasses the central-European natural heritage forest:

- The wild cat is very sensitive to the fragmentation of forest habitats and for this reason can be considered an indicator of the degree of the networking of the forests.
- The space requirements of the wild cat correspond to the benchmark level on which a nationwide habitat network for forest habitats is realizable.
- The wild cat is a typical species of uncultivated, undisturbed woodlands with high structural variety and ample dead wood.
- The wild cat is a European faunal element. Germany is at the center of its distribution area and has a particularly important role to play in the preservation of this species.
Semi-natural forests with sufficient networking are not just a prerequisite for the survival of the wild cat. They guarantee that a multitude of other species also benefit from this.

The wild cat is a definite mascot, serving as an ambassador in the promotion of nature conservation measures.

4.4. Is the Wild Cat Corridor Map Realistic?

A network of 20,000 km of forest corridor seems to be on a utopian scale. When considered in the context of the area of the German Federal Republic or the forest area in Germany this figure gains a new relativity. Presuming an average corridor width of 50 m, this results in a total area requirement of 1,000 km². In comparison: the Federal Republic of Germany has a total area of 358,000 km² with a total forest area of 110,400 km². So the wild cat corridor plan requires about 0.3% of the total area of the Federal Republic and corresponds to 0.9% of the forest area in Germany. In comparison: In less than 3 years, a similarly large area in Germany was built upon.

The fundability of the nationwide corridor network is a given as the finances required in comparison to investment in the gray infrastructure is comparably low. For the development of a one kilometer long and approx. 50 m wide corridor, including the purchase of the area and the complete planting, an investment amount of approx. 300,000 Euro is estimated. The average costs for a kilometer of motorway are about 12 million Euro, approximately forty times higher. Presuming that a large part of the corridor network can be realized through the bundling of compensatory and alternative measures, the burden on the already modest nature conservation budget of the country and the federal states is kept down.

One example for the implementation of forest corridors is the wild cat corridor between Hainich National Park and the Thuringian Forest Nature Park, which originated from the BUND project “A Safety Net for the Wild Cat”. Through close cooperation with the responsible land consolidation authority, the nature conservation authorities and the roadbuilding authorities compensatory measures could be bundled with the relocation of the A4 Motorway, resulting in a 1.2 km long and 50 m wide forest corridor connecting the two large conservation areas (Mölich & Vogel 2007).

Therefore, the realization of the nationwide wild cat corridor plan within a period of 10 years is a realistic perspective.

4.5. The Wild Cat Corridor Map as a Strategic Instrument for Nature Conservation

The wild cat corridor map is focused on the wild cat. However, it is by no means a pure species specific protection concept. The protection of the wild cat for the sake of it is not to the fore. The wild cat corridor map is a strategic instrument to reconnect forest habitats to one another in Germany. The wild cat was selected as a representative species for the natural communities present in woodland ecosystems in Germany. In order to ensure the survival of this species on a nationwide basis, the strategic goal of networking over 500 km² of forest habitats suitable for it was defined. The level of networking of forest habitats required to achieve this goal was determined using scientific methods. Therefore the location and extent of the corridors can always be verified and understood. The wild cat as target species provides an indicator of the success of the measures suggested here. The development of the existing population and the spread again of the wild cat provide a direct measure of the regeneration of the functional interdependence between the networked forest habitats.

This benefits not only the wild cat but all species dependent on a functioning forest network.

An interactive version of the wild cat corridor map can be found online under www.wildkatze.info. This allows for a comparison any time of all places within Germany between land use planning and the wild cat corridor map at all planning levels. In preparation for large-scale projects which will result in the heavy fragmentation of the landscape, exclusion areas can be identified and information on the least destructive variety derived.

Whether it’s for the agreement of suitable compensatory measures, the planning of conservation areas, an undertaking to develop lands or the implementation of a nature conservation project, it can be checked at any stage whether a bundling in favor of a nationwide habitat network along the wild cat corridor makes sense.

Finally, with the wild cat as a mascot the prerequisites for the political viability of the suggested measures are fulfilled. Measures to protect the wild cat achieve a high level of acceptance amongst both the general population and political decision makers.
4.6. Implementation

Since 2004, the German environmental group Friends of the Earth Germany/BUND is working together with government authorities, landowners and other stakeholders such as hunters and farmers to implement the wild cat corridor map in order to develop 20,000 kilometers of migration corridors. Under the BUND initiative, connectivity between existing and potential habitats will be restored through the planting of trees and shrubs along migration routes and the construction of ‘green bridges’.

A first corridor has been realized between the Thuringian Forest and the Hainich National Park (in the Thuringian region) after years of careful preparation and studies. Two more corridors have followed already. For 2011-14 construction of several new corridors in Germany is planned, for example in Rhineland Palatinate which is home to almost half of the German wild cat population. In cooperation with scientific partners new monitoring methods based on hair samples and genetic analysis were developed and improved. The next step is the introduction of an open database with wild cat DNA samples from eight key regions of the distribution in 2011.

Although the wild cat is the target species of the initiative – many other species will benefit, thereby improving the health of entire forest ecosystems. In 2010, the BUND started an accompanying publicity campaign to raise public awareness and garner support for what has become one of the largest conservation projects in central Europe. Thus, stakeholder dialogues and public relations are major parts of the project. Activities include public fun runs, round tables and TV commercials. The campaign is funded by the EU (Life+). In addition, proposed corridors in Thuringia will be financed by EU ELER Fund. The BUND is now searching for partners for the next stage of the wild cat network – the international linkage. Countries with similar conditions like France, the Czech Republic, Austria, and others may join this wild cat network which one day may reach from Spain to the Balkans – the natural range of the European wild cat.

5. ACKNOWLEDGEMENTS

The author would like to thank those active contributors working for public authorities, companies and institutions, as well as the full-time and voluntary employees of the “wild cat safety net” for their commitment. A particular debt of gratitude is owed to the Deutsche Bundesstiftung Umwelt (DBU) and the Zoologische Gesellschaft Frankfurt (ZGF) for their sponsorship of the project “A safety net for the wild cat”.

6. BIOGRAPHICAL SKETCHES

Dipl. Biol. Thomas Mölich
Job: Scientific Head of Friends of the Earth Wildcat Projects
Career:
1985–1991  Study in Biology at the Universities of Mainz and Goettingen
1996–1999  Head of FOE Project “A Conservation Programme for the Wildcat in Thuringia”
2000–2004  Referent for science and nature protection at National Park Hainich Administration
2004–2011  Scientific head of FOE project “A Safety – Net for the Wildcat”
Honorary post:  Member of the wolf – task force at Department of the Environment of Federal State of Thuringia.

Dipl. Biol. Mark Hörstermann,  Biologist
Job: Project Director Biotope Networks
Career:
1988–1995  Study in Biology at the Universities of Würzburg, Germany and Duke, North Carolina (DAAD Scholarship)
2004–2011  Head of Communication, Friends of the Earth Germany, Dept. Conservation

Dr. Nina Klar, Biologist
Career:
1997–2003  Studies of Biology at Free University Berlin and University Of Wales, Swansea
2003–2009  Field research in cooperation with OEKO-LOG.COM, Parlow: Road Ecology, GIS, Models, Wildlife biology
2004–2010  Phd "Habitat fragmentation and (Re-)connection – a conservation concept for the wildcat in Germany" at Institut für Humanbiologie und Anthropologie, Free University Berlin and Helmholtz Centre for Environmental Research - UFZ, Leipzig
Since 2009
Honorary post:  Referee for species protection and biodiversity at Freie und Hansestadt Hamburg, Behörde für Stadtentwicklung und Umwelt, Abteilung Naturschutz
Dr. Burkhard Vogel, Biologist
Job: Secretary of Friends of the Earth Thuringia
Career:
1984–1991 Study in Biology at the Universities of Saarbrücken, Freiburg, Würzburg
1992–1994 Research Fellow at the Centre of Environmental Research UFZ, Leipzig
1994–1998 Research Fellow at the Center of Nature Conservation of the University of Göttingen
1998 Ph.D.
Since 1999 Secretary of Friends of the Earth in Thuringia
Honorary post: Chairman of the advisory board for Nature Conservation of the State of Thuringia

7. BIBLIOGRAPHY


DEVELOPING AND IMPLEMENTING A COMPREHENSIVE WILDLIFE MONITORING PROGRAM FOR THE I-90 SNOQUALMIE PASS EAST PROJECT

Craig Broadhead (509-577-1751, broadhc@wsdot.wa.gov), WSDOT South Central Region Assistant Environmental Manager, 2809 Rudkin Road, Union Gap, WA 98903 USA
Jason Smith (509-577-1750, SmithJW@wsdot.wa.gov), WSDOT South Central Region Environmental Manager, 2809 Rudkin Road, Union Gap, WA 98903 USA
Amanda Sullivan (509.899.5708, asullivan@prrbiz.com), Communications Consultant, PRR, Inc., 1109 First Ave, Suite 300, Seattle, WA 98101 USA

ABSTRACT

The Washington State Department of Transportation (WSDOT) is currently constructing Phase 1 of a project that will ultimately improve a 15-mile stretch of Interstate 90 east of Snoqualmie Pass. The I-90 Snoqualmie Pass East (I-90 Project) is unique in that it addresses traditional transportation issues and also invests heavily in improving ecological connectivity. The ecological investments of the project include retrofitting existing structures to provide or improve connectivity, installing new wildlife crossing structures and wildlife fencing, improving hydrologic connections, and enhancing stream and lakeshore habitat. In order to determine how these investments in ecological connectivity perform over time, and to incorporate lessons learned into future phases of design and construction, a comprehensive wildlife monitoring program is needed. WSDOT, in partnership with several agencies and organizations, developed and is implementing a multi-tiered approach to wildlife monitoring. Implementation of this type of monitoring effort will provide scientifically defensible baseline and post-project data, define the parameters of successful connectivity enhancement, and provide adaptive management to help guide final design as the I-90 Project progresses.

INTRODUCTION

The Washington State Department of Transportation (WSDOT) has begun constructing a project to improve a 15-mile stretch of Interstate 90 east of Snoqualmie Pass that addresses traditional transportation issues and invests heavily in improving ecological connectivity.

WSDOT received funding from the 2005 Transportation Partnership Account (a 9.5 cent gas tax) to design and construct the first five miles of the 15-mile I-90 Snoqualmie Pass East Project (I-90 Project). Total current project funding is $525 million. Construction of the five-mile project – the Hyak to Keechelus Dam Project – began in 2009. As WSDOT continues to construct the Hyak to Keechelus Dam Project, wildlife monitoring efforts are also underway to collect baseline data and determine if ecological connectivity goals of the project are achievable, and/or if expectations need to be modified.

WSDOT has partnered with Western Transportation Institute (WTI), Central Washington University (CWU), and the US Forest Service (USFS) on a long-term, multi-tiered monitoring program that will yield scientifically defensible data regarding pre- and post-construction wildlife activity. The program addresses not only large, wide-ranging species, but also lower-mobility species such as amphibians, small mammals, and fish. The monitoring program emphasizes a unique, multi-tiered approach that identifies basic project-level performance standards and the information needed to answer large-scale questions regarding the long-term success of connectivity enhancement measures.

Ultimately, a successful wildlife monitoring program will allow WSDOT and its partners to evaluate the fulfillment of the I-90 Project’s objectives of increasing motorists’ safety by reducing wildlife-vehicle collisions and improving the ecological permeability of the highway for fish and wildlife. In addition, the systematic collection of pre- and post-construction wildlife data will help with performance measurements and guide the design of highway improvements in later stages of the unfunded portions of the project and on projects occurring elsewhere.

Before detailing components of the wildlife monitoring plan, it’s important to first understand the project corridor and how WSDOT and partners arrived at developing a preferred alternative and mitigation strategy for the entire 15-mile I-90 Project.

UNDERSTANDING THE I-90 PROJECT CORRIDOR

I-90 spans 300 miles in Washington state from the Port of Seattle to the Idaho state line, and then continues east across the United States to Boston, MA. I-90 is the major east-west transportation corridor across Washington and is vital to the state’s economy (WSDOT 2008). The I-90 Project improves a 15-mile portion of I-90, beginning on the eastern side of Snoqualmie Pass at milepost 55.1, just east of the Hyak Interchange, where the existing highway
narrowed from six lanes to four lanes. The project end point is at milepost 70.3 at the West Easton Interchange, where the terrain becomes flatter and the highway is straighter. This 15-mile stretch of I-90 is in Kittitas County, WA, and passes through the Okanogan-Wenatchee National Forest (see Figure 1).

FIGURE 1. State of Washington map showing Interstate 90, the I-90 Project location, and typical topography.

I-90 is a critical link connecting Puget Sound’s large population and business centers with the farmlands, diverse industries, and extensive recreational areas of eastern Washington. The uninterrupted movement of people, freight, and business over Snoqualmie Pass is essential to quality of life and the economic vitality of Washington State (WSDOT 2008).

The I-90 Project presents many unique environmental and design challenges due to its location along a high mountain pass in the Central Cascades. The general topography is one of mountainous peaks and valleys. For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake, a deep-water agricultural reservoir of glacial origin, and steep mountain slopes (see Figure 1). These steep mountain slopes contain volcanic bedrock at varying depths that are subject to deep fissures and stress cracks with weakened slip planes, which when combined with high annual precipitation and freeze-thaw conditions, makes them susceptible to landslides, debris flow, and avalanche. Geotechnical studies indicate that certain portions of the project area contain stable rock and favorable sediment, while other areas contain soft friable rock and liquefiable soil conditions. These conditions, combined with short construction windows (May through October) and a planned annual winter shutdown, require a unique set of plans for designing bridges, improving ground conditions for foundations, and stabilizing rock slope cuts before and during construction.

The I-90 Project area (15 miles) is built on National Forest land. The large areas of protected state, federal, and conservation land north and south of I-90 support a broad range of habitats and a diverse array of plants and wildlife. Since the late 1990s, the area has been managed according to the Snoqualmie Pass Adaptive Management Area Plan. This plan requires protection of old-growth habitat, removal of portions of existing U.S. Forest Service (USFS) roads, and management of recreation to facilitate species movement. In recent years, through the acquisition of private land, there have been substantial private and public land conservation efforts to protect old-growth forest, provide larger contiguous blocks of forested habitat, and facilitate habitat connectivity across the I-90 corridor. The Cascades
Conservation Partnership, Mountains-to-Sound Greenway Trust, U.S. Fish and Wildlife Service (USFWS), and USFS have invested over $100 million in these efforts during the last seven years. These land purchases, along with the I-90 Land Exchange, have added 75,000 acres (approximately 117 square miles) of land to the National Forest system adjacent to and within the I-90 Project area. The land management by USFS and conservation groups has given WSDOT confidence that ecological connectivity investments will be protected in perpetuity.

Even with conservation efforts, I-90’s presence limits wildlife movement and forms a physical barrier between upstream and downstream terrestrial and aquatic environments. Existing culverts and narrow bridges limit aquatic species movement, and in many cases, the highway embankment has filled in habitat that once made up channels, floodplains, and associated wetlands. Adequate connections between habitats and hydrologic features on either side of I-90 are necessary for the continued health of the project area’s diverse ecosystems.

**PROJECT SETTING DEFINES ECOLOGICAL DESIGN**

The unique project setting and WSDOT’s strong partnerships with resource agencies and conservation groups identified the need for an investment in ecological connectivity early in the project planning process.

For the design of this project, WSDOT adopted the ecological approach. This ecosystem-based approach helped WSDOT and its partners develop a long-term vision for the I-90 corridor and mitigate the effects of the project. In 2000, an inter-agency interdisciplinary team (IDT) was formed and preliminary engineering and environmental analysis began (see Figure 2). Through the IDT and subsequent sub-committees, WSDOT accomplished ecological project goals by applying a landscape-level, watershed-based mitigation strategy. This mitigation strategy allowed WSDOT and its partners to consider multiple ecological needs in the project design, including connecting habitat, streams, and groundwater across I-90 at various focal linkage areas identified as Connectivity Emphasis Areas (CEAs).

**FIGURE 2.** Figure 2 shows the core members of the I-90 Project IDT, including USFS, USFW, Department of Ecology, USFWS, Kittitas County, US Bureau of Reclamation, US Army Corps of Engineers, US Parks and Recreation, and Environmental Protection Agency.

When financing was secured for the project in 2005 by the Washington State Legislature, WSDOT received funding to ramp up the design effort, finish National Environmental Policy Act (NEPA) compliance, and prepare construction documents for the first five miles of the project area from Hyak to the Keechelus Dam vicinity. WSDOT published the I-90 Snoqualmie Pass East Project Draft Environmental Impact Statement (Draft EIS) for public review and comment in
summer 2005. When the Draft EIS was published, the I-90 Project became the first project in Washington State with a purpose and need statement that included commitments to improve ecological connectivity. Additionally, the landscape-level, watershed-based approach helped WSDOT secure the necessary agency and citizen approval for the Draft EIS. Over the next two years, WSDOT continued using existing partnerships and formed new teams, including specialized technical committees, to identify a preferred design alternative for the I-90 Project. These collaborative efforts culminated with the release of the Final EIS in August 2008 that identified WSDOT’s preferred design alternative for the I-90 Project. In October 2008, FHWA issued its Record of Decision selecting the preferred alternative for construction.

The I-90 Project, as stated in the Final EIS and approved by FHWA, will improve the safety and reliability of this corridor by reducing avalanche risks to the traveling public, minimizing road closures required for avalanche control work, and reducing the risk of rock and debris falling onto the interstate from unstable slopes. WSDOT will also fix structural deficiencies and provide for the recent and predicted increases in traffic volume. WSDOT will work to reduce wildlife / vehicle collisions by re-connecting habitat across I-90 and improving mobility of aquatic species and wildlife.

Plans for the project include widening the existing four lane interstate to six lanes, replacing deteriorated concrete pavement, straightening sharp roadway curves, stabilizing unstable rock slopes, building a new, more efficient snowshed (a concrete shed covering the roadway to provide permanent protection from avalanches and other falling debris to travelers passing through Snoqualmie Pass), and constructing wildlife crossings structures.

The preferred alternative for the entire 15-mile project includes 24 large crossing structures (11 bridge crossings, seven new or larger culverts, three wildlife overcrossings, and three replacement bridge crossings) for improved wildlife passage. Hydrologic Connectivity Zones (HCZs) were also identified as focal areas where the existing infrastructure isolates or disrupts the natural movement of surface and groundwater. Work in these areas will include the facilitation or reconnection of hydrologic features.

**ESTABLISHING THE MITIGATION DEVELOPMENT TEAM**

As a transportation agency, WSDOT could not provide the context necessary for a landscape-scale connectivity enhancement project. To integrate ecological connectivity into the project design, the IDT convened a multi-agency team of biologists and hydrologists to form the Mitigation Development Team (MDT). Partnership agencies included WSDOT, USFS, USFWS, and Washington Department of Fish & Wildlife (WDFW).

The MDT was tasked to make recommendations that responded to the following central question: *Given what we know about wildlife movement, habitat fragmentation, and ecological connectivity needs, and framing this knowledge within the context of a limited design / construction budget, where are the locations within the project area that provide the highest benefit-to-cost ratio and long-term solutions to the issue of ecological connectivity?* (MDT 2006).

The MDT’s first order of business was to review the existing scientific information and site-specific technical report data developed by WSDOT, USFS, and other agencies during the 1990s to determine the existing ecological conditions within the project area. Among other topics, the MDT considered high-mobility species, low-mobility species, roadkill data, fish passage, landscape permeability, existing habitat conditions, aquatic habitat connectivity, and hydrologic function.

The MDT further identified objectives to determine whether project designs would meet the goal of increased ecological connectivity. These objectives were refined into three questions:

- Are aquatic and terrestrial habitats sufficiently linked to function properly for the species they support?

- Are hydrological processes sufficiently connected to permit the proper function of stream channels, riparian areas, floodplains, channel capacity and movement, wetland flow paths and hydroperiods, and groundwater-surface water interactions?

- Will highway-related mortality and impediments to movement be reduced sufficiently to provide a moderate to high probability of sustaining local and regional populations of all species, and to reduce risks associated with demographic isolation and limited genetic variability?

These objectives provided the general indicators of landscape-scale performance and the basis for a set of measurable performance standards to help define success.
DEFINING CEAS

Once the performance objectives were defined, it was necessary to determine at what areas relative to the project scale each objective was the most applicable. To do this, the MDT identified Connectivity Emphasis Areas (CEAs) - areas where opportunities exist to improve connectivity for a unique assemblage of species and / or habitat types.

The MDT identified three generalized north-south linkage zones—the Gold Creek Valley, Keechelus Lake to Amabalis Mountain, and the Easton Hill area. Within these zones, they also identified 14 CEAs across the project area. CEAs ranged in complexity from single stream crossings to multiple stream crossings with associated wetlands and areas of diffuse surface flow, to upland areas that are important movement routes for wildlife (see Figure 3) (MDT 2006).

Seven CEAs were identified as having a high potential for improving ecological connectivity for wildlife at the CEA-scale as well as project-wide: Gold Creek, Price/Noble Creek, Bonnie Creek, Swamp Creek, Hudson Creek, Easton Hill and Kachess River. Each CEA's design measures differed based on whether they sought to provide connectivity for fragmentation-sensitive species (i.e., rare, wide-ranging and/or localized species generally sensitive to roads) or common species (i.e., widespread species in project area that are generally less sensitive to road disturbance). This distinction also helps determine the allocation of sub-samples for monitoring as well as the type of performance evaluation.

The I-90 Project design team collaborated with the MDT to develop alternative conceptual designs for the highway at each CEA. The design team also developed some designs independently so that a range of alternatives could be evaluated. The IDT requested that the MDT evaluate the likely performance of the resulting array of different design options to determine which would meet ecological connectivity objectives.

After evaluating design options and developing specific performance standards and CEA-specific connectivity objectives, the MDT found that crossing structures would be more effective for some species if they contained habitat, rather than simply being physical connections for opposite sides of the highway. For instance, lower mobility animals would feel more secure crossing a structure containing hiding cover. Different animals show different preferences for crossing structures, whether the structures are small, medium, or large (MDT 2006).

The MDT also noted that project-wide wildlife connectivity objectives were likely to be met and would profoundly improve ecological connectivity relative to the existing condition by:

- Combining design options at CEAs that meet CEA-specific objectives,
- Installing small or medium crossing structures at upland sites, and
- Implementing recommended performance standards outside of CEAs.
The MDT also recommended a combination of structure types (i.e., overcrossing and undercrossing) that would be most beneficial for the variety of species to be served. They recommended additional small or medium (drainage-type culverts or box culverts) crossings at intervals throughout the corridor to further support the linkage of upland habitats and the movement of smaller animals. From a hydrologic perspective, project-wide connectivity needs are predominantly met by design options that meet objectives within CEAs (MDT 2006). These recommendations were presented to the IDT, who integrated them into the overall recommendations for the preferred alternative and forwarded them to FHWA and WSDOT decision makers.

After these recommendations were adopted by the decision makers, the I-90 Project design team has and will use these recommendations to move conceptual design to final design plans at each CEA.

IMPLEMENTING A WILDLIFE MONITORING PROGRAM

The defined project objectives, specifically regarding wildlife connectivity, are to focus on improving motorists’ safety by reducing wildlife-vehicle collisions while improving the ecological permeability of the highway. In order to understand how WSDOT’s investments perform over time, and to incorporate lessons learned into future phases of design and construction, a robust wildlife monitoring program was needed.

Because of the landscape context of road systems, ecological connectivity objectives, and surrounding land management agencies, wildlife monitoring and assessment had to address the broader landscape, ecological processes, and restoration of important linkages for a multiple-species ecosystem. WSDOT, other agencies, and interested groups came together to launch a multi-tiered wildlife monitoring program.

WSDOT first formed a Wildlife Monitoring Technical Committee to assist with developing a wildlife monitoring program and help manage the objectives of the project. The committee provided a venue where experts in wildlife biology and road ecology could develop guidance on how to perform wildlife monitoring for WSDOT (WSDOT IDT). Members of the committee included WSDOT, USFS, USFWS, Environmental Protection Agency (EPA), WDFW, Central Washington University (CWU), and Western Transportation Institute (WTI) at Montana State University.

The cornerstone of the I-90 Project wildlife monitoring program was a wildlife monitoring plan that clearly defined program objectives, highlighted funding and partnership opportunities needed to realize goals, and guided the long-term monitoring effort. The key idea of the monitoring plan was that it must be dynamic, adaptable, and guide the design and implementation of pre- and post-construction monitoring of ecological connectivity for wildlife. WSDOT contracted with WTI in 2007 to help develop the initial Wildlife Monitoring Plan. The project relied heavily on a coordinated, interagency approach and a common understanding among stakeholder groups.

TIERED MONITORING APPROACH

In order to assess the many aspects of meeting ecological connectivity objectives on the I-90 Project, the I-90 Wildlife Monitoring Plan focused on a two-tiered approach. Tier 1 evaluates basic transportation management questions regarding the performance of crossing structures and fencing (such as changes in wildlife-vehicle collisions and use of new crossing structures). Tier 2 builds on the results of Tier 1 to address more complex questions about the positive effects of the project on wildlife populations (such as genetic and demographic structure, viability, and dispersal) (WSDOT/WTI 2008).

Project monitoring is being conducted at three spatial scales:

- Local-scale or site-specific monitoring at particular CEAs
- Project-scale monitoring covering the entire 15-mile project area
- Landscape- or regional-scale monitoring and research

Information obtained from individual CEA-based monitoring will be of value for evaluating project objectives at those CEAs, or for wildlife with localized populations (i.e., low-mobility species such as pikas with entire populations centered around one or within a few CEAs). Additionally, the collective information from CEA-based monitoring will be used to determine whether project-wide ecological connectivity needs were met for high-mobility species. Project- and landscape-scale monitoring will be used to evaluate project-wide objectives, particularly for wide-ranging species.
Tier 1

Tier 1 monitoring is designed to evaluate the project’s connectivity measures at the scale of the project corridor and to answer the most fundamental transportation management questions regarding the ecological connectivity goals of the project. Tier 1 monitoring addresses WSDOT management concerns regarding the performance of the project’s connectivity design measures. These are the six basic Tier 1 monitoring objectives and metrics:

- **Characterize the locations and rate of wildlife-vehicle collisions.**
  
  *Monitoring metric: Incidence of road-killed wildlife in the project area.* What species are affected by collisions? Where are collisions occurring and how frequently? Are there changes in wildlife-vehicle collisions in the project area after measures are in place?

- **Assess the use and effectiveness of wildlife crossing structures (existing and planned).**
  
  *Monitoring metric: Use of crossing structures.* Do animals use the existing below-grade structures prior to construction? If so, which species and how frequently? Do animals use the installed wildlife crossings? If so which species, how frequently and what design and habitat factors affect passage? Do the crossing structures allow for the reconnection of habitats and organisms?

- **Characterize the rate of at-grade highway crossings by wildlife.**
  
  *Monitoring metric: Crossing rates, locations and activity of wildlife in the project area.* Do animals cross I-90 above the road? What species, where, and with what frequency prior to construction?

- **Assess species occurrence and distribution in project area.**
  
  *Monitoring metric: What species are present in areas adjacent to crossing structures?* Assessing occupancy in areas adjacent to crossing structures is essential for evaluating the effectiveness of the crossing structures, as expected use of a given structure by a species is contingent on the species occurring there. What are the species’ distributions and abundances and how do these change after construction? Do rare (e.g., wolverine) or extirpated species (e.g., grizzly bear) re-colonize or use the project area after connectivity measures are installed?

- **Assess the effectiveness of wildlife fencing.**
  
  *Monitoring metric: Reports of wildlife in the right-of-way and surveys of fence breaches (e.g., holes in fence and under fence).* How effective is fencing for various wildlife species throughout the project area?

- **Assess the effectiveness of jump-outs.**
  
  *Monitoring metric: Effectiveness of wildlife jump-outs.* If wildlife accesses the right-of-way, how effective are jump-outs at allowing wildlife to escape?

Tier 2

Tier 2 monitoring activities, research, and objectives will focus on landscape and population-level connectivity and complement Tier 1 monitoring by providing a more comprehensive understanding of how the project connectivity measures perform at a larger scale. Tier 2 monitoring efforts are somewhat unique to the I-90 Project, as few other Tier 2 monitoring efforts have been instituted in the country. Tier 2 efforts will allow WSDOT and its partners to evaluate wildlife usage and performance of the various crossing structures to determine their effectiveness. Research methods will include: pre- and post-population level benefits (hair collection, scat-detection dogs); pre- and post-regional species occurrence (remote cameras, hair collection, tracking, scat-detection dogs); post population viability analysis (computer-based analysis); and pre- and post-extent of human disturbance (GIS mapping, spatial stats, trail / traffic counters).

The key component of Tier 2 research is that it is defined and conducted by agencies and organizations outside of the purview of WSDOT. Tier 2 efforts will advance the science of road ecology, and will require a continued collaboration and partnership between WSDOT and other entities in order to be successful (WSDOT/WTI 2008).
Some ideas of research areas for Tier 2 are:

- **Assessing the population-level benefits of wildlife crossings.**

  The project’s connectivity measures are intended to enhance the movement of organisms, increase genetic diversity, and provide for naturally sustaining populations (MDT 2006).

  *Research questions:* Wildlife crossing structures may be used many times by different species, but how many individuals and what sex and age group classes are using the structures? Are populations benefiting from the wildlife crossings? What is the genetic structure (pre-construction) of target populations and does this structure significantly change after construction?

- **Assessing species occurrence.**

  Improved connectivity across I-90 in the project area should result in positive changes in species distribution (greater movement and dispersal) when compared with pre-construction baseline conditions. For high-mobility species, assessment will be required at scales larger than the CEAs and beyond the project corridor.

  *Research questions:* How are species distributed and what are their abundances in the larger landscape prior to construction? Do species distributions and abundances change after construction? Do absent species re-colonize the study area after connectivity measures are installed?

- **Conducting population viability analysis.**

  The project’s connectivity measures are intended to eventually provide for naturally sustaining or viable populations in the project area. Population viability modeling is a powerful tool and evaluation method.

  *Research questions:* Using information from species-specific Tier 2 research and spatially explicit population viability models derived from that research, assess whether there are changes in key life-history attributes that will affect long-term, local-scale population growth and viability.

- **Evaluating the effects of human activity on crossing structure performance.**

  Evaluation as to whether ecological connectivity needs are being met after construction will require the identification and possible control of potentially confounding human activity and disturbance in the project area (i.e., is sub-optimal use of a particular crossing structure the result of poor design or human disturbance?).

  *Research questions:* How does the distribution and level of human activity (e.g., recreational activities, built areas, low-volume and forest road traffic) affect the use of specific crossing structures?

Numerous other Tier 2 projects can be conceived of as either highly applied studies that will complement Tier 1 monitoring or independent projects that are more academically focused. Such projects will develop as Tier 1 monitoring is carried forward, potential collaborators are identified, and relationships with partnering organizations formed.

**FOCAL SPECIES SELECTION**

It is crucial to narrow wildlife monitoring efforts to a select group of focal species. Both high- and low-mobility focal species should be used based on the assumption that they will provide an indication of the generalized response to a given stimulus by a larger assemblage of species.

Several criteria can be used to identify potential focal species for monitoring connectivity enhancement efforts. Each criterion pertains to either the specific monitoring objective or the ecosystem context of the monitoring plan. With regard to the monitoring objectives of the project, the ecological attributes of the focal species along with their sampling potential (i.e., their ability to generate sufficient data for statistically robust analyses) are the most important (WSDOT/WTI 2008).

Ecological attributes and data gathered during Tier 1 monitoring activities will be used to determine which species serve as the best indicators of change. Some examples are: black bear and bobcat (area-limited species); marten, northern flying squirrel, various amphibians and reptiles (dispersal-limited species); elk and mule deer (process-limited species); mountain lion (keystone species); and pika (narrow-endemic species).
These species and species-groups may change as more information from the project area becomes available and Tier 2 research is initiated. The collection of genetic information prior to construction will be critical for evaluations of barrier effects at the project scale. Therefore, DNA samples (e.g., hair or scats) will be collected from select focal species when possible.

**PRE-CONSTRUCTION MONITORING – BASELINE FOR SUCCESS**

Pre-construction wildlife monitoring (Tier 1) objectives include quantifying existing rates at which various species and species groups cross the highway; assessing the rate of road kill and wildlife-vehicle collisions; and surveying the general project area to evaluate species occupancy and distribution.

WSDOT and its partners, WTI and CWU, have been conducting both CEA-specific and project-wide monitoring for Tier 1 activities to identify baseline conditions since 2008. WTI is monitoring high-mobility species. Methods being used by WTI to meet Tier 1 objectives include: assessing wildlife use of existing culverts and underpasses via remote cameras; documenting crossing rates via snow tracking; evaluating the distribution of various target species via non-invasive survey methods and live-capture; and documenting wildlife-vehicle collisions.

CWU is monitoring low-mobility species such as fish, amphibians, and pikas. Early monitoring results have documented species occurrence along the project corridor, and genetic samples collected from various target species will be used for assessment of highway permeability both pre- and post-construction and to jump-start Tier 2 research.

WSDOT and project partners intend to share this monitoring data once complete with research organizations and transportation designers to help assist with developing future policy, design standards, and monitoring methods. This will also help to ensure that future transportation projects can be integrated into the natural environment more effectively than their predecessors.

**POST-CONSTRUCTION MONITORING – REALIZING SUCCESS**

Construction of Phase 1, or the funded five-mile Hyak to Keechelus Dam Project, will be complete in 2017. After Phase 1 is complete, studies regarding the population-level benefits of newly constructed crossings can begin. It is important to define and outline this Tier 2 activity prior to completion of crossing structures in order to begin at year-one to acquire meaningful data.

For Tier 2, post-construction monitoring will occur at new crossing structure locations. Collection of wildlife-vehicle collision data, species occupancy monitoring within and adjacent to the project area, and monitoring of wildlife fence and jump-out effectiveness will also continue.

Adequate and accurate dissemination of information relating to both monitoring progress and results is a critical component of the monitoring program. WSDOT will publish results of studies and research activities in order to define the state of the science and provide meaningful examples of connectivity enhancements for this and future transportation projects.

**ADAPTIVE MANAGEMENT – RESEARCH TO GUIDE DESIGN**

WSDOT is using an adaptive management approach to the wildlife monitoring plan and future phases of the I-90 Project. A key component of the adaptive management process consists of using results from pre-construction monitoring to inform decision-making in relation to the planning and design of subsequent phases of the project. Species and baseline information acquired during pre-construction monitoring also allows the modification of the pre-defined performance measures for each objective.

An example of adaptive management based on early monitoring would be changing the design of wildlife crossing structures during subsequent phases of the project after obtaining empirical data from the use of structures from earlier phases. Microhabitat elements within wildlife crossings may require adaption if monitoring results suggest that they do not facilitate the movement of certain target species or groups. Monitoring of fencing and jump-outs may identify deficiencies that lead to revised design or suggest that new fencing materials could be used for future phases. Pre-construction data on local species occurrence and wildlife movements may lead to slight changes in the locations and types of wildlife crossing structures should monitoring reveal previously undocumented unique populations or important habitat linkages.
Successful adaptive management of the project design based on pre-construction monitoring results requires regular communication between WSDOT Environmental and Design personnel and all research and monitoring proponents. To aid in facilitating and using available research on the project, WSDOT has established an Ecological Connectivity Research Team (ECRT) and a Wildlife / Design Working Group (WDWG).

The role of the ECRT – which consists of personnel from the USFS, USFWS, WDFW, non-governmental research groups, academic institutions, and other research and monitoring organizations - is to provide resources and research for WSDOT regarding ecological connectivity enhancement goals for the project. This includes conducting research and baseline monitoring to assess the permeability of the highway for all organisms, and providing recommendations for the long-term sustainability and facilitation of population movement in the project area. This group will primarily focus on assessing the success of whether or not ecological connectivity goals are met.

The WDWG is made up of biologists from WSDOT, USFS, WDFW, and USFWS. This group will ensure the I-90 Project design adequately captures the opportunities identified through research and monitoring for enhanced ecological connectivity. This includes acting as an advisor to the ECRT in the identification of research needs and prioritization of research and monitoring objectives. The group will also act as a liaison between the ECRT and WSDOT Design and Construction during all phases of the project to provide meaningful and scientifically based recommendations for meeting the stated ecological connectivity objectives.

**NEXT STEPS FOR WILDLIFE MONITORING**

The third construction contract within the first phase of the I-90 Project is under public review and bid as of June 2011, with construction scheduled to begin fall 2011. The five-miles of highway improvements from Hyak to Keechelus Dam will be complete by 2017. The 2011 Transportation Budget has provided WSDOT with up to $8 million in project savings to design the next two miles of the project (beginning Phase 2) from the Keechelus Dam vicinity (milepost 60) to the Stampede Pass Interchange (milepost 62). The budget also approves the use of additional savings from the I-90 Project to be used in the corridor. WSDOT will start designing the next two miles from Keechelus Dam to Stampede Pass Interchange in summer 2011.

WSDOT, WTI, and CWU are entering the fourth year of the Tier 1 baseline monitoring effort. The monitoring focus as Phase 1 construction is underway is to continue acquiring baseline data in the project area and refine performance measures as they relate to the construction of crossing structures.

WSDOT is committed to working with the ECRT to identify and carry out the ecological research needs for the wildlife monitoring plan’s Tier 1 objectives and support partners in reaching the plan’s Tier 2 objectives. As design begins on Phase 2 of the I-90 Project, the role of WSDOT and the WDWG will become increasingly important to ensure project design and construction incorporate and reflect the lessons learned from current monitoring efforts.

In summation, a wildlife monitoring plan of this scale must be developed and implemented in collaboration with project research partners, resource agencies, and land management agencies. In addition, the plan must be actively managed to maintain the state of the science and adapt to changing designs and parameters. The theory of “if you build it, they will come” is not good enough when the goal is to provide landscape-scale connectivity enhancements. Collaborating early and often, adapting constantly, and setting the science will ensure meaningful investments and help achieve the lofty goal of ecological connectivity.

**BIOGRAPHICAL SKETCHES**

**Craig Broadhead** is Assistant Environmental Manager for the Washington State Department of Transportation South Central Region, where he manages the Biology and Mitigation program for the region and oversees the wildlife monitoring effort for the I-90 Snoqualmie Pass East Project. Prior to his 10 years with WSDOT, Craig spent seven years with the US Forest Service as a wildlife biologist in Wyoming and Utah. Craig has degrees in Wildlife and Fisheries Management from the University of Wyoming.

**Jason Smith** is Environmental Manager for the Washington State Department of Transportation South Central Region, a position he’s held since 2008. Prior to then, Jason was the I-90 Snoqualmie Pass East Project environmental manager from 2005. Before then, Jason was WSDOT Assistant Environmental Manager and the Project Delivery Manager for the Multi-Agency Permitting Team. He joined WSDOT in 1994, shortly after he graduated from Central Washington University with a degree in Resource Management specializing in Botany and Environmental Studies.
Amanda Sullivan is an associate at PRR Inc., where she serves as the company’s central and eastern Washington business development contact and consults for the Washington State Department of Transportation’s I-90 Snoqualmie Pass East Project, a client she’s worked with since 2008. Sullivan has over seven years’ experience in public relations, public affairs, writing and publishing. She holds a bachelor’s degree in public relations from Central Washington University.

REFERENCES


