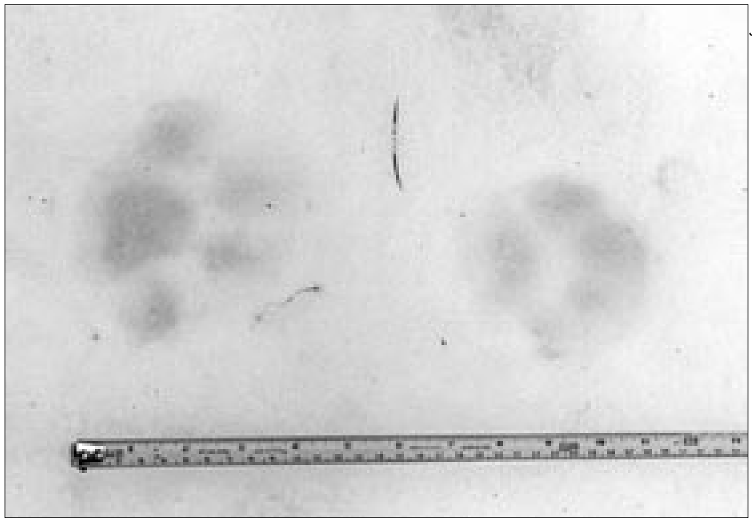
YELLOWSTONE SCIENCE

volume 13 • number 2 • spring 2005

The Elusive Lynx

Snowshoe Hares

Yellowstone's First General Store



NPS/JUSTIN HADWEN

People are lucky even to see Canada lynx tracks in the snow.

It's a Sign!

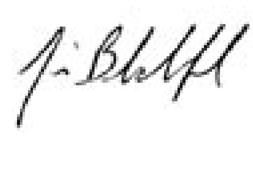
SIGNS OF SPRING, signs of life, signs of Yellowstone's elusive critters—sometimes that's all we see. It's amazing that of the roughly three million annual visitors to Yellowstone, almost none ever sees a lynx—a mid-sized carnivore! After four years of intense study specifically seeking out the cat, no actual sightings were made. Instead, confirmations of the cat's presence were made on tracks and DNA analysis of hairs snagged from baited lures. Lynx have been able to survive here almost under the radar.

This paucity of sightings highlights an important statistic—likely only 1% of species in the park have been identified and classified. In a place like Yellowstone, where more than 200 researchers are hard at work each year, that may seem surprising. But the park covers a vast landscape, and we're just beginning to look in certain areas, for example, the thermal areas, where it is believed that the vast majority of thermophiles (heat-loving microbes) remains unknown.

Yellowstone National Park is a protected place—development is tightly regulated and wildlife safe from hunting—making it a haven for the reticent and rare. It provides refugia for species such as lynx, which reside in only two other places in the U.S. (northwest Montana and the Cascade Range of the Pacific Northwest).

Yet the park lacks critical baseline data and monitoring programs on many species. Lynx studies were undertaken primarily because funding became available after the cat was listed as threatened under the Endangered Species Act in 2000. Often, it is funding or passion that drives the focus of research efforts. In the case of lynx, it was both. The park's hostile winter environment is not conducive to comfortable conditions for researchers. The lynx crews winter-camped, skied, and snowshoed to search for signs of the cat. These hardy researchers have added significantly to our current knowledge of lynx populations and their habitat in the park. The ongoing research of Karen E. Hodges and L. Scott Mills on the park's snowshoe hares dovetails nicely with the results of the lynx study, adding essential habitat information—where you find hares, you are more likely to find lynx. Bob Goss's article on the history of the park's first general store also delves into a relatively unexplored aspect of the park's story.

One study at a time, researchers are increasing the body of knowledge that exists about Yellowstone and the Greater Yellowstone Ecosystem. I am excited to serve as the new editor of *Yellowstone Science,* a journal intended to share the results of some of these studies. Keep your eyes open this spring, and you, too, may get a glimpse of something extraordinary.



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You may also email: Tami_Blackford@nps.gov.

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on the cover:
Snowshoe hare and Canada lynx.
Photos © Karen E. Hodges and Maggie Purves.

NPS

A boreal forest with a well-developed understory. This habitat is favored by both snowshoe hares and lynx.

FEATURES

DEPARTMENTS

NEWS & NOTES

NPS/CHARLES D. RAFKIND

John Varley (left) and Mike Soukup, NPS Associate Director for Natural Resources (right) at the ceremony.

John Varley Wins Director's Award

In March 2005, Yellowstone Center for Resources (YCR) Director John D. Varley accepted the Director's Award for Natural Resource Management for 2004. John was recognized both for recent accomplishments and for the scope of his contributions to the National Park Service (NPS) through the course of his 30-year NPS career.

In 2004, John Varley initiated or led two significant natural resource stewardship initiatives: Yellowstone's Molecular All-Taxa Biodiversity Inventory (MATBI), and the development of the NPS Servicewide Benefits-Sharing EIS. The Yellowstone MATBI represents the first step toward solving one of Yellowstone's thorniest and longstanding resource stewardship issues: despite a century of near-heroic efforts, scientists have still only identified and classified possibly 1% of species in Yellowstone. In this prototype MATBI, bio-samples taken from Yellowstone Lake will undergo nucleic acid extraction and microbial diversity analyses to construct a tree of life that will include bacteria, *Archaea,* microscopic eukaryotes, and small metazoans. This has become John's career signature: take the best elements of a great idea, such as the Great Smoky Mountains ATBI, inject a large dose of the latest, cutting-edge science (in this case, using genetic rather than classic morphological characteristics to classify life forms), and develop a product that is so fresh that it stands to revolutionize the way the NPS carries out its resource stewardship mission.

John also served in 2004 as the co-project leader on the NPS Servicewide Benefits-Sharing EIS, a document that analyzes NPS options to benefit from research conducted in parks. The concept of "benefits-sharing" is new to the NPS, and would allow parks to receive financial benefits if legally permitted research activities become commercially valuable, such as in the case of Taq polymerase, an enzyme derived from a Yellowstone microbe that is an essential component of the DNA fingerprinting process. The Benefits-Sharing EIS could harness the power of science to assist the NPS to meet our mission for resource stewardship and preservation, and to help correct a longstanding disconnect between scientists, entrepreneurs, and park managers. The NPS's course on these issues could have implications throughout the U.S. and in many other nations.

With these accomplishments, John Varley caps his career as an acknowledged leader of resource stewardship within the NPS, a position he has earned by pushing for innovative new resource programs. John has led several remarkable resource initiatives, including restoring the gray wolf to Yellowstone and the northern Rocky Mountains, putting the 1988 Yellowstone fires into an ecological context, and being the primary architect in the 1970s for radical changes in Yellowstone's fishing regulations, many of which have been adopted nationwide. John has firmly established science and research as a foundation for resource management in the park through the creation of the YCR, the organization of the Biennial Scientific Conferences on the Greater Yellowstone Ecosystem, the collaboration between YCR natural and cultural resource staff, and the establishment of a research permit coordinator to serve the park. John has also developed the most aggressive and professional resource publication program in the NPS, which has produced many large milestone reports and books, as well as *Yellowstone Science*.

The thread that runs through all of these accomplishments is John's passion for science and talent for applying scientific solutions to resource stewardship problems. In each of the above cases—and others that range from rare native plants to grizzly bears, bison to Indian wickiups—John has let the science lead the way. He has used it as the most fundamental platform to improve resource preservation, and in doing so has changed public attitudes, enabled the positive evolution of park and Service policies, and facilitated the park's ability to initiate actions to solve real-time resource problems. In the three decades John has been associated with Yellowstone's resources, he has earned a legacy that few will ever claim: he has made a lasting change in the way the NPS conducts resource stewardship.

Errata

In the winter 2005 issue of *Yellowstone Science,* 13(1), the photo of the wolves arriving in the park on page 9 should have been credited to Diane Papineau. The quote attributed to Aldo Leopold on pages 4 and 45 should have been credited to Stanley P. Young and Edward H. Goldman, authors of *The Wolves of North America*. We regret these errors.

YS

Snowshoe Hares in Yellowstone

Karen E. Hodges and L. Scott Mills

ALL PHOTOS COURTESY KAREN E. HODGES

This snowshoe hare is starting to turn from its brown summer coat to its white winter coat.

WHEN PEOPLE THINK of "Yellowstone wildlife," the most immediate images that spring to mind are likely bison, elk, wolves, and bears. But Yellowstone National Park also acts as a haven for scores of other species, some of which are more elusive and rarer than these bigger animals. For example, Canada lynx (*Lynx canadensis*) occur in Yellowstone, but with very low numbers (see article by Murphy et al. in this issue of *Yellowstone Science*). Canada lynx were listed as threatened under the Endangered Species Act in 2000, and researchers across the country began more intensive work on them as the listing was developed. Because historic records showed that lynx occurred in Yellowstone, park biologists wondered how many lynx the park could support. Lynx are specialist predators on snowshoe hares (*Lepus americanus*), and it is clear from previous research that insufficient hare densities mean no lynx. We therefore initiated snowshoe hare studies in Yellowstone, in part to assess what the prey base was for lynx.

In undertaking this research, we were basically asking one of the fundamental questions in ecology: what determines the distribution and abundance of a species? Prey species, like snowshoe hares, can respond to physiological limits (e.g., climate variables), food abundance, presence of competitors, and predator abundance. In Yellowstone, we knew snowshoe hares occurred; people saw them periodically, and the presence of lynx was another sure indicator. But we knew nothing about what habitats snowshoe hares used in the park, how abundant they became in the best habitats available, or what factors were shaping where they occurred. We knew from previous research, by ourselves and others, that snowshoe hares respond strongly to understory structure; they like dense cover close to the ground or snow surface. Dense understory is even better when accompanied by reasonably thick overstory cover. Given the dramatic fire history of Yellowstone, we speculated that some of the stands regenerating after the 1988 burns would be good for hares: the dense, regenerating trees could provide excellent understory cover, and in some places the trees were getting tall enough to impair hunting raptors.

Our goals with this research were therefore simple: we wanted to identify where snowshoe hares were in Yellowstone, how large their populations were, and whether areas regenerating after the 1988 fires provided good habitat for them. In 2004, we were provided with another opportunity to address the impacts of fire on snowshoe hares. The large East Fire in 2003 burned three study areas that we knew had contained hares during our previous surveys. We re-sampled these areas in 2004 to find out whether snowshoe hares persisted there immediately after the fires.

Our results clearly show that snowshoe hares are uncommon in Yellowstone.

We also wanted to address some of the temporal dynamics of snowshoe hares in Yellowstone. In the northern forests of Canada and Alaska, snowshoe hares have stunning population cycles every 10 years, with peak abundances dramatically higher than low abundances. Researchers still are not certain whether snowshoe hares cycle in southern portions of their range, like the Rocky Mountains and Yellowstone. So far, we have three years of data on snowshoe hares in Yellowstone—too short to answer the cycle question definitively, but a good start along the way.

We approached our questions with a mixture of field techniques. We used some live-trapping with mark/re-capture estimation, one of the best methods for estimating densities of small mammals. We also used pellet counts—that is, surveying a forest stand by counting all snowshoe hare pellets on 50 to 100 small rectangular patches of forest floor. Our other work in Yukon Territory and Montana, as well as work by other research groups, has shown that pellet counts provide a pretty good indicator of snowshoe hare relative abundance in different forest types. These pellet surveys are fast and easy compared to trapping, enabling us to sample many more stands than we could with trapping alone. During the three years we have surveyed so far, we sampled some locations in each year to get an idea of how snowshoe hare populations change with time, and sampled many areas once only, to see how hares are distributed.

We chose to survey a variety of stand types across the entire park. Because biologists have been studying snowshoe hare habitat use for a century, we were able to immediately target the most likely sites. Areas with well-developed understories (e.g., saplings, shrubs) typically have the most hares, and mature forests with well-developed canopies also usually support snowshoe hares. Good bison habitat was out of the picture for hares: open forests and meadows are simply not used by this forest-dwelling herbivore, so we did not need to sample there. We used Yellowstone's GIS maps of habitat types to select lodgepole pine stands of differing stages, ranging from the stands regenerating after the 1988 burns to mature stands with lodgepole understories. We also targeted forest stands containing Engelmann spruce and subalpine fir, because there was some speculation in the literature that hares would prefer these more boreal trees to the lodgepoles.

Our results clearly show that snowshoe hares are uncommon in Yellowstone. The highest densities we recorded were less than one hare per hectare; densities above 0.5 hares per hectare were rare in the park. There was no evidence of snowshoe hares in the majority of the stands we surveyed. In our

All of these areas burned in the 1988 fires. Fire severity and regeneration patterns are very different. The center picture is of a site with one of the highest snowshoe hare densities seen in Yellowstone.

first year, we trapped in 13 large stands, and caught snowshoe hares in only four of them—for a total of 13 animals. In contrast, when we did similar trapping in northwest Montana in the same year, we caught over 250 individuals, and had some stands with hare densities of two to three hares per hectare. The snowshoe hare pellet surveys confirmed this picture of Yellowstone. Over half of the more than 60 stands surveyed had no pellets or only one pellet present. Only six stands had enough pellets to indicate a reasonable resident hare population. Even on these best plots, the pellet counts were quite low, reflecting small numbers of hares. Yellowstone simply is not good snowshoe hare country.

So where do we find snowshoe hares in Yellowstone? We divided our sites according to whether they had fewer or more than five pellets present per survey. This pellet count value is quite low, corresponding to hare densities of roughly one every ten hectares. Below this number, we suspected that hares may have been traveling through a habitat but were not resident. Hares can produce 400 to 700 pellets per day, so when we sampled a 20-hectare area and found fewer than five pellets, it means hares basically aren't using the stand. In Figure 1, we show that the more boreal habitat types of spruce-fir and LP3 (a mixed canopy of lodgepole, spruce, and fir) were the most likely to have snowshoe hare pellets present. In contrast, only a quarter of the lodgepole-dominated young stands that were either regenerating after the 1988 fires (LP0) or that had a lodgepole canopy and understory (LP2) had reasonable evidence of snowshoe hares. Snowshoe hares are more likely to use stands with boreal characteristics.

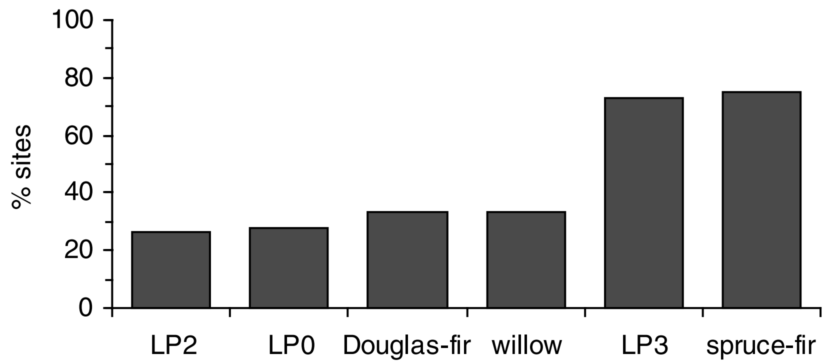


Figure 1. The percentage of each habitat type with more than five snowshoe hare pellets per survey (i.e., >0.06 pellets/plot). LP is lodgepole. LP0 sites are stands regenerating after the 1988 fires. LP2 stands have a canopy of lodgepole with some understory trees. LP3 has a mixed canopy of lodgepole, spruce, and fir. "Willow" refers to three riparian areas we sampled, one of which had some pellets; the other two did not.

The photos above and right show a mature stand before and after the 2003 East Fire.

We obtained a slightly different view of what makes the best Yellowstone habitats for snowshoe hares when we considered the stands where we trapped snowshoe hares or where we observed the highest pellet counts. We caught the most hares on an LP0 site near Madison Junction and on an LP2 site near the South Entrance—a pattern that held true for all three years of trapping. For pellets, our top six sites—which were substantially better than all the rest—were a Douglas-fir site, two post-1988 regenerating stands, two LP2 stands, and one LP3 stand. These sites were scattered throughout the park, from the Gallatin Mountains to the East Entrance, meaning there is not a cluster of good sites in the park. Pellet counts on these sites ranged from 0.47 pellets per plot to 1.44 pellets per plot, which corresponds roughly to hare densities of one hare per four hectares to one hare per 1.5 hectares. We think these stands support the highest hare densities we have seen in Yellowstone because they have some of the best mix of understory and overstory cover; we are currently analyzing our data on vegetation structure in more detail. Curiously, no spruce-fir stands made it into our top list of sites, even though three quarters of the spruce-fir stands we sampled had more than our cutoff of five pellets.

So far, there are no clear temporal patterns for the sites we sampled in all three years. Some sites stayed constant from year to year, while others showed slight year-to-year variation in the pellet counts. Our trapping data have also not shown any clear patterns through time. These data do not yet allow us to distinguish whether hares cycle in Yellowstone or not, because even in populations that cycle dramatically, there can be two-to-four year periods with little change in numbers.

Our results from the sites that burned in the 2003 East Fire are clear. We surveyed three stands (Douglas-fir, spruce-fir, and an LP3) in 2002 and prior to the fire in 2003. All three had high pellet numbers before the fire; indeed, the Douglas-fir stand showed our third-highest pellet count in Yellowstone. The 2003 fire burned all of these stands completely, leaving no green vegetation. In 2004, unsurprisingly, none of these sites had any sign of snowshoe hares.

Our work in Yellowstone has confirmed the general pattern of snowshoe hare habitat studies from elsewhere, in that dense stands are much more likely to support hares than open stands. We were surprised to find that snowshoe hare densities were so very low. Even the best stands we have found in Yellowstone support far fewer hares than can occur further north in the Rockies (i.e., our Montana sites) or in the truly boreal forests of Canada and Alaska.

We think snowshoe hares in Yellowstone are probably quite mobile, for two reasons. First, we found some snowshoe hare pellets in almost all of the locations that had reasonable understory cover, which suggests that snowshoe hares are able to colonize these sites even if they are surrounded by very poor habitat types. Second, about a quarter of our sites had one to four pellets present, suggesting a snowshoe hare had been there, but likely did not stay for long. Snowshoe hares in Yellowstone may therefore be behaviorally different than hares that live in better habitats.

Our data about snowshoe hares' response to fire indicates quite clearly that fire initially destroys habitat, and that the regeneration pattern is the key ingredient for whether snowshoe hares will use a burned area or not. A substantial proportion of the stands burned in 1988 have regenerated with low tree densities. These stands are essentially useless for snowshoe hares and, we suspect, will remain useless until a canopy has formed with a second story underneath. For now, the trees are simply too thin on the ground. In contrast, regenerating stands where saplings form fairly continuous cover (e.g., branches are touching and trees are reasonably tall) are currently supporting some of the highest hare densities we have observed in Yellowstone. These stands are certainly good now, but we are not sure how long they will remain of high quality. As the trees increasingly compete with each other, loss of lower branches and the deaths of some saplings may make these stands less and less appealing to snowshoe hares. This process will take years or decades, however, and hares may well start to find other good habitats as these decline.

What do these patterns mean for lynx? The most obvious implication is that Yellowstone is unlikely to support large lynx populations. Even the snowshoe hare hotspots had very few individual hares in them, so any lynx present in the park probably have to travel widely to find prey consistently. Still, a wide range of places had hare pellets within them, so a traveling lynx might encounter a snowshoe hare that was also traveling to find better habitat. We suspect that lynx in Yellowstone may make more use of alternative prey (e.g., squirrels, grouse, maybe even carrion) than do lynx in areas with many more hares.

YS

Dr. Karen E. Hodges is an assistant professor of conservation biology at Okanagan University College in Kelowna, British Columbia. **Dr. L. Scott Mills** is a professor of wildlife biology at the University of Montana.

Between them, they have researched snowshoe hares for over 15 years, and worked on the population dynamics and habitat use of small mammals for over 35 years. They have been studying snowshoe hares in Yellowstone since 2002.

The Elusive Canada Lynx

Surveying for Yellowstone's Most Secretive Threatened Carnivore

Kerry Murphy, Tiffany Potter, James Halfpenny, Kerry Gunther, Tildon Jones, and Peter Lundberg

CINDY MERNIN

This rare photo of a Canada lynx in Yellowstone National Park was taken near the Lake Hotel by Cindy Mernin, who saw the cat or its tracks various times in that area during 1971–75.

YELLOWSTONE National Park visitors who have seen gray wolves and grizzly bears roaming park wildlands can justifiably consider themselves fortunate. Luckier still are those who have seen one of the some 30 cougars that traverse the park's rocky haunts. But the crowning jewel of a Yellowstone mammalogist's list is the Canada lynx (*Lynx canadensis*), owing to its affinity for heavy forest cover, rareness, mystique, and adaptation to deep snow.

Among the three wild felids that reside in the park—Canada lynx, bobcat (*Lynx rufus*), and cougar (*Puma concolor*)—the lynx shows the most morphological specialization. Adult bobcats and lynx are similarly sized at 8–14 kg, and both have a short, bobbed tail, ear tufts, and a prominent facial ruff. However, the lynx has longer legs than a bobcat, and the rear legs of a lynx appear longer than its front legs, lending a stooped appearance. Lynx feet can be larger than a cougar's, and twice the size of a bobcat's. These adaptations allow lynx to exploit habitats with deep, uncrusted snow.

The lynx is primarily associated with boreal forests in Canada and Alaska. In the U.S. Rocky Mountains, the species occurs in cool, moist, coniferous forests, including boreal forests that extend as peninsulas into the continental U.S. or occur as discrete islands. These environments typically support heavy snowpack and snowshoe hares (*Lepus americanus*), the lynx's principal prey. Snowshoe hares require dense conifer or deciduous shrub thickets for food and cover from predators. In suitable habitats in Canada and Alaska, snowshoe hare populations fluctuate up to 25-fold over 8–11 year periods. In the continental U.S., snowshoe hares likely cycle much like their northern counterparts, except that peaks and lows of hare abundance in the south are not as great as in areas north of the U.S.–Canada border. Consequently, lynx in the continental U.S. do not appear to show strong fluctuations, and their life history characteristics are similar to those of lynx populations at northern latitudes during the low periods of the hare cycle.

In 2000, the lynx was federally listed as a threatened species in the conterminous U.S., primarily because national forest plans lacked adequate regulatory mechanisms to protect the species. Sightings information from Yellowstone National Park files, the U.S. Forest Service, state wildlife agencies, and other sources suggest that the lynx has always existed in the Greater Yellowstone Ecosystem (GYE).

Very little is known about the historic numbers and distribution of lynx in Yellowstone. Early writers dating from the late 1800s noted that lynx were present, but their estimates of parkwide numbers were highly subjective and varied widely, ranging from "about 10 individuals" to "quite common." The park archives contain several reliable photos of lynx, and the Smithsonian Institution in Washington, D.C., contains a single skull, dated 1895. Park files contain records of 73 direct or indirect (tracks) observations of lynx made by park visitors or employees from 1887 to 2003. In addition, there are 34 references to lynx (tracks or direct observations) in ranger logbooks found in the Yellowstone National Park archives, dating 1895–1926, including references to at least six individuals trapped or shot in the park. Collectively, Yellowstone historical records suggest a parkwide distribution. However, sightings data are difficult to interpret—lay park visitors and untrained park staff may misidentify look-alike species, such as bobcats, and have difficulty correctly distinguishing lynx tracks from those of cougars.

Recent threatened status for lynx and lack of survey data in the park underscored the need for basic information on this ecologically and aesthetically important species. Inventory data are essential to avoid adverse effects of park management activities, such as road reconstruction, and to support joint conservation planning efforts among federal and state agencies. In response to the dearth of information, we undertook a parkwide survey from 2001 to 2004 with the objective of documenting lynx distribution in the park.

Identifying Lynx Habitat

We began by identifying areas in the park most likely to support lynx, i.e., prime habitats (PH)—a recommendation of biologists we consulted who had lynx survey experience. This approach allowed us to direct more search effort to where we thought lynx and their prey might occur, and avoid spending time in marginal habitats.

We identified PHs based on their potential to support snowshoe hares using the scientific literature, advice of experts, our own experience, and cover types described and digitally mapped in the park (Figure 1). We classified PHs as high quality: Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and lodgepole pine (*Pinus contorta*) stands in climax, late, middle, or pygmy (wind-blown and snow-free) successional stages, and riparian shrubfields; medium quality: stands listed above that were mixed with non-forest areas; and low quality: aspen (*Populus tremuloides*) stands, and mixed whitebark pine (*Pinus albicaulis*), Douglas-fir (*Psuedotsuga menzeisii*), and selected other lodgepole pine stands.

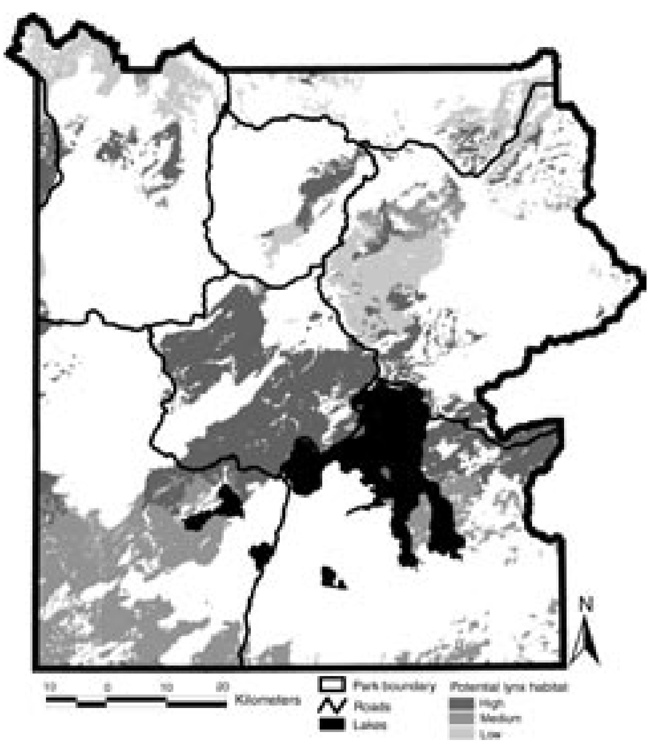


Figure 1. Prime habitat (PH) for lynx identified in Yellowstone National Park, 2001–2004. See text for basis of classifying PH.

Lodgepole pine stands in early successional stages, typically supporting trees of less than 180 cm in height, that regenerated on sites burned between 1977 and the present, were eliminated as PH because snowpack typically reduced horizontal and vertical cover available to snowshoe hares. This category included Yellowstone forests burned in 1988. We also eliminated the park's northern winter range, because researchers conducting cougar population studies had already surveyed it for felids from 1987 to the present. We did not survey in grasslands, talus fields, or krummholz (stunted forest at treeline), because they lacked abundant cover.

Detection Methods

We used two methods to detect lynx: snow-tracking surveys conducted in winter on skis, snowmobiles, and from airplanes; and hair-snare surveys conducted in the summer. Because lynx tracks might be confused with bobcat or cougar tracks, personnel received six hours of classroom and field instruction annually on the identification and documentation of lynx sign and data collection procedures. As part of the training, we identified tracks and other lynx sign in northwest Montana, where lynx are radio-collared in a research project managed by

NPS/JUSTIN HADWEN

Lynx tracks at a walking gait, travelling through a spruce forest, a typical habitat for this cat in the northern Rockies.

the Rocky Mountain Research Station (U.S. Forest Service). Project personnel also received training on deployment of hair snares and data collection prior to the summer field season.

For winter work, we identified geographic sectors of the park based on their characteristic range of elevation, soils, and overstory vegetation (Figure 2). Starting locations of 33 snow-tracking surveys, all in PH, were chosen based on their accessibility to park roads or ski trails and the absence of avalanche hazards (Figure 3). Surveys were classed as "formal" or "informal," based on the timing of recent snowfall and type of data that were collected. Formal surveys were conducted at least 12 hours after a snowfall, but only tracks left within the last 24 hours of the survey were tallied. The 12-hour rule was designed to allow tracks to accumulate following the last snowfall; the 24-hour rule ensured that counts of tracks would be limited to short, standardized time periods. The formal data we recorded included information on rare carnivore tracks, such as those of lynx or wolverine (*Gulo gulo*) and other common carnivores such as coyotes (*Canis latrans*), tracks of their prey (e.g., snowshoe hares), cover types, and snow-tracking conditions encountered along transect segments. Informal surveys were conducted when the 12-hour rule precluded a formal survey, or when we prioritized transect distance over detailed survey data. Backcountry rangers who were trained in track identification often conducted informal surveys. To increase snow-tracking effort, we also used snowmobiles to conduct formal and informal surveys along groomed park roads, a technique used by biologists from the Montana Department of Fish, Wildlife and Parks, to monitor forest carnivores. Finally, we used airplanes and helicopters to survey very remote PHs for lynx tracks, a technique used in Alaska. Flights occurred at least 24 hours after a new snowfall. When feasible, we landed helicopters to examine and document tracks of rare carnivores.

We recorded standard information such as UTM location, time, habitat characteristics, and weather and snow conditions where sign of lynx or other rare carnivores was encountered. Tracks of carnivores were documented using measurements, plaster casts, and photographs. We also collected hairs along tracks and from bed sites and stored them in vials for DNA-based identification at the Carnivore Conservation Genetics Laboratory at the University of Montana, Missoula. The reliability of rare carnivore tracks was rated as "definite" if the species' identity was verified by DNA tests and all gait patterns and print measurements were supportive of lynx presence; "probable" when nearly all gaits and prints were supportive, but some aspects of tracks were non-interpretable and/or non-supportive (no usable DNA); and "possible" when most interpretable evidence suggested lynx presence, but details of prints or gait patterns were consistently unclear (no DNA). We collected scats for DNA-based species identification and to identify prey items.

During four winter seasons, we completed 103 formal snow-tracking surveys ranging from 1 to 23 km in length, totaling 563 km, and 136 informal surveys ranging from 0.4 to 90 km in length, totaling 1,051 km (Figure 4, pg. 12). Combining formal and informal data, surveys totaled 1,614 km over four winters. Surveys were widely distributed across park sectors and occurred under uncrusted snow conditions

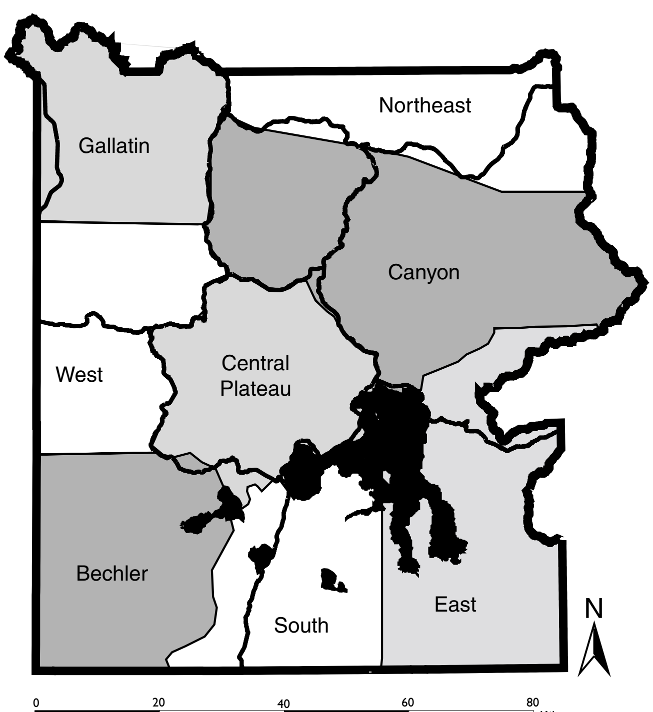


Figure 2. Canada lynx habitat sectors, Yellowstone National Park.

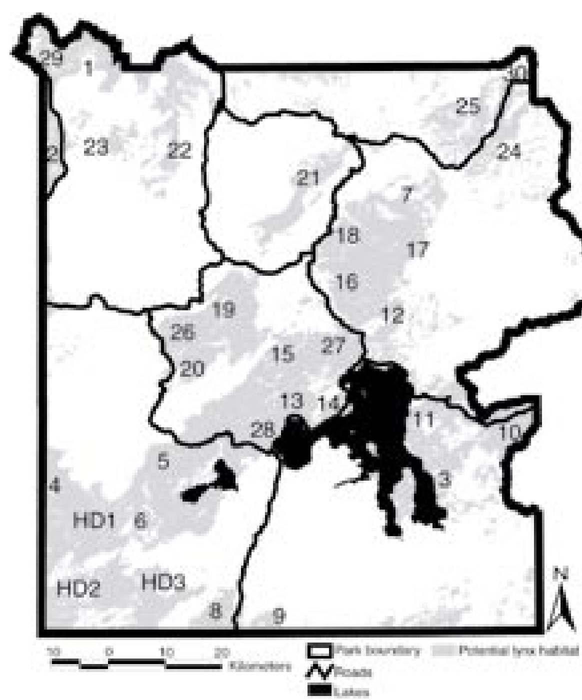


Figure 3. Locations (starting points) of ski-based snow-tracking surveys, Yellowstone National Park, 2001–2004. HD sites are locations of helicopter drops.

that consistently revealed animal tracks. As the study progressed, we decreased snow-tracking efforts in the Bechler sector after encountering little snowshoe hare sign, but increased efforts in the East sector, attempting to re-verify lynx first detected during winter 2001. During 2004, we focused nearly all winter effort there, attempting to document lynx numbers and their sex and age characteristics. We also completed 41 snowmobile-based surveys totaling 749 km, and six in aircraft totaling 693 km.

To detect lynx with hair snares, we used two approaches for establishing sets of hair sampling stations, called "transects," across the landscape (Figure 5, pg. 12). First, we deployed transects on a single, 14×14-mile grid (196 mi^2) located on the east side of Yellowstone Lake, following the guidelines of the National Lynx Detection Protocol (NLDP), developed by the U.S. Forest Service in the late 1990s. Transects were spaced at 3.2-km intervals and consisted of five stations spaced at 100-m intervals. Stations contained a hair snare nailed to a tree 46 cm above the ground, with visual (aluminum pie plates) and scent lure attractors (beaver castor oil and other ingredients) hung from nearby tree limbs. Hair snares consisted of a 10×10-cm square of carpet containing nails inset to snag and hold animal hairs, such as those of cheek-rubbing lynx; a scent lure; and dried catnip, a common attractant for cats. Stations were deployed, and then checked twice at two-week intervals for visits by animals. Hairs were collected from the hair snare, the tree supporting (or trees growing near) the snare, or from the ground, and then stored in a vial with desiccant for subsequent identification based on visual (dissecting scope) exam of hair follicles or DNA-based techniques. All survey materials, including nails and flags, were removed from the field following the second check for hairs. The grid was deployed from early summer to early fall, 2001–2003. Because some of the transects occurred in remote areas and could not be maintained

(continued page 12)

Conservation Challenges of Managing Lynx

by John R. Squires

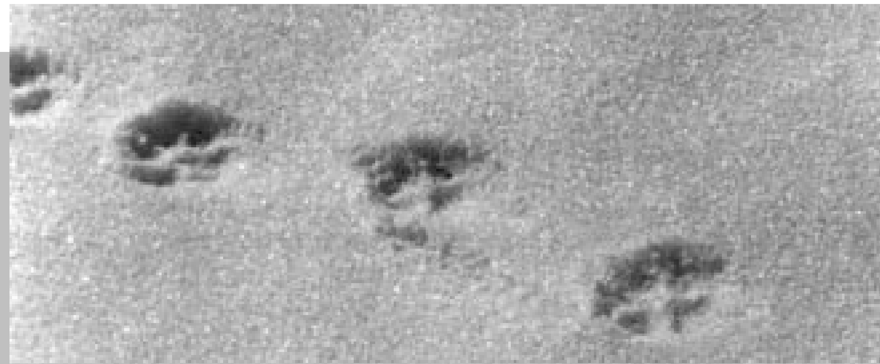
Yellowstone National Park is hallowed ground when it comes to wildlife in America. The very word "Yellowstone" conjures up images of grizzly bears digging tubers, bands of elk dotting the landscape, and gray wolves pursuing elk along the Lamar River. However, Yellowstone also provides habitat to one of the rarest cats in the continental United States: the Canada lynx (*Lynx canadensis*). The image of lynx stalking the forests of Yellowstone is absent from most people's minds because the cat is rarely observed and its life history is poorly understood in and around the park.

In March 2000, the U.S. Fish and Wildlife Service (USFWS) listed *Lynx canadensis* as a threatened species in the contiguous U.S. under the Endangered Species Act. The USFWS concluded that management actions of federal agencies may threaten lynx or their habitat, and that inadequate regulatory processes were in place to address the species' needs. The listing of lynx as a threatened species requires that federal agencies consider how their management actions may impact lynx populations. This often places land managers in the difficult position of having to assess how their activities may impact lynx based on limited information concerning the species' ecology and management needs.

A fundamental need when managing lynx and other rare wildlife is to understand historical changes in a species' distribution. Biologists are far less concerned when a species' distribution is characterized by well-connected groups of individuals with expanding population numbers as compared to few individuals in highly fragmented groups. Thus, understanding any recent changes in the distribution of lynx is important to their conservation. Accomplishing this task is difficult, given the cat's highly secretive nature, large home ranges (about 200 km^2 for males and 90 km^2 for females), and low densities (Squires and Laurion 2000). Biologists confront this difficult issue by applying several different research tools.

Archival and library research of lynx trapping records, observations, and museum specimens from the late 1800s to the present documented that lynx were present in 24 states. The greatest number of detections (>20 detections each) were in Idaho, Maine, Michigan, Minnesota, Montana, New York, Washington, Wisconsin, and Wyoming (McKelvey et al. 2000). Lynx were documented in 10 states as late as the 1990s. These results suggested a widely distributed population. However, recent snow-tracking and hair snagging studies indicate that lynx populations are fairly restricted in the western U.S. Western populations (areas with documented reproduction) are currently found in three regions: northwestern Montana, north-central Washington, and in the Greater Yellowstone Area (GYA).

The GYA supports the southernmost, non-introduced population of lynx in the U.S. Lynx from Canada were recently reintroduced in Colorado, and some of the reintroduced females produced kittens last year. This bodes well for lynx in Colorado, but it is too early to tell whether the reintroduction will result in a persistent population. In the Midwest, biologists thought that lynx were extirpated from Minnesota by the 1990s, but recent sightings, DNA evidence (scats and hair samples), and radio-telemetry studies have documented that lynx are back in the northern portion of this state.



CINDY MERNIN

Lynx tracks in Yellowstone near the Lake Hotel, winter 1973–74.

Hopefully, ongoing surveys throughout the region will document if lynx expand their range to neighboring Midwestern states. The easternmost population of lynx in the contiguous U.S. resides in northern Maine. Little is known regarding the number of individuals that are present in the native populations in the contiguous U.S. However, these populations may support few individuals (Aubry et al. 2000).

We know from basic principles of conservation biology that small, relatively isolated populations are generally at greater risk compared to large, contiguous populations. Thus, it is important to know how lynx populations interconnect. Genetic similarities among lynx from Alaska, Canada, and Montana suggest that individuals move throughout this northern region (Schwartz et al. 2002). This notion is supported by trap records indicating that lynx populations in the contiguous U.S. may be periodically augmented by animals from Canada (McKelvey 2000). However, we do not understand the extent of this potential augmentation.

The GYA is the only place in the contiguous U.S. that apparently supports a lynx population that is not immediately adjacent to the Canadian border. There are currently too few genetic samples or trap records from lynx in the GYA to rigorously evaluate the relationship of these animals to other populations. The GYA may be large enough to support a persistent population in relative isolation, or there may be interchange from populations in Montana and Canada.

Bob Oakleaf, of the Wyoming Game and Fish Department, first radio-collared a male lynx that became known as "George" in 1997. Oakleaf's goal was to shed light on the movements of lynx in the GYA and to better understand their habitat use patterns. In 2001, staff from the wildlife unit of the Rocky Mountain Research Station, located in Missoula, Montana, helped Oakleaf replace George's conventional collar with a satellite transmitter that could better document his movements throughout the region. In May 2002, George left his home range and traveled across the Wind River Range, the Teton Wilderness area, and Yellowstone National Park. He continued his northwesterly journey as far as the Henry's Lake Mountains on the Montana/Idaho border before returning in early autumn to his home range near Big Piney, Wyoming. His return route followed the same general route he had taken in early summer. George's summer-long trip was over 728 km in length!

Although George was only a single individual, his broad-scale movement demonstrated that lynx could traverse the entire GYA. The role that long-distance movements play in maintaining lynx in the GYA is unknown, but they may play an important role in maintaining a lynx population that is disjunct from the Canadian border.

Lack of basic ecological information is a major impediment to lynx conservation and recovery. Lynx differ from many other threatened or endangered species that have clear, well-defined management needs. For example, organo-chlorine pesticides caused eggshell thinning in peregrine falcons; banning the use of these chemicals was a clear management need. However, we know very little about the life history of lynx, including how human-caused actions may contribute to their rarity. We also know little regarding their broad-scale movements, habitat preferences, mortality factors, and population trends. Ongoing research projects in Montana, Minnesota, Maine, and Colorado are beginning to address some of these key information gaps. Carnivore surveys, such as the recent effort led by Dr. Kerry Murphy in Yellowstone National Park, are also vitally important to further delineate the species' distribution. However, much additional work is needed before lynx can be conserved based on solid, empirical data. Thus, researchers and managers, working together, play key roles in providing the necessary research and management to ensure that lynx will continue to stalk the forests of Yellowstone National Park. YS

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simultaneously, we stratified transects by watershed and subsampled the grid at different times each summer. Logistical constraints or closures due to wildfires precluded access to some transects during summers 2001 and 2003.

To sample PHs outside this grid, we deployed transects in seven other areas of the park. Transect and station sites were chosen subjectively based on vegetation, topography, and logistical constraints. In this effort, we used 1–10 transects with 2–11 stations per transect, with the same lures. Informal surveys also often occurred over only two weeks and only during a single summer.

> Lynx have persisted across the 133-year history of the park, apparently without any significant period of extinction.

We annually deployed and revisited 21–35 hair snare transects (105–175 stations) on the east side of Yellowstone Lake following the NLDP, collecting 336 total samples, analyzing 197 using DNA-based techniques, and identifying 108 to species. We also deployed from 1 to 10 transects at six "subjective" survey sites in 2002, and four in 2003, collecting 174 total samples, analyzing 166, and identifying 77 to species.

Detections of Lynx

We confirmed three lynx detections with DNA evidence, all on the east side of Yellowstone Lake (Figure 6): a female in summer 2001 (NLDP, female DNA); a female accompanied by a male kitten in winter 2003 (skis; DNA of a male lynx that was a kitten, based on the size of its tracks, alongside a set of far larger lynx tracks); and an adult male in winter 2004 (skis; male DNA). Four probable detections were made, including a female accompanied by one kitten on the east side of Yellowstone Lake (a separate finding from the pair cited above). Four possible tracks, including two observed from a helicopter, were also found. Three lynx scats we collected contained remains of snowshoe hares (hair, bones, and claws) or snowshoe hare stomachs (e.g., lichens). Lynx DNA was present in each scat. We detected nearly all other small, medium, and large carnivores known to occur in the park. We found wolverines in three park sectors, but no fisher (*Martes pennanti*).

Status and Distribution of Lynx in the Park

Based on our survey, it appears that lynx have persisted across the 133-year history of the park, apparently without any significant period of extinction. However, the species is limited in distribution, occurring in the best habitats only. Our cumulative detections from 2001 to 2004 likely represented at least four individuals, including two kittens born in two different years. The presence of offspring indicates that resident, breeding individuals were present—an important finding, because lynx reproduction has not been previously documented in the park, and rarely in the GYE. As in most carnivores, reproducing lynx females are typically resident (i.e., have well-established home ranges), as opposed to being nomadic.

The distribution of lynx was largely restricted to the East

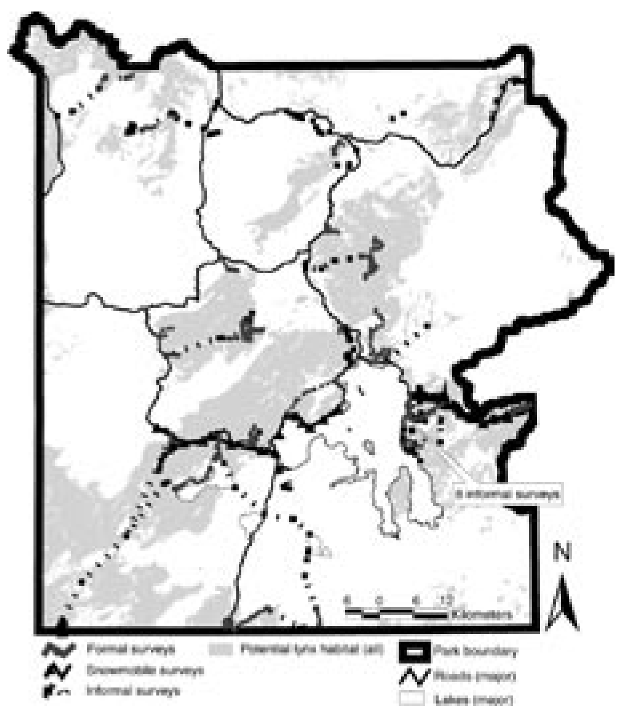

Figure 4. Snow tracking surveys, Yellowstone National Park, 2002.

Figure 5. Hair snare locations in Yellowstone National Park, 2001–2003.

and possibly the Central sectors of the park. We did not detect this cat in other parts of the park, but lynx could have occurred, with low probability, in the marginal habitats (e.g., new burns, grasslands) that we did not survey. Also, our detection techniques did not detect individuals with certainty, regardless of location, so some could have occurred outside the East and Central sectors as well.

The distribution of our lynx detections was generally consistent with our snow-tracking data that suggested the highest densities of snowshoe hares also occurred in the East sector. This portion of the park is dominated by andesitic soils that exceed other park soils in moisture-holding capacity and nutrients. Andesitic soils better support the subalpine and Engelmann spruce forests and thick understory vegetation that provide the horizontal and vertical cover needed by snowshoe hares. Also, growing conditions for boreal forest habitats within 100 m of Yellowstone Lake may be enhanced by fine soil materials (clay-sized particles) deposited in terraces that were formed in response to historic fluctuations in the lake level. Frequent storms create conifer windfalls along the lakeshore, breaking up the forest canopy and encouraging a denser understory that attracts snowshoe hares.

The explanation for our few observations of lynx in Yellowstone likely stems from poor habitat conditions for its primary prey, the snowshoe hare. Although the extensive, cold, boreal forests that characterize snowshoe hare habitat in the Canadian Rockies and Alaska extend southerly into the U.S. Rocky Mountains, forests here are fragmented when considered at a broad spatial scale, and limited to sites with optimal (high) elevation, adequate soil moisture and nutrients, and shady aspects. In particular, the central and western portions of Yellowstone are dominated by well-drained, nutrient-poor

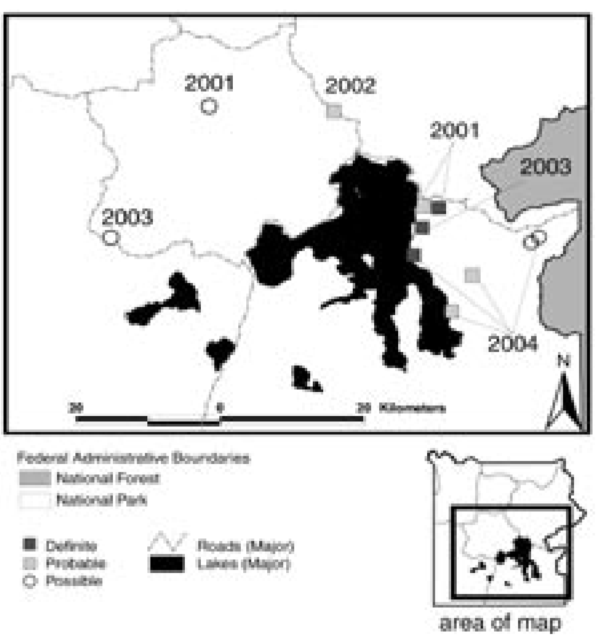

Figure 6. Lynx detections in Yellowstone National Park, 2001–2004.

NPS PHOTOS/TIFFANY POTTER

Hair snares are nailed to a tree 46 cm above the ground, in hopes of snagging hairs from cheek-rubbing lynx.

A hair snare that has been chewed, likely by a bear. It is made of carpet with inset nails to snag and hold animal hair, and contains a scent lure and catnip.

Aluminum pie plates are used as visual lures at hair snare sites. This plate was also chewed.

rhyolitic soils of recent volcanic origin that primarily support lodgepole pine. In mature forests, these soils provide for poor growth of understory cover, and open, park-like conditions prevail—to the detriment of cover-seeking snowshoe hares. Our companion prey studies (see article by Hodges and Mills in this issue of *Yellowstone Science*) indicate that the mature montane and boreal forests of the park typically support few, if any, snowshoe hares. Sparse conifer regeneration and woody debris often provide the only understory cover available. Consequently, we expect low numbers of lynx in the park. Although lynx food habits typically include other common prey (e.g., red squirrels, *Tamiasciurus hudsonicus*; voles, *Microtus sp*.), lynx do not appear to thrive where their winter diets consist primarily of these alternatives.

Lynx trapping and shooting in the park during the late 1800s and early 1900s may also help explain our few observations of lynx from 2001 to 2004. Human-caused deaths in the park, GYE, and northern Rockies likely reduced lynx populations, leaving few individuals to reproduce and repopulate vacant habitat. Park records of early gray wolf and cougar kills by trappers and control agents during the early years of management as a national park suggest that those losses profoundly affected the abundance of these large carnivores. Although the historical abundance and number of lynx removed from the park is unclear, it is possible that lynx numbers were considerably higher than present, and that removals were an important factor in the present-day levels we see.

Lynx Numbers in the GYE

Our scant lynx detections in the park were consistent with the few DNA-based detections by local U.S. Forest Service personnel and conservation organizations that have used similar methods in attempts to locate lynx (Figure 7). Of approximately 14 widely-distributed hair snare grids deployed in the GYE from 1998 to the present, lynx were detected in only six grids, in three portions of the ecosystem. In addition, although snow-tracking surveys have been completed in most units, DNA-based detections were made in only three. Lynx clearly occur in the GYE, but as in the park, they appear to be limited in distribution.

How Might Lynx Persist in the GYE?

How lynx manage to persist despite a spotty presence in the GYE is an important, unanswered question for managers. Because of our limited information on the lynx, we can only speculate on how it survives. Hodges and Mills have recently begun documenting relationships between forest succession, forest structure, and snowshoe hares in the park. Their data show that although a majority of forest stands in Yellowstone, regardless of age, support no hares, some widely-dispersed patches retain sufficient cover to support an abundance of hares (albeit in low numbers relative to those of northern latitudes). Through high mobility, lynx may be able to exploit these patches sufficiently well to establish home ranges, and even reproduce successfully to a limited extent. The two cases of lynx reproduction we documented may serve as cases in point. We know from the scientific literature that lynx are capable of long-distance movements, motivated by an apparent desire for exploration, emigration from home ranges due to declines in prey, and dispersal among newly-independent offspring. Perhaps this high capacity for long-distance travel also extends to efficient exploitation of widely dispersed patches of snowshoe hares. Reliance on alternate prey during winter may also help explain lynx persistence in the ecosystem. Indeed, the scientific literature indicates that during periods of hare population lows at northern latitudes, and during the summer and fall seasons, lynx increase their use of alternate prey.

Finally, linkages with other populations may explain lynx persistence in the GYE. Distant populations, perhaps even those as far north as northwestern Montana, Alberta, or British Columbia, may provide, through dispersal, new recruits that augment numbers here. Lynx numbers appear to increase, sometimes rapidly, in the contiguous United States after their populations reach high levels north of the U.S.–Canadian border, and then begin to decline. Scientists hypothesize that lynx

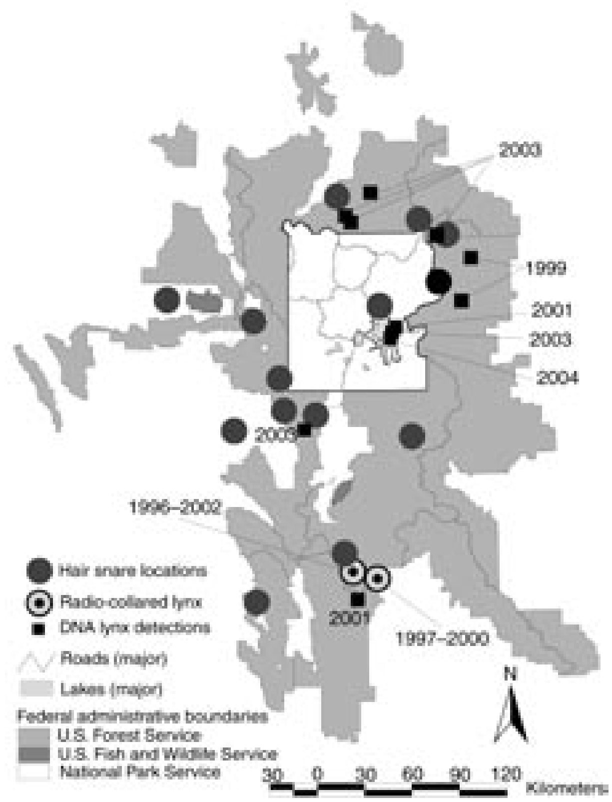

Figure 7. DNA-based detections of lynx using hair snares, snow tracking, or captures for research in the Greater Yellowstone Ecosystem, 2000–2004. Data from Squires et al. (2003) and courtesy of the Gallatin, Caribou-Targhee, and Shoshone National Forests.

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The lynx crew after shovelling out Harebell Cabin, YNP, 2003. Left to right: Nate Berg, Justin Hadwen, Andy Weidman, Margo Higgins, and Tiffany Potter.

may exist in metapopulations—groups of semi-isolated, individual populations that collectively persist through exchange of individuals. Some populations supported by a high quantity and quality of habitat would contribute more dispersers than they would recruit (population sources); others would mostly absorb recruits and rarely produce excesses themselves (population sinks). In this scenario, the smaller the lynx population, and the less ingress it received from distant populations, the more likely it would be to go extinct in the area where it occurred. The strong evidence from radio telemetry data that some lynx are highly mobile, and the lack of regional genetic differentiation among their populations, supports the idea that lynx in the northern Rocky Mountains exhibit metapopulation structure.

The Future

What have we learned from our work that will help ensure the future of this unique carnivore in the park and the GYE? First, at the beginning of the twenty-first century, lynx still exist at detectable levels in the park, but occur in low numbers. Mature forests of the park that are considered productive habitat for lynx prey are limited in acreage, spatially fragmented, and appear to support lower prey densities than other areas at northern latitudes. Yet, lynx persist in the park despite the marginal habitat and population conditions. Movement and connectivity (i.e., population exchange) of lynx between and within ecosystems may be key to maintaining populations.

Although we know very little about lynx in the park, obtaining detailed information would require investment in a long-term project that would necessitate capturing, radio-marking, and monitoring many of the individuals that are present. Such a study would involve some disturbance of the few individuals present and would likely yield low sample sizes. Alternatively, repeat surveys of the sort we have done would enable us to see if lynx numbers and distribution change dramatically through time, but would leave key biological questions unanswered. We are continuing the snowshoe hare studies in cooperation with Hodges and Mills to better understand hare population dynamics, their relationship to forest structure, and the effects of disturbance agents such as fire on snowshoe hare and lynx habitat. In the absence of more detailed information on lynx, maintaining the pristine character and historic disturbance processes in park forests and habitat connectivity within the GYE and between the GYE and other forest ecosystems is probably the best long-range management strategy for sustaining this mysterious cat.

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Acknowledgements

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BOB WIESNER

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