Yellowstone National Park
Yellowstone Wolf Project 2023
Wyoming, Montana, Idaho

Yellowstone Center for Resources
National Park Service
Department of the Interior

Yellowstone Wolf Project Annual Report

2023

Summary

At the end of December 2023, there were 124 wolves in eleven packs (six breeding pairs) living primarily in Yellowstone National Park (YNP). Pack size ranged from two to 25, averaging 10.8 members. Throughout YNP, a minimum of 58 pups were produced, with at least one additional litter that was born but died before it could be observed. Forty-six pups survived (79%) to the end of the year with 30 in the six northern packs (three breeding pairs) and 16 in the five interior packs (three breeding pairs). At the end of 2023, pups comprised 37% of the wolves living in YNP.

One new pack called 1386F group dissolved approximately six months after forming when three of the six pack members were killed during wolf hunting seasons outside of YNP. Another new group, called 1330F/1336M group, formed in fall 2023. At the end of 2023, we recorded more lone wolves (5) than the 10-year average (1.2).

The winter of 2022-2023 was among the coldest and snowiest since wolf reintroduction in 1995. Early, heavy snowfall paired with three different, multi-day cold spells reaching -20 to -50 degrees Fahrenheit created challenging conditions for all ungulates, and staff doing field work. In the early months of 2023, approximately 90% of the northern range elk herd were outside the park, and the largest and earliest migration of YNP bison was recorded, including about 4,000 bison migrating north of Mammoth Hot Springs into the state of Montana in search of lower elevation forage. Wolf Project staff documented many winter-killed (died of starvation or exposure) ungulate carcasses into the spring. Wolves readily scavenge winter-killed carcasses, which influences predator-prey dynamics and kill rates. Climate change studies indicate that extreme weather events are becoming more common and that climatic conditions are shifting beyond the historical range of variability and therefore, predictability.

In addition to wolves, project staff study cougars and elk. The current cougar research has been ongoing since 2014 and is considered Phase 3 of a long-term effort starting nearly four decades ago. Elk have been monitored in YNP for nearly a century and the recent work using advanced radio collars began in 2011. Efforts to monitor and understand the ecological importance of Yellowstone's two top predators (wolves and cougars) and their relationship with their primary prey (elk) are synergistic and critical to YNP's mission. General information about cougars and elk can be found at YNP's webpages for these species (www.nps.gov/yell/learn/nature/cougar.htm and www.nps.gov/yell/learn/nature/elk.htm) but they are briefly discussed in sections below.

Wolf-Prey Relationships

Project staff detected 170 kills definitely, probably, or possibly made by wolves in 2023: 96 elk (56%), 33 bison (19%), eight mule deer (5%), eight deer of unknown species (5%), three moose (2%), three wolves (2%), three badgers (2%), one pine marten (<1%), one bighorn sheep (<1%), one coyote (<1%), one undetermined rodent (<1%), and 12 unidentifiable species (7%, likely ungulates). The composition of wolf-killed elk was 27% calves, 3% yearlings, 30% adult females, 39% adult males, and 1% of unknown age and sex. The composition of wolf-killed bison was 33% calves, 6% yearlings, 36% adult females, 12% adult males, 6% adults of unknown sex, and 6% of unknown age and sex. The number of winter-killed ungulate carcasses scavenged in 2023 (55) was nearly three times higher than the average number documented from 1995 through 2022 (19.5), and second only to the severe winter ending in 2011 (60).

Wolf predation was intensively monitored for four months of the year—one month in late winter (March), one month in early winter (mid-November to mid-December), and the summer predation study period lasted two months—from May 1 through June 30.

Predation Studies

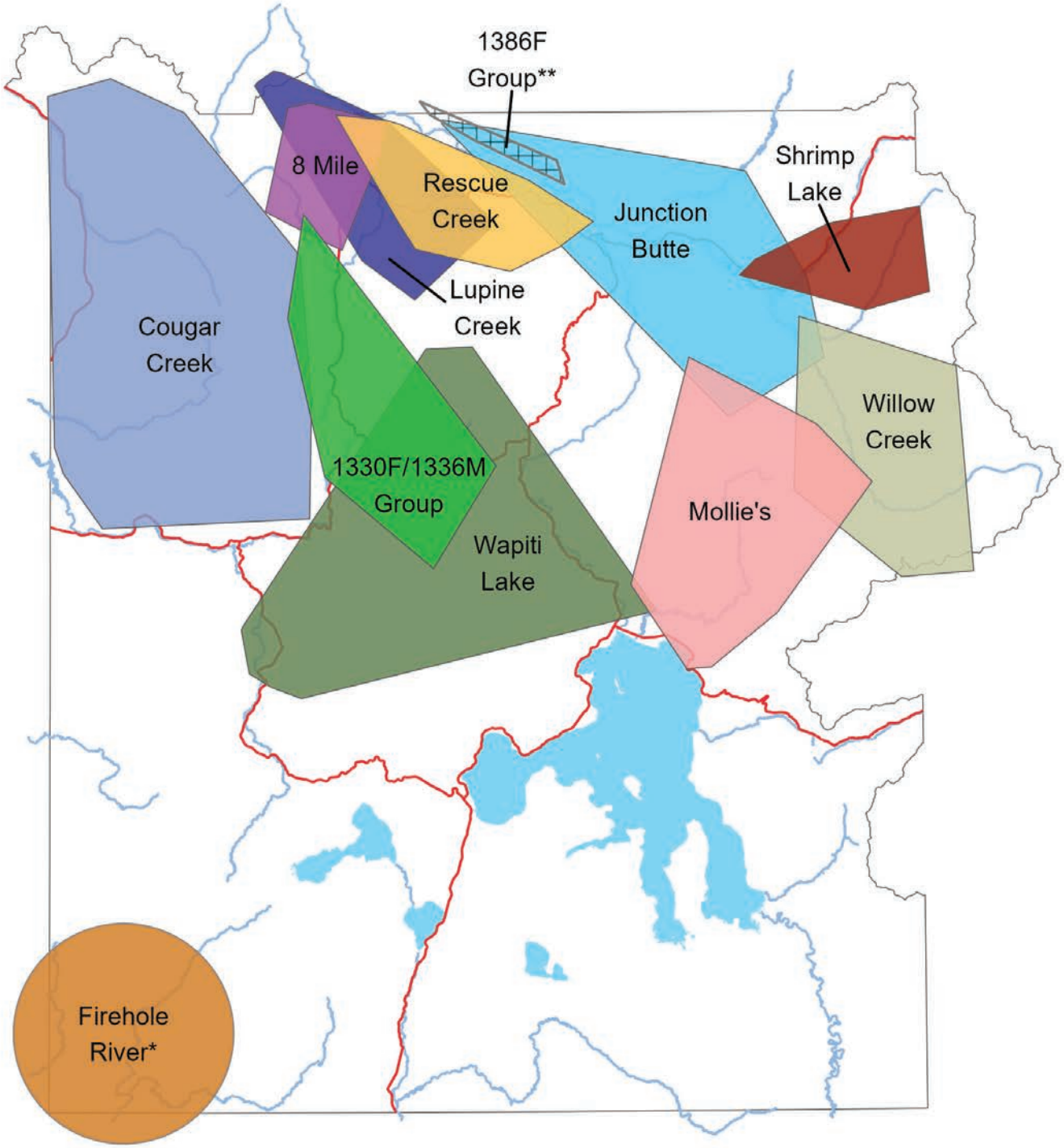
During the 30-day March 2023 late winter study period, three teams (air, ground, and GPS [Global Positioning System] cluster-search crew) discovered 83 ungulate carcasses fed on by wolves. In addition, wolves killed one beaver. The air crew was able to fly on 19 of the 30 days and tracked all radio-collared packs in YNP. One ground crew observed the Rescue Creek pack for 22 of the 30 days and another crew observed the Lupine Creek pack for 18 of the 30 days. The GPS cluster-crew hiked or skied a total of 523 kilometers (325 miles) to investigate a total of 166 GPS clusters—106 clusters for three wolves in the Rescue Creek pack, 53 clusters for one wolf in the Lupine Creek pack, and seven clusters for cougar F230 (see Cougar Research and Monitoring section below). For wolves, a cluster is defined as two or more locations within 100 meters of each other within a three-day span, and for cougars, two locations within 200 meters of each other within a six-day span. In winter, GPS collars are set to take a location fix every hour for wolves and every three hours for cougars.

Fifty-five (66%) of the ungulates were killed by wolves, including 25 elk, 14 bison, 10 deer, three moose, one bighorn sheep, and two ungulates of undetermined species. Of the elk, three were calves (12%), nine were adult females (36%),

Front cover. The Wapiti surrounding a bison during an unsuccessful hunt. NPS Photo/D. Stahler

2023 Yellowstone Wolf Pack Territories

(95% minimum convex polygons of aerial locations)



Note: Aerial locations are not obtained during wolf hunting seasons outside of the park. Some wolf pack territories do not represent all transboundary space use.

* No radio collars present, unable to estimate territory size.
** Pack not present at end of the year.

Yellowstone Wolf Population as of 12/31/2023

Yellowstone Wolf Population as of 12/31/2023	Adults	Pups	Total
Northern Range			
8 Mile	7	18	25
Lupine Creek	5	1	6
Rescue Creek	8	7	15
Junction Butte	10	1	11
Shrimp Lake	4	3	7
loners (1437M, 1090F, 1411F, 1341F/1384F, 1407M)	5	0	5
Northern Range Total	**39**	**30**	**69**
Non-Northern Range			
Cougar Creek	11	0	11
Mollie's	9	4	13
Wapiti Lake	9	6	15
Firehole River, estimated pack size	3	3	6
Willow Creek	5	3	8
1330F/1336M group	2	0	2
loners	0	0	0
Non-Northern Range Totals	**39**	**16**	**55**
YNP Total	**78**	**46**	**124**
underline denotes a breeding pair			

2023 Yellowstone Wolf Mortalities

Wolf #/sex	Date of Death	Age	Pack	Cause of Death
1229F	1/13/2023	adult	Junction Butte	Trapper-killed (MT)
1278M	2/6/2023	adult	Rescue Creek	Hunter-killed (MT)
1271F	3/2/2023	adult	8 Mile disperser	intraspecific
1391F	3/5/2023	pup	Rescue Creek	intraspecific
1415M	6/5/2023	yearling	Cougar Creek	kicked by ungulate
1383F	7/2/2023	adult	Junction Butte	intraspecific
1382F	9/10/2023	old adult	Junction Butte	kicked by ungulate
uncollared	9/25/2023	adult	1386F group	Hunter-killed (MT)
uncollared	9/25/2023	yearling/adult	1386F group	Hunter-killed (MT)
1276F (presumed)	est 10/6/2023	adult	Junction Butte	unknown injury (starvation)
uncollared	est 10/15/2023	yearling	possibly Rescue Creek	intraspecific
uncollared	10/24/2023	yearling	1386F group	Hunter-killed (MT)
1235F	12/1/2023	adult	Firehole River	Trapper-killed (ID)
1375M	12/3/2023	adult	Willow Creek	Hunter-killed (WY)
uncollared	12/11/2023	pup	Lupine Creek	Hunter-killed (MT)
uncollared	12/12/2023	pup	Lupine Creek	Hunter-killed (MT)
1272M	12/25/2023	adult	Mollie's	Hunter-killed (MT)

2023 Yellowstone Wolf Capture

Wolf #/sex	Date of Capture	Age	Color	Pack	Collar Type
1382F	1/5/2023	old adult	black	Junction Butte	VHF
1383F	1/5/2023	yearling	black	Junction Butte	GPS
1384F	1/5/2023	yearling	gray	Junction Butte	GPS
1385F	1/5/2023	pup	black	Junction Butte	VHF
1386F	1/5/2023	adult	black	Junction Butte	VHF
1387M	1/5/2023	pup	black	Lupine Creek	VHF
1388F	1/5/2023	pup	gray	Lupine Creek	VHF
1232M	1/5/2023	adult	black	Lupine Creek	GPS
1389F	1/6/2023	yearling	gray	8 Mile	GPS
1390M	1/6/2023	yearling	gray	8 Mile	VHF
1391F	1/6/2023	pup	gray	Rescue Creek	GPS
1392M	1/6/2023	pup	black	Rescue Creek	VHF
1393M	1/6/2023	adult	black	Rescue Creek	GPS
1278M	1/6/2023	adult	gray	Rescue Creek	VHF
1407M	2/6/2023	adult	black	Willow Creek	VHF
1408F	2/6/2023	pup	gray	Willow Creek	GPS
1409M	2/6/2023	adult	black	Wapiti Lake	GPS
1410F	2/7/2023	yearling	black	Mollie's	GPS
1411F	2/7/2023	pup	black	Mollie's	VHF
1412F	2/7/2023	pup	black	Cougar Creek	GPS
1413M	2/7/2023	pup	black	Cougar Creek	GPS
1414F	2/7/2023	pup	black	Cougar Creek	VHF
1415M	2/7/2023	pup	black	Cougar Creek	VHF
1344M	2/7/2023	yearling	gray	Cougar Creek	VHF
1435M	3/18/2023	yearling	gray	Hawk's Rest	GPS
1436F	3/18/2023	yearling	gray	Hawk's Rest	VHF
1437M	3/18/2023	adult	gray	Hawk's Rest	VHF

11 were adult males (44%), and two were yearlings (8%). The wolves also scavenged on 20 bison, seven elk (all adult males), and one moose they did not kill.

During the 30-day November-December 2023 early winter study period, the three teams discovered 28 ungulate carcasses fed on by wolves. In addition, wolves killed one badger. The air crew was able to fly on 20 of the 30 days and tracked all radio-collared packs in YNP. One ground crew observed the Junction Butte pack for 25 of the 30 days and another crew observed the Rescue Creek pack for 28 of the 30 days. The GPS cluster-search crew hiked or skied over 408 kilometers (254 miles) to investigate 52 GPS clusters from one Lupine Creek pack wolf (31 clusters) and two cougars: F210 (10 clusters) and M229 (11 clusters; see Cougar Research and Monitoring section). Twenty-three (82%) of the ungulates were killed by wolves, including 16 elk, three bison, three deer, and one moose. Of the elk, three were calves (19%), five were adult females (31%), and eight were adult males (50%). The wolves also scavenged on three bison and two elk (both adult males) they did not kill.

During the two-month summer predation study period, the GPS cluster-search crew hiked over 364 kilometers (226 miles)to investigate 117 clusters from one Lupine Creek pack wolf and discovered that the wolf had fed on 22 fresh ungulate carcasses. In addition, the wolf also visited and likely obtained some biomass from older, non-wolf-killed carcasses on the landscape due to severe winter conditions in early 2023.

Mortality

Ten radio-collared wolves died in 2023. Five of the wolves were killed during the wolf hunting seasons in states surrounding YNP—1229F from Junction Butte, 1278M from Rescue Creek, 1235F from Firehole River, 1375M from Willow Creek, and 1272M from Mollie's. Three wolves were killed in conflicts between packs: 1271F from 8 Mile, 1391F from Rescue Creek, and 1383F from Junction Butte. Wolves 1415M from Cougar Creek and 1382F from Junction Butte both died from injuries sustained while hunting large ungulates, likely an elk or moose (1415M) and a bison (1382F).

Although her collar was not functioning, staff also documented the presumed death of wolf 1276F, the lead female of the Junction Butte pack. She was observed in late September with a severe injury, of unknown cause, to her lower jaw. Both mandibles had broken and were freely hanging but still attached with soft tissue. Project staff closely monitored 1276F, and for a time, she continued to travel with her pack as the leader and attempted to eat and drink despite the severity of her injury. She was last seen on October 6th and likely died soon after. Staff diligently grid-searched the area she was last seen and other commonly used areas for the pack to try to recover her body for examination in hopes of determining the cause of the injury but were unsuccessful. Seeing an injury as severe as 1276F's was shocking and difficult, but seeing her steadfast persistence to live was extraordinary.

In addition to the radio-collared wolves, staff recorded six deaths of uncollared wolves, one was killed by other wolves and five were killed in late 2023 during the wolf hunting season in Montana—three wolves from a new group called 1386F's group and two from the Lupine Creek pack.

Disease

There was no indication of disease in the wolves this year. The 1386F group seemed to lose their pups before den emergence and the Junction Butte pack had two litters but all except two of the pups died of unknown causes during the month of May. The pup carcasses could not be recovered or found later in the summer so disease testing could not be completed. It is also possible the pups died of non-disease related causes such as drowning, predation, or malnutrition.

Reproduction

In April 2023, prior to the birth of the 2023 litters, there were approximately 96 adult wolves in YNP. At least 58 pups were born to ten packs. Two packs produced multiple litters this year: 8 Mile (18 pups from three litters), and Junction Butte (seven pups from two litters). The Lupine Creek, Rescue Creek, Shrimp Lake, Willow Creek, Mollie's, Wapiti

"Field Technician Nikki Tatton records data at an elk calf kill made by wolves during summer predation work. Wolves consume nearly the entirety of young elk calves, leaving only bone shards and bits of hair." NPS Photo/D. Stahler

Lake, Firehole River, and 1386F group had one litter each. The Cougar Creek pack was not confirmed to have denned. Of the minimum 58 pups produced in all packs, 46 (79%) survived to the end of the year. Pup survival was mostly high with the exception of the Junction Butte and Lupine Creek packs, which had at least seven and five pups, respectively, but by the end of the year had only one surviving pup each. The 1386F group exhibited denning movements but lost their pups before they could be counted.

Capture

Twenty-seven wolves from nine packs were captured and collared in 2023. New collars were deployed on 11 pups, seven yearlings, five adults, and one old adult wolf. Older or nonworking collars were replaced on two adult wolves—1278M from Rescue Creek and 1232M from Lupine Creek. Yearling wolf 1344M from Cougar Creek was recollared after his original collar was chewed off the previous summer.

In addition to fitting the radio collar, staff took blood samples for disease screening, a whisker for isotopic diet analysis, body and tooth measurements, and weights. A uniquely-identifying pit-tag was inserted under the skin near the shoulder in case a collar is dropped or chewed off and the wolf is recaptured in the future. This is the way we were able to confirm the identity of recollared wolf 1344M of Cougar Creek.

Twelve of the collars were GPS which send data through satellites, can be programmed remotely, and are used to evaluate habitat selection, movement patterns, prey selection, biomass consumption, and multi-species interactions during certain seasons. These collars last for approximately two years and are programmed to record locations from four to 48 times per day, depending on the season and study objectives. The other 15 collars were VHF (Very High Frequency), which emit a tracking beacon and have a battery life generally lasting five to seven years. The Yellowstone Wolf Project aims to have approximately 25%-30% of the wolves collared to gather information for dozens of long-term monitoring and research objectives. At the end of 2023, there were 33 collars on 124 wolves (27%).

Wolf Management

YNP wolf management team temporarily closed areas around the Junction Butte and Wapiti Lake den areas to protect young pups from disturbance and allow the adult wolves to travel near the den unimpeded. When both packs moved their pups to a secondary den area in early June and late summer (respectively), both closures were lifted.

In 2023 there were few recorded cases of habituated behavior. In YNP, habituated behavior by wolves is carefully monitored and attempts to correct the behavior through aversive conditioning are made as soon as possible. Aversive conditioning is performed by trained staff during a teachable moment when the wolf makes the decision to be in close proximity to humans or vehicles. When wolves are wary of humans, they are less likely to interact with and be influenced by humans. It can be difficult to successfully execute aversive conditioning unless staff monitor the wolf of concern daily for many hours. Visitors can help prevent habituation by refraining from approaching or following wolves on foot or with their vehicles. Visitors must maintain at least 100 yards distance from wolves (and bears and cougars). This distance should be maintained even when wolves are near or on roadways and pullouts, and even further if necessary to avoid disrupting natural wolf behavior.

Wolf Hunting Near YNP

Outside of the YNP boundary, in the states of Montana, Wyoming, and Idaho, wolves can be hunted and trapped during certain times of the year. Each state has different regulations including season dates and bag limits. Wolves from packs monitored by YNP staff occasionally travel outside of YNP borders and are legally killed by hunters and trappers. Each year we record wolves killed near the shared boundary between northern YNP and Montana due to the ease of human-access, the presence of the northern range elk herd, and the frequent presence of hunter-provided carrion from elk and bison hunting outside the park. Wolves from YNP packs are also killed in Wyoming and Idaho but these are less frequent because areas close to the park boundary are less accessible for humans. In Montana, the Fish and Game Commission reinstated a quota along the YNP border prior to the 2022-2023 season. Wolf Management Units 313 and 316 were combined into one unit (WMU 313) with a quota of six. This spatial delineation and quota size remained the same for the 2023-2024 season.

YNP staff use radio collars and intensive, year-round observations and detailed knowledge of pack composition to determine which wolves are killed when packs travel outside of YNP. This science-based information is critical to understanding transboundary wolf management issues. See the Mortality section for details on the ten wolves killed by hunters or trappers—two in early 2023 and eight from September to December of 2023.

Outreach

Wolf Project staff gave 156 formal talks and 53 interviews, presented one conference poster, gave three conference presentations, and led 18 field trips. During the summer months, staff helped educate at least 15,540 people while viewing wolves and gave 124 informal talks in the field. In addition, Taylor Rabe and Jeremy SunderRaj counseled 27 staff from other divisions in YNP on research in the field, and Brenna Cassidy taught a 3-day course through Yellowstone Forever.

Graduate Research

In addition to National Park Service (NPS) and Yellowstone Forever staff research, monitoring, and wolf management projects, the project supports several graduate student collaborations. In 2023, there were three primary graduate students. Brenna Cassidy, a PhD candidate at the University of Montana advised by Dr. Mark Hebblewhite, focused on gray wolf population dynamics, survival, and cause-specific mortality. Jack Rabe, PhD candidate at the University of Minnesota, advised by Dr. Joseph Bump, is examining how Yellowstone carnivores compete for resources across time and space, how such competition impacts predator-prey relationships, and how predation by Yellowstone's diverse carnivore community influences elk population dynamics. Wes Binder, a PhD student at Oregon State University advised by Dr. Taal Levi, has projects focusing on wolf and cougar interactions. These topics leverage GPS telemetry datasets, cougar density and abundance estimates across northern Yellowstone from trail camera detections, and fine-scale predator behavior using advanced GPS and accelerometer data.

In 2023, two supported graduate students completed their projects. Nicole Tatton completed her Master of Science degree at the University of Minnesota advised by Dr. L. David Mech. Her thesis focused on wolf homesite selection. Dr. Brian Smith completed his PhD at Utah State University advised by Dr. Dan MacNulty. His dissertation examined the demographic consequences of elk spatial response to predation risk from wolves and cougars, including how elk density can modify the relationship between spatial response and predation risk.

Pack Summaries

8 Mile (25 wolves: 7 adults, 18 pups)

After reaching a low of six pack members in early 2023, 8 Mile produced three litters of pups and all 18 of them were still alive by the end of the year. One of the litters was produced by pack leaders 1328F and 1326M, while the other two litters were likely fathered by males from other packs. Lone wolf 1336M spent much of the breeding season with 8 Mile subordinate 1389F and is most likely the father of at least some of the pups. Six year-old lead male 1326M, from the Wapiti Lake and Canyon pack lineage, is recognizable as he is turning white with age.

Lupine Creek (6 wolves: 5 adults, 1 pup)

The Lupine Creek pack continues to eke out a territory in northern Yellowstone in between the much larger 8 Mile and Rescue Creek packs. The amount of territory overlap (see territory map on page 3) between the 8 Mile pack and the Lupine Creek packs is very high and may be driven by the relatedness between the packs. All of the adults in the Lupine Creek pack came from 8 Mile in 2022 and at least one subordinate has gone back and forth between the two packs several times. In the spring, yearling 1387M dispersed and was later shot under SB200 regulations southwest of Dillon, MT (note: MT's legislative bill SB200 allows for the take of wolves on private land deemed to be a potential threat to human safety, livestock, or dogs). The uncollared lead female gave birth to at least five pups. Two of the pups were lost over the summer to unknown causes and two were killed in the Montana wolf hunting season in Wolf Management Unit 313 near the end of the year.

Rescue Creek (15 wolves: 8 adults, 7 pups)

Early in 2023, long-time pack member 1278M was killed during the wolf hunting season in Montana. Two other adults died or dispersed throughout the year, including the original lead male of the pack, a five year-old uncollared gray. The pack produced one litter of eight pups and seven of them survived through the end of the year. The Rescue Creek pack was the focus of the Wolf Project's summer bioacoustics data collection efforts. It will be fascinating to see what we can learn from the voices of known individuals, starting when the 2023 pups let out their very first howls.

1386F group (0 wolves)

This group began when 1386F of the Junction Butte pack dispersed in spring 2023 to den separate from the rest of the pack. She was joined by a yearling female from Junction and at least four grays, likely all males, of unknown origin. It is possible the males were from the Hawk's Rest pack (WY) because lone wolf 1437M (also from Hawk's Rest) was with the group at least once. The group ranged north of the Yellowstone River between Bear Creek and Hellroaring Creek. Two males from this group were killed during the Montana wolf hunting season, followed by the female yearling one month later. Wolf 1386F subsequently rejoined the Junction Butte pack and the fate of the remaining two wolves is unknown.

Winter study technicians (left to right) Jackson Connors, Kyle Dudgeon, and Jack Rabe gaze at the remains of a winter-killed bison scavenged by wolves. Wolf consumption of bison has become increasingly important to predator-prey dynamics in Yellowstone. NPS Photo/D. Stahler

Junction Butte (11 wolves: 10 adults, 1 pup)

The Junction Butte pack experienced major changes during 2023, starting the year at 25 wolves and ending with just 11, the smallest the pack has been in five years. The major difference can be attributed to lower reproduction and shifts in pack dynamics. Since 2018, the pack has produced between nine and 21 pups each year. This year, the pack produced at least seven pups but most died very early of unknown causes. Only two lived to June and only one to July. In addition to pup mortality, several adult members died, including former lead female 1382F, yearling 1383F, and lead female 1276F. Some adults dispersed to the Mollie's pack, including 1339M and two uncollared males. Two adult pack members disappeared by summer and a group of six disappeared in October. Occasional sightings of a wolf with a nonworking collar suggest some of the missing wolves are alive and establishing a new group.

Shrimp Lake (7 wolves: 4 adults, 3 pups)

The Shrimp Lake pack produced four pups in 2023, and three survived to the end of the year. The pack is still led by 1228F and a gray male, and includes two yearlings: a gray male and a black female. Lead female 1228F's collar malfunctioned in the fall but the pack was occasionally seen to the end of the year.

Willow Creek (8 wolves: 5 adults, 3 pups)

The Willow Creek pack rarely left the upper Lamar River drainages in 2023. Despite beginning the year with four pups (born in 2022), by the time the cohort reached one year old, only 1408F had survived. In 2023, the pack produced three pups, and allowed two adult males (1417M and 1375M) from the Beartooth pack in Wyoming to join. It is unknown if these two males were related to presumed lead 1407M. Later sightings indicated 1417M was dominant to 1407M, which was confirmed when 1407M dispersed in late 2023. The pack spent some time in the Pahaska Tepee area just outside the east entrance of YNP in late 2023 where 1375M was killed during the Wyoming wolf hunting season. All three pups lived to the end of the year. It will be interesting to see where the Willow Creek pack shifts as the winter continues, especially given the onset of a mild winter in 2023—different from the conditions in winter from late 2022 to mid-2023.

Mollie's (13 wolves: 9 adults, 4 pups)

The Mollie's pack spent the entire 2022-2023 winter in interior Yellowstone, likely due to the availability of winter-killed bison. Interestingly, during the March winter study, the pack was only found to scavenge on winter-killed bison, with not a single detection of them making a kill during the 30-day

Nikki Tatton and Jeremy SunderRaj ford the Lamar River to search for the remains of 1276F, the lead female of the Junction Butte pack. She was presumed dead following a severe injury to her lower jaw in September. Despite staff diligently searching for her (her radiocollar no longer functioned), she remains undiscovered in the wilds of Yellowstone. NPS Photo: Dan Stahler

study. The pack produced four pups, possibly by former lead female 1090F although genetic anaylsis is needed. More male wolves from the Junction Butte pack joined Mollie's in 2023: 1339M in June and an uncollared gray and uncollared black in November. The latest two likely created tension between the first Junction Butte/Rescue Creek males to join Mollie's in mid-2022. Their age difference meant that they probably did not know each other well, despite having the same pack origins. As a result, former lead 1272M, former lead 1090F, and an uncollared black male all dispersed. Initially the trio were found together but eventually the uncollared black male rejoined Mollie's pack. Wolf 1272M was killed in Montana during the wolf hunting season, and 1090F was found alone or occasionally with or near Rescue Creek pack wolves.

Wapiti Lake (15 wolves: 9 adults, 6 pups)

For the first time since they formed in 2014, the Wapiti Lake pack did not spend part of the year in northern Yellowstone and instead spent the entire 2022-2023 winter in interior YNP. Deep snow, severe winter conditions, and many winter-killed ungulates provided the pack with excellent conditions for hunting and scavenging. Despite having six adult females and plenty of food, only one litter was observed. All six pups produced survived to the end of the year. Considering all six pups have black coats, it is possible their father, 1270M, is a rare black that does not carry the recessive gray allele. Homozygous black wolves can only produce black offspring and make up less than 3% of all wolves with a K-locus allele test.

Cougar Creek (11 wolves: 11 adults, 0 pups)

The Cougar Creek pack did not display denning behavior in 2023, which was surprising given there were at least four adult females and the severe winter provided plenty of ungulate biomass as food for the pack in the late winter and spring. Several adults died (1415M from an ungulate kick) or dispersed throughout the year. The pack occupies an area that was, at one time, home to three different packs. Ranging widely from the northwest corner of YNP to Madison Canyon.

Firehole River (estimated 6 wolves: 3 adults, 3 pups)

Both radio collars in this pack malfunctioned but trail cameras confirmed that at least one collared wolf, 1235F, was still alive and with an adult male in the summer. Sightings in the fall indicated the pack had at least seven members, including some pups. The pack was documented occupying some of the former Bechler Pack's territory in the southwest corner of YNP. Wolf 1235F was trapped in Idaho just outside of Yellowstone's boundary in December. We think the pack ended the year with as many as six members, likely split evenly between adults and pups. Because pack size and composition are partially unknown, we do not count this pack as a confirmed breeding pair.

1330F/1336M group (2 wolves: 2 adults, 0 pups)

After spending almost a full year as a lone wolf, 1336M met up with 1330F from the Wapiti Lake pack in fall 2023. The two had met several times before, in late 2021 and early 2022, when 1336M spent months with some older Wapiti Lake females. This pair ranged throughout the west-central area of the park.

Lone Wolves

1407M: With a shift in pack dynamics, former leader 1407M might have lost his position in the Willow Creek pack in spring 2023. He dispersed in late 2023 and met Mollie's female 1338F. The pair shifted away from both of their former packs; however, by the end of the year, 1338F dispersed north of YNP and 1407M remained as a lone wolf.

1437M: Wolf 1437M dispersed from the Hawk's Rest pack in spring, traveled at least 70 miles straight-line distance, and spent most of the summer satelliting the Junction Butte pack. He interacted in a friendly way with the pack females and even had some interactions with the pack males that indicated they were not threatened by him. However, by late summer, 1437M roamed more widely across YNP.

1090F: Elderly 1090F (born in 2014) was no longer Mollie's pack leader by early 2023 but remained with the pack and may have had pups in the spring. At the end of the year, she separated from Mollie's with former lead 1272M and an uncollared black male. They traveled northern Yellowstone together for a short time then split up. For a few days, wolf 1090F was found with some members of the Rescue Creek pack, but by the end of the year was seen alone.

1411F: Yearling 1411F was quite young to disperse alone but left the Mollie's pack in late 2023. She occasionally returned to the pack where she was subordinate. By the end of the year, she was considered a lone wolf traveling widely.

1341F or 1384F: Both 1341F and 1384F, wearing nonworking GPS collars, dispersed from the Junction Butte pack in fall 2023. They may be together or with other Junction Butte wolves but by the end of the year, we could only confirm that a single collared gray was still alive. The sisters 1341F and 1384F are not easily distinguished from each other and the unidentified collared wolf was alone in Soda Butte Valley.

Other Wolves

The Hawk's Rest (10 wolves: 8 adults and 2 pups) and Pahaska (6 wolves: 4 adults and 2 pups) packs used eastern and southern portions of YNP from late summer to early winter. Both packs are officially counted towards the Wyoming (non-YNP) population total and monitored by Wyoming Game and Fish Department. Three Hawk's Rest wolves are included in the Wolf Capture section because YNP staff coordinated with the Wyoming Fish and Game Department to successfully capture the pack while they were within YNP borders.

Originally from Wyoming, Wolf 1292F, who was often found with two uncollared wolves, occasionally used YNP in early 2023 but became untrackable when her collar dropped as scheduled in late February. In May, a wolf matching her description was seen over several consecutive days in Lamar Valley and may have been denning. She was not observed after that.

Elk Research

The Yellowstone Wolf Project also studies the northern range elk herd—one of at least seven elk herds that use YNP in the summer, and the only elk herd which partially winters in YNP. Elk have been monitored in YNP for over 100 years and the current study has been ongoing since 2011. Radio collars are deployed on 15 to 20 adult female elk each winter and the elk are monitored year-round. Research topics include cause-specific mortality, survival, migration, predator/prey dynamics, reproduction, disease, and habitat selection.

Wolf Project and Bear Management staff participate in annual aerial counts of the northern herd to estimate herd

size in most years. Aerial counts are an interagency effort with Montana Fish Wildlife and Parks (MTFWP) personnel. Depending on survey conditions, snow cover, and pilot/observer availability, counts are conducted by multiple planes to provide a minimum estimate of elk occupying the northern range which occurs both inside and outside the park. Additionally, MTFWP conducts an annual helicopter classification survey designed to determine age and sex structure of elk as well as estimating elk calf recruitment and bull to cow ratios.

MTFWP and YNP were unable to conduct a cooperative fixed-wing trend count during the 2023 calendar year. Helicopter classification counts that attempt to count all elk are not directly comparable to fixed-wing trend counts because (all other conditions being equal) detection probability is greater from a helicopter than from fixed-wing aircraft. However, on December 16th 2022, a count was done that represents the 2022-2023 winter range occupancy. During this fixed-wing count, 5976 elk were observed, including 654 elk (11%) inside Yellowstone National Park and 5,142 elk (89%) north of the park. In March 2023, MTFWP conducted a helicopter elk classification count (to determine ratio of calves and bulls to cows) across the northern range. The total number of elk observed during 2023 helicopter classification count was 6651 elk (including both in and outside the park), which was similar to the number observed in 2022 (a 0.3 percent decrease from the 6673 elk observed during the 2022 classification flight).

Raw counts underestimate the actual abundance of elk, and the extent of undercount could vary markedly depending on survey conditions. Sightability studies conducted during 1986-1991 found that up to 91% of northern Yellowstone elk were detected during good survey conditions, with an average detection rate of 75%. However, detection probabilities may have changed in areas of the northern range following wolf recovery, with elk in the park being more widely distributed in small groups and timbered areas, while elk north of YNP near Dome Mountain and Dailey Lake continue to congregate in relatively large groups in open areas. Smaller and more widely spread groups in the park and north to Yankee Jim Canyon are more difficult to detect compared to larger groups of congregated elk near Dome Mountain and Dailey Lake. Elk sightability models have been developed to better estimate the number of elk not observed during each count. The northern herd elk numbers have stabilized since their decline coinciding with the first decade of wolf recovery. Collaborative research involving Wolf Project personnel has demonstrated that changes in elk abundance have been influenced by a variety of factors, notably the restoration of wolves, cougars, and bears, along with human hunting of northern herd elk outside of the park. Ongoing research seeks to understand the relative role of these factors in shaping elk population dynamics.

At the beginning of 2023, 57 cow elk in YNP were radio-collared. Of these, 55 were GPS collars and two were VHF collars. There were 15 radio-collared elk mortalities documented this year. Six were killed by wolves, four died of malnutrition/exposure due to severe winter conditions

A winter view of Blacktail Plateau from the window of a Supercub during a wolf tracking flight is spectacular. NPS Photo/D. Stahler

Dominant male of Lupine Creek Pack, 1232M, howls to reconnect with his packmates while some elk observe safely nearby. NPS Photo/T. Rabe

that accumulated throughout early 2023, one was killed by a cougar, one of unknown natural causes, two from unknown causes, and one in the Gardiner youth hunt in Montana. The average age of collared elk that died in 2023 was just over 14 years old, ranging from 8 to 19.8 years old. Three elk went missing in 2023 when their radio collar beacons failed, but at least one, elk 2305, was found alive near the end of the year. This was confirmed when staff observed her and matched up the unique number on her collar's belting.

At the end of 2023, 39 elk wore trackable radio collars—36 were GPS collars, two were VHF collars that were deployed in late 2012, and one was a GPS collar which has partially malfunctioned and only transmitted a VHF beacon. At the end of the year, the average age for living, collared elk was just over 12 years, ranging from 5.5 to 21.5 years old. No new collars were deployed on elk in 2023 but collaring will resume in 2024.

By the end of 2023, two cow elk, with identification numbers 1306 and 2002, were the oldest, living collared elk, both at 21.5 years old. Another cow elk, 2012, led an interesting life: she was captured in late 2019, left the northern range herd, and joined the Clarks Fork elk herd which winters near Cody, Wyoming. Before she died in 2023, she rejoined the northern range herd. This elk is an excellent example of how cow elk occasionally change herds and migration patterns. Such herd-switching behavior may enable greater resiliency to continuously changing environmental and anthropogenic conditions, and is an important factor in genetic health and elk resiliency at a large scale.

Cougar Research and Monitoring

This program aims to understand cougar population dynamics, predation patterns, and multi-species interactions across northern Yellowstone. This is where the park's year-round, resident population of cougars live. Cougars move

Harmony of the Howl: Unveiling the Secrets of Wolf Communication through Bioacoustic Research and Artificial Intelligence Integration

By: Dan Stahler

The iconic sound of a wolf pack's chorus howl reverberating across the Yellowstone landscape is as impactful as seeing the wolves themselves. Tuned over millennia, this fundamental aspect of wolf social behavior is a key aspect to their communication, whether among individuals of the same pack, or across territorial boundaries to their neighbors. After decades of research conducted around the world, the generalized consensus is that howling functions as a means of social bonding, mate finding, territorial advertisement, and as an expression of emotions. For those of us that have spent time in Yellowstone observing wolves and experiencing their songs, all of these purposes resonate.

Pioneering wolf biologists John and Mary Theberge have spent hours observing and recording wolf howling in Yellowstone and described seasonal shifts in the patterns of intra- and inter-pack vocalizations (e.g. peaking during the pre-breeding and breeding season periods; McIntyre et al. 2017). From these data, they also described a high degree of flexibility in vocalizations, influenced by various triggers and resulting in consequences that align with communication theory principles (Theberge and Theberge 2022). Additionally, biologists Vicente Palacios and Bárbara Martí-Domken compared howling rates during the pup-rearing season across North America (including Yellowstone), Asia, and Europe (Palacios et al. 2023). They demonstrated that frequency of howling depended on location, pack size, and density of human settlements, being less where more people live, perhaps in response to perceived risks of living near humans. An exception was high howling rates in Yellowstone National Park – a place where wildlife are protected, few people live, but many hundreds of thousands of visitors are present throughout the summer. Another study led by Arik Kershenbaum used the differences in the time of arrival of howl vocalizations (recorded by multiple GPS-sychronized audio recorders) to accurately locate wolves in YNP. This study found that the location of a vocalizing animal can, under some circumstances, be determined to within an error of approximately 20 yards and at ranges over four miles. All of these innovative studies leveraged the natural scientific laboratory to which the YNP wolf population belongs.

The Yellowstone Wolf Project has been observing wolves for many years. The use of radiocollars to monitor the population, coupled with the power of routine visual behavioral observations, has allowed us to gather much knowledge. Now we are beginning to listen, to allow the wolves to tell us their story. Starting in 2023, we initiated new research that uses bioacoustics monitoring tools and methodology to study Yellowstone's wolves by listening to their voices. In collaboration with Grizzly Systems Inc, and other partners, we have deployed autonomous

Jeff Reed of Grizzly Systems Inc (left) and Jeremy SunderRaj attach one of the autonomous recording units to a tree. This unit will collect audio data for at least 30 days, 24 hours each day and provide valuable information on all vocal wildlife species and human-generated noise in Yellowstone's northern landscapes. NPS Photo/ T. Rabe

Wolf packs use howling as a means of communication both between and within packs. Often, a few howls by one wolf will trigger other wolves to join in, eventually leading to a chorus and a social greeting with pack mates. This often includes wagging tails, licking faces, and submission or dominance postures to reinforce social hierarchies and bonds. NPS Photo/ D. Stahler

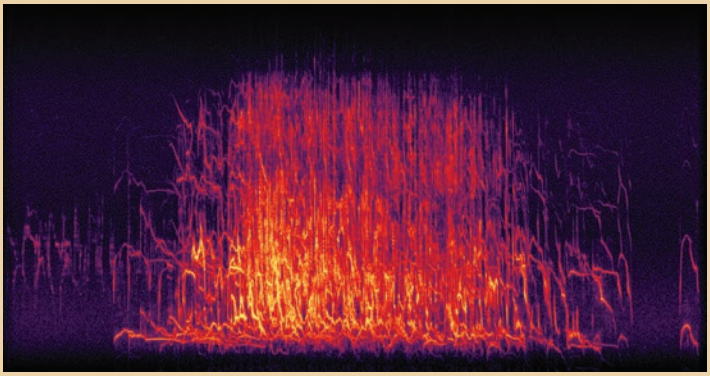
recording units (ARUs) in efforts to monitor presence and distribution of wolves across the park. Accurate population and occupancy estimates play a vital role in the Yellowstone Wolf Project's objectives. Because wolf vocalizations carry for relatively long distances, the use of ARU's can enhance existing census efforts that largely involve monitoring radio-collared wolves and the packs to which they belong. As we move forward in our long-term efforts to monitor wolves, we seek to incorporate ever-advancing technologies and methods that are viable alternatives to radio collars.

While bioacoustic monitoring for wildlife is not a novel concept, the advent of advanced artificial intelligence (AI) algorithms has opened new possibilities to reduce costs and enhance researcher productivity in monitoring. Through the utilization of advanced AI algorithms, scientists can efficiently analyze enormous data sets to identify wolf vocalizations as well as track the presence of other species native to Yellowstone National Park. The Greater Yellowstone region holds immense potential as a prominent testing ground for bioacoustic research, offering a valuable addition to existing methods such as radio collaring, flight surveys, camera traps, and field surveys.

Our current objectives are to collect around-the-clock bioacoustic data from wolves and other wildlife in Yellowstone National Park that overlap with wolf pack territories. A general-purpose data collection protocol to create effective AI models for bioacoustics will be created for long-term data collection in Yellowstone. This protocol can be applied and used for multiple species research both inside Yellowstone and beyond. With the help of partners, we are creating an AI classifier pipeline to process large sets of ARU recordings, and classify wolf detections. This data is useful for wolf census, presence, movement and behavior studies (e.g. the function of certain wolf calls). AI will drastically reduce the time invested in finding wolf calls within long time-scale recordings and help cluster calls into common

features. These "features" can then be used to answer specific questions such as: how many wolves were present, were there any pups, which pack was it, where was the pack? Furthermore, we hope that AI will facilitate the identification of individual wolves or packs based on their unique vocal signatures, aiding in population monitoring without the need for direct visual observation.

Collectively, we plan to apply these innovative approaches to allow us to study the nuances of wolf communication, and gain insights into; wolf abundance and distribution, pack social dynamics, territoriality, and reproductive behavior. Validating the efficacy of this non-invasive method to monitor wolves in Yellowstone will enhance conservation efforts by providing valuable data on wolf populations, distribution, behavior, and ecological interactions. Beyond the data, experiencing the sounds that emanate throughout the natural world can inspire and connect us to nature in unique ways.



A spectogram is a visualization of an audio recording's frequency over time. This image of a chorus howl demonstrates the typical low frequency of the howls plus the chorus started by one wolf, then joined by a few others before the whole pack is involved. The chorus ends but a few wolves continue to let out individual howls for a short time. Spectogram/J. Reed

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Use this QR code to listen to the Rescue Creek pack chorus howl on a cold winter's day in late 2023. NPS Recording.

In combination with radio collars and direct observations, we hope to learn even more about wolf communication using autonomous recording units. Work developed in YNP may someday be used to achieve conservation and monitoring goals of different species of wildlife around the world. NPS Photo/ D. Stahler

in and out of the interior of the park seasonally when their primary prey, deer and elk, migrate back for the spring, summer, and fall months. Otherwise, they are largely absent from the park's interior during winter. The primary goals are to (1) refine existing and implement new survey methods for studying cougars (e.g. noninvasive genetic surveys, remote camera trap surveys, GPS collaring) to estimate cougar abundance, distribution, and population change over time, (2) evaluate cougar predation patterns to more adequately address the role of multiple carnivores' impacts on ungulate population dynamics, (3) evaluate multi-species interactions to study how cougars compete with wolves and bears, and how prey respond to predation risk, and (4) generate data analyses, peer-reviewed science and popular writings that feed into public outreach and education about the role of cougars in Yellowstone. Cougars were first monitored in YNP in 1987 and continued to be monitored until 2006 by non-NPS entities (Hornocker Wildlife Institute and Wildlife Conservation Society). Today, this NPS-led program is in its 10th year. Together with the efforts of the Wolf Project, we increased understanding of the role of top predators in Yellowstone National Park.

A noninvasive genetic survey conducted from 2014-2017 estimated between 34-42 cougars (of all age and sex classes) resided in the northern range of YNP. This indicates a stable population similar to population estimates near the end of 2006. Today, the Cougar Project uses a remote camera survey grid established in the winter of 2020-2021 to estimate population trends, leveraging data from both GPS-collared and unmarked individuals that trigger cameras. While data analyses are still underway, preliminary estimates suggest similar abundances to the 2014–2017 monitoring period, and that YNP's cougar population remains stable.

Adult male cougar M229 triggers a remote camera a week after he was successfully captured and GPS-collared. M229 was a territorial male in northern Yellowstone in 2023. Photo/Kyle Dudgeon

A primary objective of the Yellowstone Cougar Project is to understand the cougar's role as a top predator in the ecosystem. Given that Yellowstone is home to multiple carnivore and ungulate species that interact in complex ways, understanding the dietary habits of cougars is critical for evaluating their role in the ecosystem relative to wolves, bears, and even humans hunting just outside park boundaries. Since 2016, we have investigated and collected samples from over 550 cougar kills found largely through GPS cluster searches, similar to the previously mentioned methods used to study wolves. These samples have yielded a robust data set to compare with predation patterns from earlier phases of cougar research in northern Yellowstone (312 cougar kills from 1987-1994; 465 cougar kills from 1998-2006). Typically, we can determine a cougar killed the prey animal from evidence from tracks, disturbed ground and vegetation from the attack, a drag trail, caching behavior (wolves don't cache, but bears do), presence of cougar scat buried in latrines near the kill site, and bedsites with cougar hair in them. Determining whether a cougar has also been kicked off from their kill by wolves or a bear is also important information. Such displacement can influence the frequency at which cougars kill and how much food they lose from their kills. While earlier phases of monitoring (1987-1994; 1998-2006) found cougars killing predominantly elk, since 2016, we've observed an increased presence of deer in cougar diet. This increase likely reflects changes in elk abundance over time and demonstrates the importance of monitoring predation patterns in a multi-carnivore, multi-prey system.

At the beginning of 2023, three cougars in YNP wore radio-collars. All were older females in northern YNP that had multiple litters of kittens throughout their lives. Two more collars were deployed in February, one on a 3.5 year old male numbered M229 and one on a 1.5 year old female numbered F230. Cougar F230 dispersed from YNP in the spring but was still alive in the Greater Yellowstone Ecosystem by the end of the year. Staff recorded one cougar mortality in 2023 when F222 died at 11 years old of an unknown natural cause. She tested negative for HPAIV (Highly Pathogenic Avian Influenza Virus), which was recently documented as a source of mortality for some cougars in the Rocky Mountains. By the end of 2023, three cougars wore GPS collars in northern YNP: two females and one male.

Mid-morning on September 2nd, cougar F223 ran across the road near Floating Island Lake and was struck by a vehicle. The driver did not stop but a witness in a different vehicle saw F223 run off the road and lie down, in distress and seemingly injured. The witness called park staff and over the next 48 hours we searched for F223 and monitored her radio signal to determine the extent of her injuries. During that time staff witnessed both of F223's three month-old kittens nearby and, while we did not see F223 directly, movements from her radio collar signal indicated she was still mobile. We continued to monitor her signals and within a week she had travelled at least five kilometers (three miles). Eventually we observed F223 making kills and traveling with both of her kittens. Whatever injuries she sustained, F223 made a full recovery.

During the Nov-Dec predation session, we followed and searched clusters for adult female F210. We documented her killing four ungulates (one adult bighorn sheep ram, one adult mule deer buck, one mule deer yearling, and one deer of unknown species and age). We also documented her scavenging on one adult cow elk that had been killed by another cougar (M229). We began the Nov-Dec predation session following and searching clusters for adult male M229 but stopped part-way through due to the logistical challenges of following his far-ranging movements. We did not document M229 feeding on any carcasses before transitioning away from searching his clusters.

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Seasonal Technician Hours

Name	Hours
Megan Petersohn	720
Gordy Scott	660
Hannah Beroske	360
Jackson Connors	360
JJ Daniell	360
Kyle Dudgeon	360
Nicole Mittman	360
Jake Owens	360
Lauren Swett	360
Matthew Zavaleta	360
Dani Freund	300
Louis Kreemer	300
Aubrey LaBarre	300
Agapito Lopez	300
Colby Slezak	300
Ivy Smith	300
Erika Zimmermann	300
Oscar Dalling	18
Hilary Zaranek	16
TOTAL HOURS	6,394

Wolf Project staff Jeremy SunderRaj (left) draws blood from an anesthetized wolf from the 8-Mile Pack while Kira Cassidy (right) assists, and Erin Stahler (center) observes. Blood samples collected over the last 29 years during wolf capture have yielded many new insights about wolf ecology, behavior, and evolution. NPS Photo/D. Stahler

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Back cover photo: Members of the Willow Creek Pack travel across the winter landscape with Abiathar Peak looming in the backdrop. NPS Photo/D. Stahler

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*All photos are NPS unless noted.