



Yellowstone Wolf Project Annual Report

2021

Summary

At the end of December 2021 there were at least 97 wolves in eight packs (six breeding pairs) living primarily in Yellowstone National Park (YNP). This count marks a decrease of 21% from 2020 but is close to the previous decade's average end of the year count (2010-2019 average = 94.5). Pack size ranged from three to 21, averaging 12 members. Throughout YNP, at least 47 pups were produced, with an additional four litters that were born but died before they could be counted. Twenty-nine pups survived (62%) to the end of the year with 12 in northern YNP and 17 in the interior of the park. At the end of 2021, pups comprised 30% of the park population, lower than in 2019 and 2020 (44%), but similar to the last decade average of 34%.

The number of packs in YNP has been decreasing slowly since 2009 when YNP had approximately 16 packs, while the number of breeding pairs has changed little, and average pack size has increased. Small packs have always had difficulty persisting in YNP because of intraspecific competition. A small number of wide-ranging, large packs may prevent small groups of wolves from even trying to establish territories in the study area. Prey availability and vulnerability and seasonal movements, wolf hunting seasons in the states surrounding YNP, and radio-collar distribution may also play a role in the apparent drop in the number of packs primarily living in YNP.

Wolf-Prey Relationships

Project staff detected 134 kills that were definitely, probably, or possibly made by wolves in 2021: 82 elk (61.2%), 22 bison (16.4%), three coyotes (2.2%), three mule deer (2.2%), three wolves (2.2%), two deer of undetermined species (1.5%), two moose (1.5%), one beaver (0.7%), one cougar (0.7%), one muskrat (0.7%), one raven (0.7%), one striped skunk (0.7%), and 12 unidentifiable animals (9.0%; almost all are likely ungulates). The composition of wolf-killed elk was 26% calves, 1% yearlings, 33% adult females, 33% adult males, 2% adults of unknown sex, and 5% of unknown sex and age. The composition of wolf-killed bison was 18% calves, 9% yearlings, 46% adult females, 4% adult males, 9% adults of unknown sex, and 14% of unknown sex and age.

Wolf predation was monitored intensively for two months of the year—one month in late winter (March) and one month in early winter (mid-November to mid-December). The summer predation study period (normally May through July) was not conducted in 2021.

Winter Studies

In accordance with CDC and YNP guidelines winter study crews were reduced, and extra precautions were taken to prevent the spread of SARS-CoV-2 during each study period. During the 30-day March 2021 late winter study period, three teams (air, ground, and GPS cluster-search crew) discovered 47 ungulate carcasses fed on by wolves. The air crew tracked all packs in YNP while the ground crew focused on the Junction Butte pack and opportunistically collected information on other packs in northern YNP. The GPS cluster-search crew investigated 141 GPS clusters (locations a GPS-collared animal spent at least one hour) for the Junction Butte pack and two mountain lions and hiked or skied 375 kilometers (233 miles). Thirty-eight (81%) of the ungulates were killed by wolves, including 26 elk, five bison, two deer of undetermined species, two moose, two ungulates

of undetermined species, and one mule deer. Of the elk, four were calves (15%), five were adult females (19%), and 17 were adult males (65%). The wolves also scavenged on eight bison and one bull elk they did not kill.

During the November-December 2021 early winter study period, the three teams discovered 37 ungulate carcasses fed on by wolves. The air crew tracked all packs in YNP, and the ground crew focused on Junction Butte. This month the GPS cluster-search crew searched 243 GPS clusters for the Rescue Creek pack and two mountain lions and hiked over 612 kilometers (380 miles). Thirty-two (86%) of these ungulates were killed by wolves, which included 28 elk (88%), two mule deer (6%), and two ungulates of undetermined species (6%). Of the elk, 14 were calves (50%), nine were adult females (32%), and four were adult males (14%). The wolves also scavenged on three bison and two undetermined ungulates they did not kill.

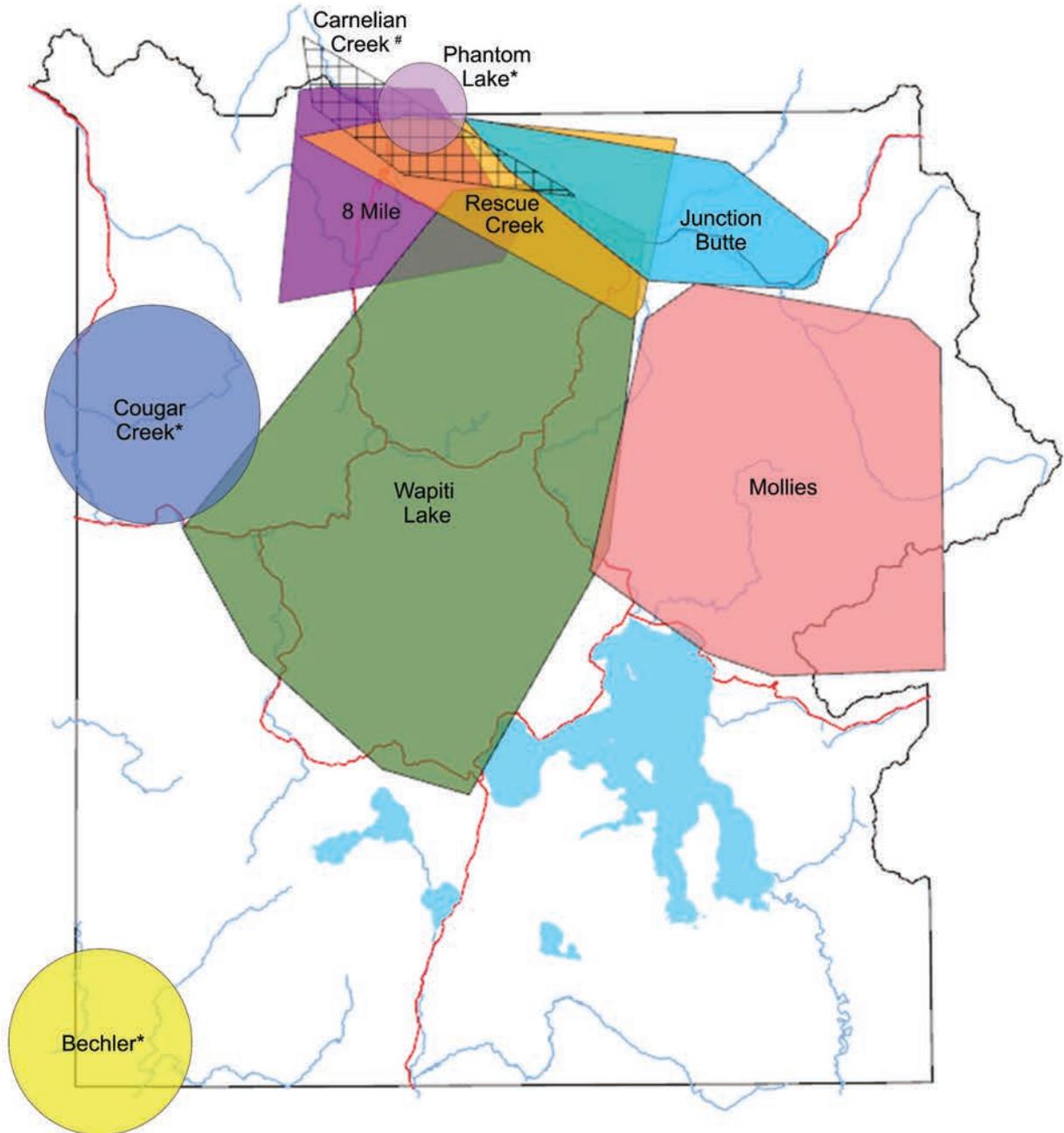
Dr. Matt Metz completed his PhD in December 2021 at the University of Montana with Dr. Mark Hebblewhite. Much of Matt's PhD focused on the information collected during the 53 winter studies starting in 1995. See inset for highlights.

Mortality

Nine radio-collared wolves died in 2021. Three died during inter-pack conflicts between the new Rescue Creek pack (1047M and 1274M) and the long-term 8 Mile pack (1269F). As the Rescue Creek pack has tried to establish a territory, they have used many areas the 8 Mile pack also uses, leading to aggressive inter-pack encounters. Cougar Creek disperser 1199F died of unknown natural causes in the spring and 1005F died of unknown causes in mid-summer. Three radio-collared wolves were harvested during the wolf hunting seasons in the states surrounding YNP: 1155M (in a pair) in Montana, 1109F (a loner) in Wyoming, and 1238M (from Mollie's pack) in Wyoming. One collared wolf was killed illegally: 1266M of the Wapiti Lake pack was shot with

2021 Yellowstone Wolf Pack Territories

(95% minimum convex polygons of aerial locations)



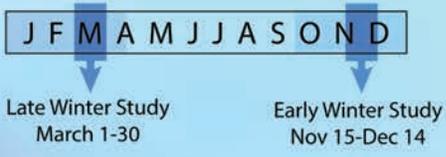
* No radio collars present, unable to estimate territory size.

Pack not present at end of the year.

Winter Study: the heart of wolf predation research in Yellowstone National Park

Study purpose:
To estimate prey composition, wolf kill rates, and biomass acquisition rates in order to learn about wolf-prey dynamics

Study design:
Monitor wolf packs for 30-day periods in early and late winter using three different methods: aerial observation, GPS collar cluster searches, and ground observation



All three detection methods have advantages and disadvantages

For more information about Winter Studies check out the dissertation and publications from Dr. Matt Metz.

Matt started working in Yellowstone in 2002, and even monitored the Leopold Pack for 10 winter studies. Matt helped develop many of the winter study research questions and the results shown here are just a small selection from his dissertation.

In December 2021, Matt completed his PhD at the University of Montana with Dr. Mark Hebblewhite. Congratulations, Matt!

Since 1995, flight crews track most packs in YNP (2 to 14 packs per study)
Average 14.7 flights per study

- tracks all radio-collared pack members
- best at detecting medium and large carcasses
- weather cancels flights
- only a few minute snapshot of the pack's day

Since 2009, cluster crews follow 1 to 3 wolves, from 1-2 packs, per study

- constant effort, 24 hours per day
- best at detecting medium and large carcasses
- detection depends on GPS-collared wolf presence
- misses carcasses where wolves spend less than 1 hour

Since 1995, ground crews follow 1 to 3 packs per study
Average 20.1 days in view per pack per study

- constant effort during daylight hours
- finds carcasses near the road and within the road's viewshed
- misses carcasses out of view
- misses carcasses when pack is split

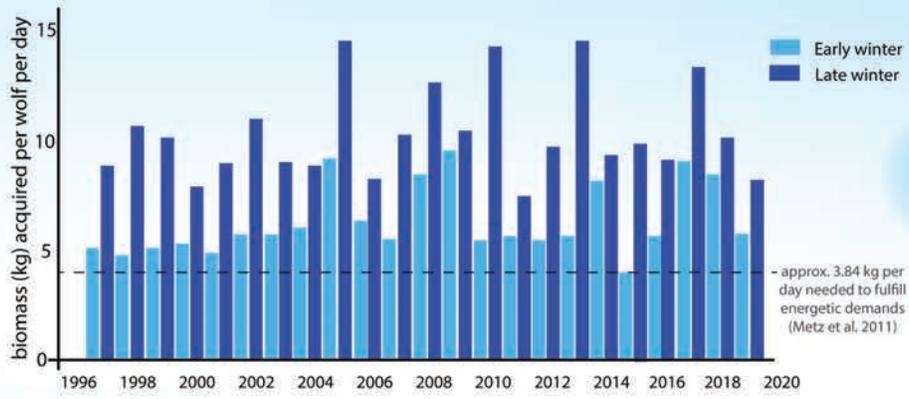
By using three detection methods, we can estimate how many carcasses were also missed for each pack.

How much estimates increase from detected carcasses is driven by which methods were used for that pack.



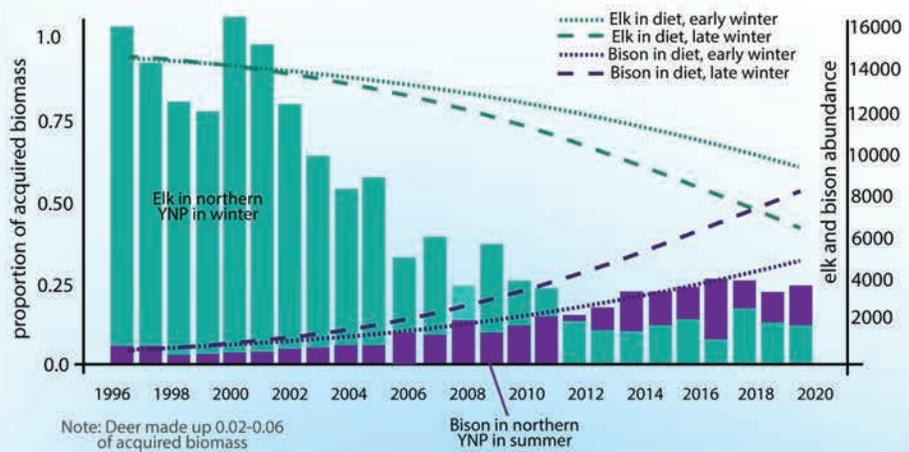
How much food do wolves acquire each day?

Late winter always has higher rates of biomass acquired than the preceding early winter.

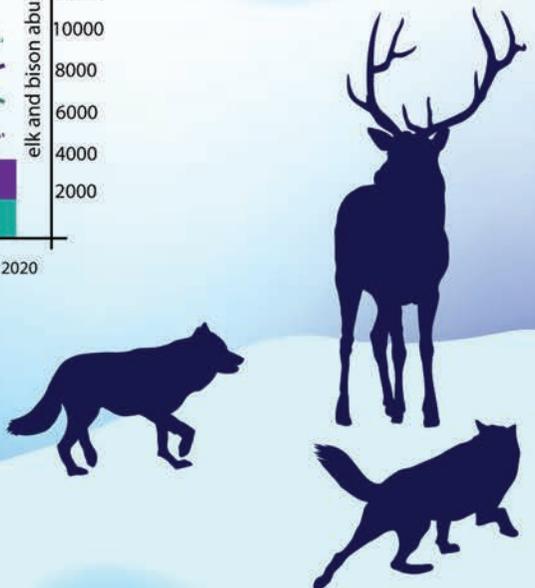


Biomass is acquired from kills and scavenged carcasses. Some of each carcass is lost to scavengers such as ravens, coyotes, eagles, and bears.

Has wolf diet changed over time?

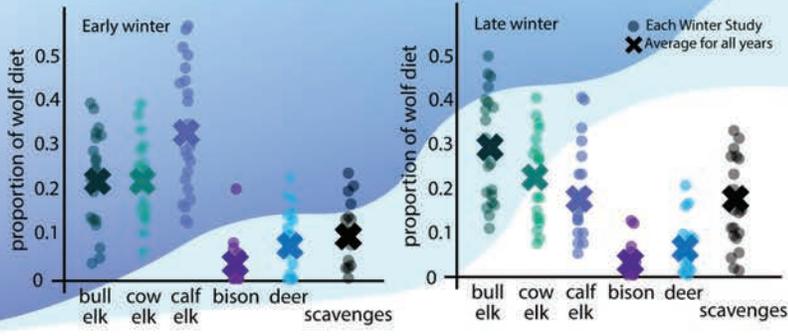


What began as a wolf-elk system has shifted to a wolf-elk-bison system. Bison are often acquired through scavenging.



Is the breakdown of prey different between early and late winter?

Note: proportion is out of the total number of prey animals wolves fed on



Calf elk and bull elk flip in their importance to wolf diet from early to late winter.

Scavenging is more common in late winter, when prey sometimes die of malnutrition and when bison carcasses emerge from melting ice.

The past suggests the future will bring some unpredictable findings. Future work will continue to evaluate how wolves are affected by elk and bison population changes and vice versa. In addition, other predators and factors such as chronic wasting disease and transboundary management of all relevant species may also affect wolf-prey dynamics. We look forward to continuing this work.



graphic by Kira A Cassidy

birdshot along the highway outside of Grand Teton National Park when the pack made an extra-territorial foray south. His death counted towards the Wyoming wolf hunting quota in the area.

In addition to the collared wolf mortalities, we recorded 16 deaths of uncollared wolves, all from being hunted outside of the YNP boundary (see Wolf Hunting Near YNP section below for information about the state wolf hunting seasons). Six Junction Butte wolves were harvested in two events (three wolves in mid-September in Wolf Management Unit 316 and another three in mid-December in Wolf Management Unit 313). At least seven members of the Phantom Lake pack were harvested in Montana Wolf Management Unit 313, as well as one wolf from the Rescue Creek pack. Two uncollared wolves from the Bechler pack were harvested in Idaho.

Disease

In early 2021, some members of the Junction Butte pack showed signs of mild to moderate mange infection. Mange is a mite which burrows into the skin and causes major itching and discomfort. Infected animals scratch and bite and often lose fur, sometimes in large patches. Infection seems to be correlated with overall health and may have been an indication that some of the youngest members of the Junction Butte pack (over 30 wolves) were experiencing food stress. This may have also led to the dispersal of many of the male pups (at 10 months old) to join their older brothers in forming the Rescue Creek pack. Instead of one large pack trying to find enough food, the pack essentially split into two with the main pack of about 22 and the new pack with about 10 members. Every wolf that showed signs of mange in early 2021 seemed to be recovered by summer.

Two of the four denning females from Junction Butte localized around separate dens but stopped attending their dens after one week (uncollared alpha female) and three weeks (1276F). We believe both gave birth to litters but lost their pups to unknown causes. Wolf 1154F of the Rescue Creek pack also denned but three weeks later her pups died. Scat samples indicated the pups were infected with cryptosporidium (a parasite found in water and soil that causes diarrhea); however, canines rarely die of cryptosporidiosis alone and it may have been a sign of a coinfection with an undetected bacteria or virus. Conversely, the pups may have been killed by other wolves as both the 8 Mile and Wapiti Lake packs travelled very close to the Rescue Creek pack den in early May. All other packs had normal pup production and survival and there was no indication of a widespread disease outbreak this year.

Reproduction

Prior to the 2021 pups being born, there were 110 adult wolves alive in April, the beginning of the wolf biological year. At least 47 pups were born to seven different packs. Three packs produced multiple litters this year: 8 Mile (at least 8 pups from two litters), Junction Butte (at least nine pups from two litters and two litters of unknown size), and Wapiti Lake (at least 10 pups from two litters). The Phantom Lake, Mollies, Cougar Creek, and Bechler packs had one litter each. Both the Rescue Creek and Carnelian Creek packs denned but the pups died before we could get any counts. Of the minimum 47 pups produced in all packs, 29 (62%) survived to the end of the year.

Wolf Capture

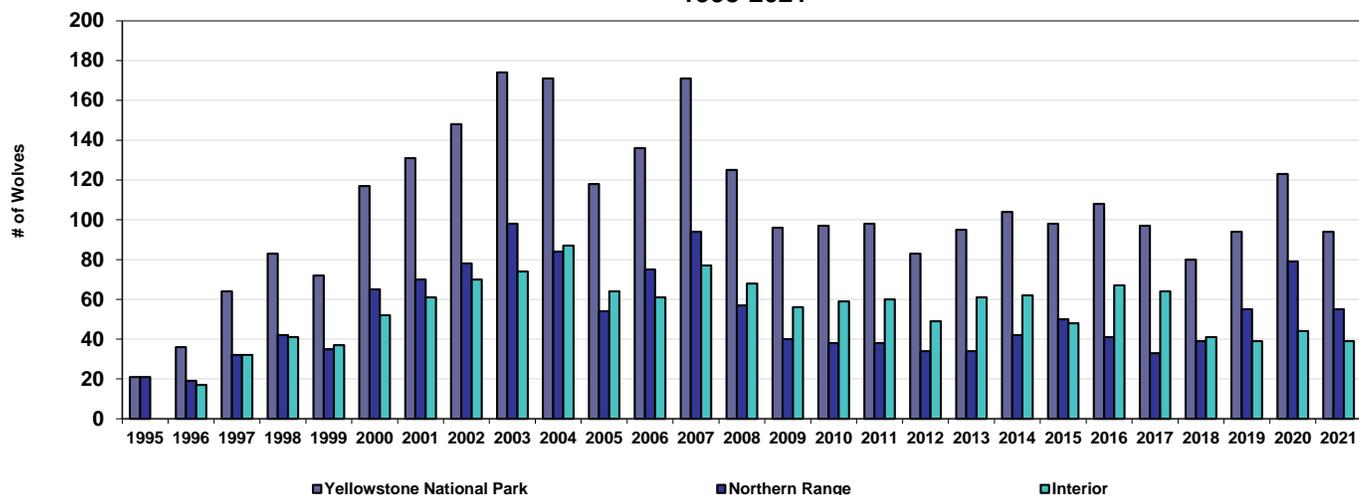
Seven wolves in two packs were captured and collared in 2021. New collars were deployed on two pups, three yearlings, and two adults. The sex ratio of captured wolves was split between males (3) and females (4). In addition to fitting the radio collar, staff took blood samples for genetic and hormone analysis, serum samples for disease screening, a whisker for isotopic 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. Three of the collars were Vectronic GPS (Global Positioning System) which can be programmed remotely and are used to achieve major studies on space-use, prey selection, and biomass consumption during specific seasons by sending updates several times per week. The other four collars were VHF (Very High Frequency) which are affordable, reliable, and have a long-lasting battery. These collars are the basis of the monitoring and tracking of wolves from the ground or the plane to determine pack size, composition, reproduction, etc.

Wolf Management

Wolf management in YNP included temporary closures around the Junction Butte and Wapiti Lake den areas to protect the young pups from disturbance and allow the adult wolves to travel to and from the den unimpeded. For the second year in a row the Junction Butte pack was visible nearly every day of the summer and most of the fall, using Slough Creek and Lamar Valley to raise their pups. By early summer, the Wapiti Lake pack moved their pups deeper into the backcountry and the original closure was lifted.

Several wolves exhibited habituated behavior and were aversively conditioned. Other wolves that had been habituated in previous years did not cause any management

Yellowstone National Park Wolf Population 1995-2021



| Yellowstone Wolf Population Estimate as of 12/31/2021 | Adults | Pups | Total |
|---|-----------|-----------|-----------|
| Northern Range | | | |
| <u>8 Mile</u> | 16 | 5 | 21 |
| Phantom Lake (no working collars) | 2 | 1 | 3 |
| Rescue Creek | 13 | | 13 |
| <u>Junction Butte</u> | 11 | 6 | 17 |
| Carnelian Creek | 0 | | 0 |
| Other (1198F) | 1 | | 1 |
| Northern Range Totals | 43 | 12 | 55 |
| Non-Northern Range | | | |
| <u>Bechler</u> (no collars) | 2 | 2 | 4 |
| Cougar Creek (no collars) | 5 | 5 | 10 |
| <u>Mollie's</u> | 5 | 2 | 7 |
| <u>Wapiti</u> | 13 | 8 | 21 |
| Non-Northern Range Totals | 25 | 17 | 42 |
| YNP Total | 68 | 29 | 97 |



For several weeks in the fall a grizzly bear shadowed the Junction Butte pack. As the wolves hunted, the bear chased elk along with them and when the wolves caught a cow elk the bear took it over and fed on it immediately. Other times, the pack was seen socializing with each other in their rendezvous site, walking within a few meters of the bear but mostly ignoring it. NPS Photo: K. Cassidy

Wolf Hunting near Yellowstone National Park

September 1, 2021 to February 17, 2022

Since 1997, the Yellowstone Wolf Project reports have been organized by the calendar year. Given recent changes to wolf hunting seasons around YNP we felt it important to report data from the full hunting season. This page reports information from the 2021-2022 wolf hunting seasons outside of Yellowstone National Park (September 1, 2021 to February 17, 2022). The rest of this annual report focuses on January 1, 2021 to December 31, 2021 only.

At least 25 wolves were confirmed harvested during the 2021-2022 wolf hunting season from packs that primarily use YNP: 19 in Montana, four in Wyoming, and two in Idaho.

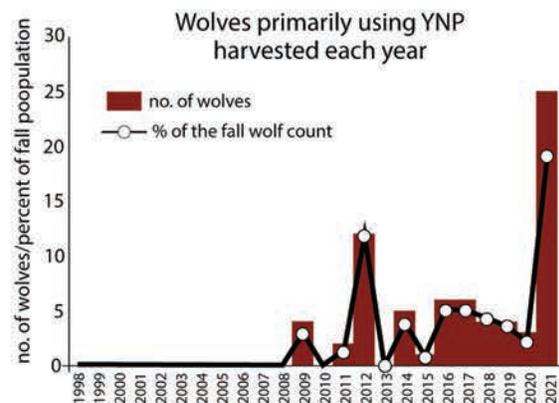
Since 2009 (with the exception of 2010) wolves have been

hunted in at least one of the three states surrounding YNP. In 2020 and 2021 Idaho and Montana adopted more aggressive wolf hunting regulations including the removal of two wolf hunting unit quotas along the northern boundary of YNP. The Wyoming hunting season ended December 31, 2021 and the area around YNP in Montana (Region 3) closed February 17, 2022. Wolf hunting in Idaho continues as of this publication.

In previous years (2009-2020), an average of 4.3 wolves that primarily use YNP were harvested each year. The 2021-2022 season, with 25 wolves, saw a 481% increase. There were 131 wolves in YNP during the 2021 pre-hunting season fall wolf count and 19.1% were harvested. Average for prior hunting seasons (2009-2020) was 3.7%.

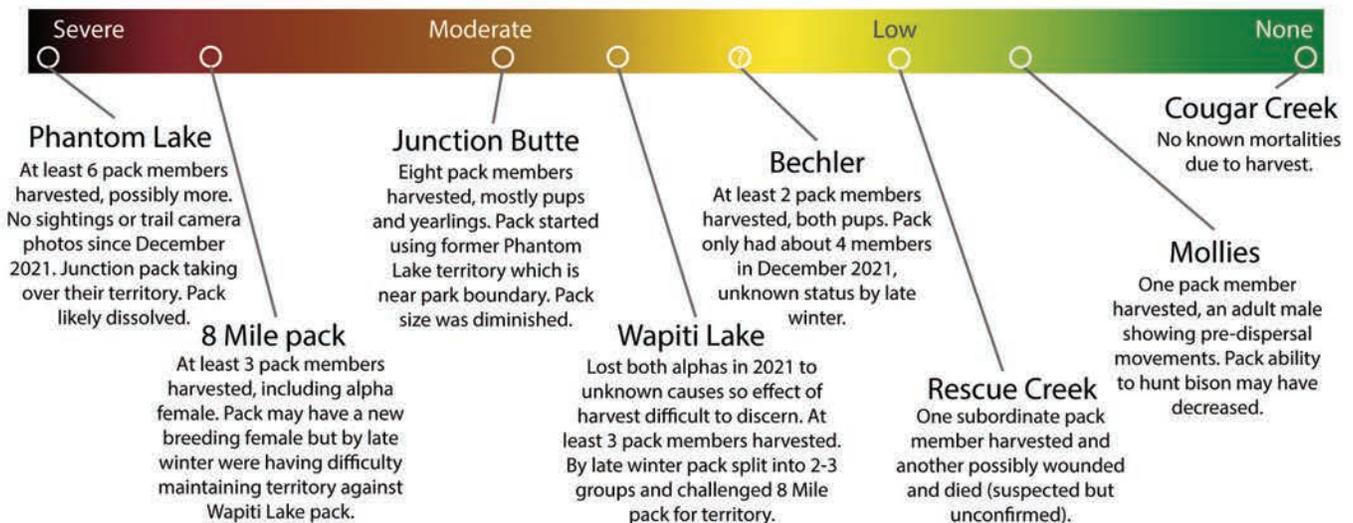
25 confirmed harvests
(from packs that primarily use Yellowstone National Park)

| | | |
|------------------------|------------------------------------|---------------------|
| 19 harvests in Montana | 3 harvests & 1 poaching in Wyoming | 2 harvests in Idaho |
|------------------------|------------------------------------|---------------------|



The effects of hunting on wolves can occur at several different scales. In other study areas human offtake levels above ~29% begin to affect wolf population growth rates (Adams et al. 2008) and in other areas hunting reduces pup survival (Ausband et al. 2015) and pack size (Sells et al. 2022). Pack size is critical for wolves to effectively hunt large prey, raise pups, defend territory, compete with scavengers, and recover from disease (Smith et al. 2020). We continue to study the effects of offtake on pack size and composition, as well as individual and pack-level metrics such as pack persistence and reproduction.

Below we estimate the effects of the hunting season on each pack based on the status of the harvested pack members, the proportion of the pack harvested, and the pack's relative impacts compared to neighboring packs (affecting inter-pack competition).

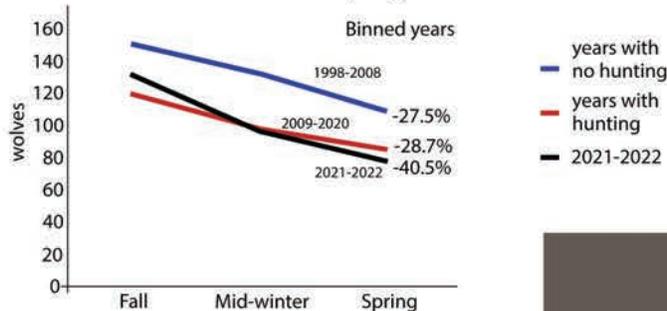


Confirmed harvested wolves from packs primarily using YNP, from 9/15/2021 to 2/18/2022

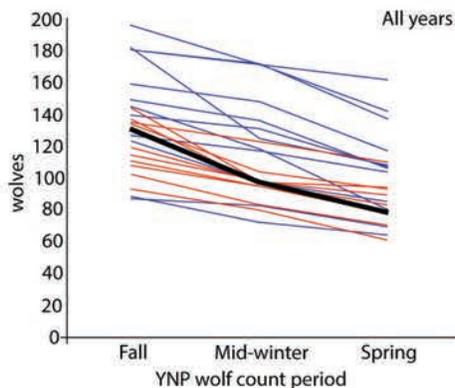
| | Date of Death | collar status/# | color | sex | age | pack | state and hunt unit |
|------|------------------|-----------------|--------|---------|---------|----------------|---------------------|
| 1. | 9/17/2021 | uncollared | gray | female | 0.4 | Junction Butte | MT WMU 316 |
| 2. | 9/17/2021 | uncollared | black | female | 0.4 | Junction Butte | MT WMU 316 |
| 3. | 9/17/2021 | uncollared | black | female | 1.4 | Junction Butte | MT WMU 316 |
| 4. | 10/10/2021 | uncollared | gray | female | unknown | Phantom Lake | MT WMU 313 |
| 5. | 10/10/2021 | uncollared | gray | male | unknown | Phantom Lake | MT WMU 313 |
| 6. | 10/10/2021 (est) | uncollared | gray | unknown | 0.5 | Bechler | ID WMU 62 |
| 7. | 10/10/2021 (est) | uncollared | gray | unknown | 0.5 | Bechler | ID WMU 62 |
| 8. | 10/28/2021 | 1109F | black | female | 6.5 | Lone wolf | WY WMU 1 |
| 9. | 10/29/2021 | uncollared | gray | female | unknown | Phantom Lake | MT WMU 313 |
| 10. | 11/16/2021 | uncollared | gray | unknown | unknown | Wapiti Lake | WY WMU 6 |
| *11. | 11/18/2021 | 1266M | black | male | 1.6 | Wapiti Lake | WY WMU 6 |
| 12. | 11/19/2021 | uncollared | gray | female | unknown | Phantom Lake | MT WMU 313 |
| 13. | 12/1/2021 | uncollared | black | female | adult | Junction Butte | MT WMU 313 |
| 14. | 12/4/2021 | uncollared | black | male | 1.6 | Rescue Creek | MT WMU 313 |
| 15. | 12/9/2021 | 1238M | black | male | 2.6 | Mollie's | WY WMU 1 |
| 16. | 12/10/2021 | uncollared | gray | male | 1.6 | Junction Butte | MT WMU 313 |
| 17. | 12/10/2021 | uncollared | black | male | 1.6 | Junction Butte | MT WMU 313 |
| 18. | 12/10/2021 | uncollared | gray | female | 0.6 | Junction Butte | MT WMU 313 |
| 19. | 12/13/2021 | uncollared | gray | male | unknown | Phantom Lake | MT WMU 313 |
| 20. | 12/13/2021 | uncollared | gray | female | unknown | Phantom Lake | MT WMU 313 |
| 21. | 1/1/2022 | 1234M | black | male | 3.7 | Wapiti Lake | MT WMU 313 |
| 22. | 1/20/2022 | uncollared | gray | male | 0.7 | 8 Mile | MT WMU 313 |
| 23. | 1/20/2022 | uncollared | silver | female | 7.7 | 8 Mile | MT WMU 313 |
| 24. | 1/26/2022 | uncollared | gray | male | 0.8 | Junction Butte | MT WMU 313 |
| 25. | 1/30/2022 | 1233M | black | male | 2.8 | 8 Mile | MT WMU 313 |

* Wolf 1266M was poached but counted toward the WY wolf quota

YNP wolf counts and percent decrease from fall to spring



Wolf abundance in YNP always decreases throughout the fall and winter through a combination of mortality (human and natural-caused) and dispersal. From 1998-2020 the wolf count decreased 28.2% from September 1 to April 1. This year, 2021-2022, wolf abundance decreased 40.5% over the same months.

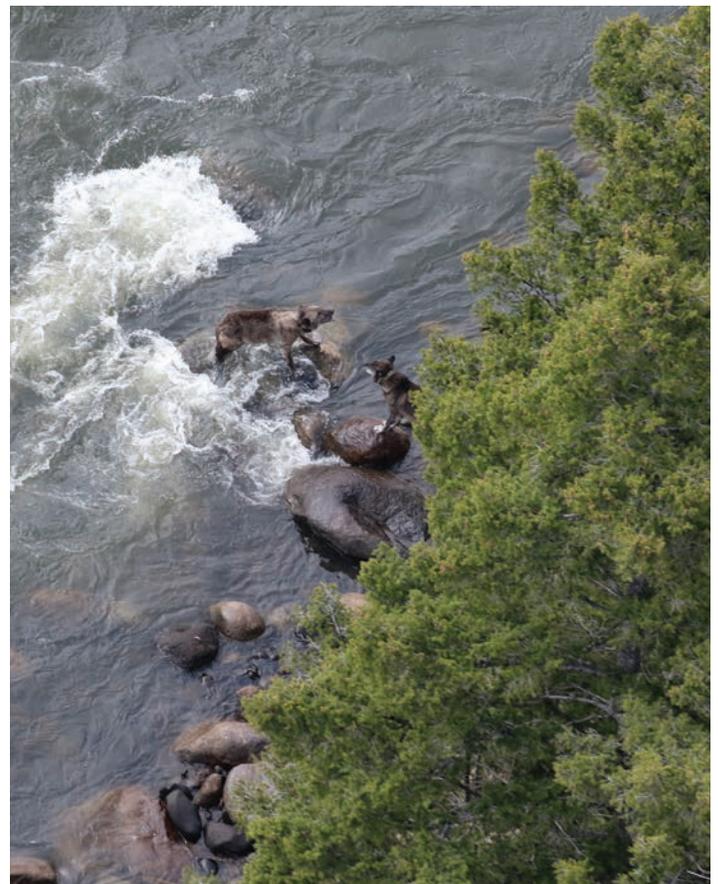


How do biologists determine to which pack a harvested wolf belongs?

YNP staff work with state biologists and game wardens to identify the pack for each wolf harvested near YNP. If the wolf is radio-collared the pack is known. If uncollared, the harvest location narrows down the pack identity to one to three packs. We determine the location of each pack either several times per month (aerial tracking), per week (ground tracking), and often every one to six hours (GPS collars) in order to collect pack composition data year-round.

The identity of the harvested wolf is matched up to the known pack composition of the pack in the area. We then track the pack post-harvest to confirm the reported wolf is no longer with the pack.

Adams, L.G. et al. 2008. Population dynamics and harvest characteristics of wolves in the central Brooks Range, Alaska. *Wildlife Monographs*, 170.
 Ausband, D.E. et al. 2015. Survival and recruitment of gray wolf pups before and after harvest. *Intermountain Journal of Sciences* 21.
 Sells, S.N. et al. 2022. Competition, prey, and mortalities influence gray wolf group size. *Journal of Wildlife Management* p.e22193.
 Smith, D.W. 2020. *Yellowstone Wolves: Science and Discovery in the World's First National Park*. U of Chicago Press.



The Rescue Creek pack encountered lone wolf 1109F (previously of the Junction Butte pack) near the Yellowstone River. Fights between wolf packs or between a pack and an intruder are often deadly and account for over 50% of wolf mortality in Yellowstone. To escape the Rescue Creek pack, 1109F ran into the river and turned back to face her attackers. Positioned at the top of the rapids, she snarled and refused to move. The Rescue Creek wolves eventually left and 1109F escaped. NPS Photo: J. SunderRaj

2021 Yellowstone National Park Wolf Mortality

| Wolf #/Sex | Date of Death | Age | Pack | Cause of Death |
|------------|---------------|-----------|-------------------|-----------------|
| 1155M | 2/15/2021 | Old Adult | 1154F/1155M group | Harvest (MT) |
| 1047M | 3/18/2021 | Old Adult | Rescue Creek | Intraspecific |
| 1199F | 4/15/2021 | Adult | Loner | Natural Unknown |
| 1269F | 4/29/2021 | Yearling | 8 Mile | Intraspecific |
| 1005F | 7/19/2021 | Old Adult | Carnelian Creek | Unknown |
| uncollared | 9/17/2021 | Pup | Junction Butte | Harvest (MT) |
| uncollared | 9/17/2021 | Pup | Junction Butte | Harvest (MT) |
| uncollared | 9/17/2021 | Yearling | Junction Butte | Harvest (MT) |
| uncollared | 10/10/2021 | Pup | Bechler | Harvest (ID) |
| uncollared | 10/10/2021 | Pup | Bechler | Harvest (ID) |
| uncollared | 10/10/2021 | Unknown | Phantom Lake | Harvest (MT) |
| uncollared | 10/10/2021 | Unknown | Phantom Lake | Harvest (MT) |
| 1109F | 10/28/2021 | Old Adult | Loner | Harvest (WY) |
| uncollared | 10/30/2021 | Unknown | Phantom Lake | Harvest (MT) |
| 1274M | 11/15/2021 | Yearling | Rescue Creek | Harvest (MT) |
| 1266M | 11/18/2021 | Yearling | Wapiti Lake | Illegal |
| uncollared | 11/19/2021 | Unknown | Phantom Lake | Harvest (MT) |
| uncollared | 12/1/2021 | Unknown | Phantom Lake | Harvest (MT) |
| uncollared | 12/4/2021 | Yearling | Rescue Creek | Harvest (MT) |
| 1238M | 12/9/2021 | Adult | Mollie's | Harvest (WY) |
| uncollared | 12/10/2021 | Yearling | Junction Butte | Harvest (MT) |
| uncollared | 12/10/2021 | Yearling | Junction Butte | Harvest (MT) |
| uncollared | 12/10/2021 | Yearling | Junction Butte | Harvest (MT) |
| uncollared | 12/13/2021 | Unknown | Phantom Lake | Harvest (MT) |
| uncollared | 12/13/2021 | Unknown | Phantom Lake | Harvest (MT) |

2021 Yellowstone National Park Wolf Collaring Activity

| Wolf #Sex | Date of Capture | Age | Color | Pack | Collar Type |
|-----------|-----------------|----------------|-------|-------------|-------------|
| 1325M | 12/10/2021 | Yearling | Gray | 8 Mile | GPS |
| 1326M | 12/10/2021 | Adult | Gray | 8 Mile | VHF |
| 1327F | 12/10/2021 | Yearling | Gray | 8 Mile | GPS |
| 1328F | 12/10/2021 | Yearling | Gray | 8 Mile | VHF |
| 1329M | 12/10/2021 | Yearling/Adult | Black | Wapiti Lake | GPS |
| 1330F | 12/10/2021 | Pup | Gray | Wapiti Lake | VHF |
| 1331F | 12/10/2021 | Pup | Gray | Wapiti Lake | VHF |

issues in 2021. One wolf, 1273M (born in the Junction Butte pack in 2019), was unafraid of vehicles and people and actively approached both when he was six to 12 months old. At six months old he grabbed a tripod abandoned near the road and when the visitor retrieved it, 1273M followed the person and was undeterred when the person swung the tripod at him. After intense aversive conditioning (including paintballs, cracker shells, and bear spray) over several weeks in spring 2020, 1273M changed behavior. He now avoids roads and humans.

Wolf Hunting Near YNP

Outside of the YNP boundary, Montana's wolf hunting regulations were changed to promote increased wolf harvests in 2021. This included removing the quotas from Wolf Management Units 313 and 316 along the northern boundary of YNP, which had been one wolf each in 2020. In addition, each individual wolf hunter could take 10 wolves by hunting and 10 wolves by trapping in one season (an increase from 5 total per person in 2019), could set out bait on public and private land, and could hunt at night on private land. As of December 31, these changes accounted for 14 additional wolves from YNP packs harvested than would have been allowed the previous season. Wyoming wolf regulations change slightly each year and include small units with adjustable quotas around YNP. Idaho wolf hunting regulations also changed with expanded seasons, but wolves from YNP packs, with the exception of the Bechler pack, rarely travel into Idaho.

Since hunting in the states surrounding YNP began in 2009, YNP staff have documented harvests of wolves living in packs monitored by YNP. Most packs spend >95% of their time within the park boundaries and occasionally travel onto National Forest Service lands. It is unknown if this will change as wolves are more intensively hunted outside of YNP, creating vacuums of good wolf habitat that other packs attempt to fill. In most years, we document between 0 and 6 wolves harvested from the YNP-monitored packs (exceptions were 2012 with 12 wolves and 2021). In 2021 we recorded 19 wolves harvested, a 342% increase from the previous decade's average of 4.3 wolves per year (2009 to 2020, not including 2010 when there was no hunting season). Prior to the state hunting seasons in fall 2021, there were an estimated 131 wolves in packs primarily using YNP, a 27% decrease from September 1 to December 31. Harvests account for approximately half of this decline and the rest (nearly all uncollared) likely died of natural causes, hunter wounding loss, or dispersed outside YNP. In recent years, the population has declined by an average of 12% over the same four months (2016-2020). This report is based on the

calendar year and does not include wolves harvested during the 2021-2022 state hunting seasons after December 31, 2021. YNP staff continue to monitor the impacts of harvests and other human-caused mortality on several key factors: wolf population growth rate, pack stability, reproduction, pack size, and wolf viewability.

Outreach

As SARS-CoV-2 remained a concern in 2021, public outreach usually took place over virtual platforms with some in-person outdoor gatherings. Wolf Project staff gave 105 formal talks, 50 interviews, presented one conference poster, and led 16 field trips. During the summer months staff helped educate at least 20,190 people while viewing wolves and gave 164 informal talks in the field. One of the interviews with Project Leader Doug Smith highlighted gray wolves for CBS Mornings. In addition, collaborating University of Montana PhD candidate Brenna Cassidy taught a 3-day course about wolves through Yellowstone Forever.

The book synthesizing the first 25 years of wolf research after reintroduction, *Yellowstone Wolves: Science and Discovery in the World's First National Park*, was released in the last few days of 2020 and by early 2021 was already in a second printing. At least 6,000 copies were sold by the end of 2021. The book was awarded the Wildlife Society's 2021 Wildlife Publication Award in the Edited Book category. It can be found at most book retailers and through Yellowstone Forever's gift stores online and in YNP.

Wolf Pack Summaries

8 Mile (21 wolves: 16 adults and 5 pups)

The 8 Mile pack continues to be led by an uncollared female, now 7.5 years old, recognizable by her silver-brown coloration. She is the second female to lead the pack since their formation in 2011. The male dominance hierarchy was unknown after the poaching loss of 1015M but by early 2021 leadership was clearly held by an uncollared gray male, likely from the Wapiti Lake pack. The pack produced two litters in 2021 but only one litter was seen by early summer. As all six pups were gray, it is unlikely the dominant female was their mother (since black-gray parents generally produce litters that are 50% gray and 50% black), but it is unknown if a gray female produced the entire litter or if the six pups were a combination of two litters and by chance no black pups survived the first few months of life. Over the summer two-year-old 1230M dispersed to join the Lower Gros Ventre pack in Grand Teton National Park and several other wolves died or dispersed. Overall survival and pack cohesion was very high. By the end of the year, five of the pups were still alive. Despite being one of the largest packs in YNP, the 8

Mile pack is not often seen and seem to be very wary of the road and humans.

Phantom Lake (estimated 3 wolves: 2 adults and 1 pup)

With no working radio-collars, we relied on reports of wolf sign in their traditional territory and a system of trail cameras to document this pack. Wolf 1106M (with a nonworking collar) led the pack with a new female and the pack produced at least one litter of pups. At least six gray pups and seven gray adults were observed on cameras in the early fall. The pack may spend a portion of their time along and outside the boundary of YNP, especially in the early winter months as they follow ungulates to lower elevations. At least seven wolves harvested in Montana Wolf Management Unit 313 were from the Phantom Lake pack. By the end of the year the only sightings were a trail camera video of 1106M alone. This pack could still have a few individuals alive, perhaps three, but we do not count them as a breeding pair.

Carnelian Creek (0 wolves)

By early 2021, Carnelian Creek had been pushed out of their territory near Tower Junction by larger packs and the pups from 2020 disappeared one by one. Lead female 1005F started to travel widely and was occasionally seen with one to two other wolves. In the spring, 1005F denned but in midsummer died of unknown causes. Over the years many new packs in YNP attempt to establish a territory

in the seam between larger packs, usually in the Tower Junction/Geode Creek area. Few packs have lasted longer than three years, possibly due to the area being so prey-rich that large packs take it over seasonally and force the smaller, establishing pack to relinquish the area or risk intraspecific death.

Rescue Creek (13 wolves: 13 adults)

This new pack formed in February 2021 when males from the Junction Butte pack met 1154F (born in the 8 Mile pack but had been a loner and with 1155M in 2020) and an uncollared female. Five adult males started the pack, including nearly seven-year-old 1047M, who joined the pack as a subordinate after losing his lead position in Junction several months earlier. They were joined by between four and nine Junction Butte pups (10 months old at the time), some which went back and forth between the new pack and their natal pack until the fall, when they were yearlings. Even though the pack localized at a den, the pack's new pups died around three weeks old, and the pack travelled as a cohesive unit most of the summer, making trips as far south as Pelican Valley. By fall, the pack membership had solidified and remained stable, despite losing one wolf in one of several fights with the 8 Mile pack and another just outside of the park boundary during the Montana wolf hunting season. This pack has established a territory but different parts of it overlap with the three largest packs in YNP: Wapiti Lake, 8 Mile and Junction Butte.



Visitors and biologists were able to watch pups from the Junction Butte pack from the time they were three weeks old until they were full grown. Here the pups explore Slough Creek for the first time. NPS Photo: T. Bland

Junction Butte (17 wolves: 11 adults and 6 pups)

Starting 2021 as the second largest pack ever recorded in YNP, the Junction Butte pack experienced some major changes this year. Five of the adult males dispersed during the breeding season to form the Rescue Creek pack and long-time pack member 996M disappeared around the same time. Approximately half of the 18 Junction Butte wolves born in 2020 stayed with the main pack (likely most were females) and the other half went back and forth to the new group (the males) through the summer. The pack produced four litters but two of them were lost early and one only had one pup survive to July. The fourth litter was produced by beta, and oldest pack member at 8.5 years old, 907F. The females who lost their own litters helped to raise 907F's litter of eight, even nursing them. The pack rarely left their Hellroaring to Lamar territory until fall, when the pack of 28 began to follow migrating ungulates. Three wolves (two female pups and one female yearling) were harvested in Montana Wolf Management Unit 316 in September. During October and November, three other pack members joined the Rescue Creek pack and two others disappeared, likely died or dispersed. In December, the pack again crossed the park boundary, and three more pack members were harvested (three yearlings). The pack ended the year with 17 members. Unlike late 2020, when the pack hunted bison more frequently than elk, this year the pack mostly switched back to elk; possibly due to their reduced pack size and far fewer adult males. The pack also has four wolves over the age of five, an extremely rare situation as only about one in every five wolves lives to reach five years old. The only other pack with multiple elders is the Mollie's pack, with two.

Mollie's (7 wolves: 5 adults and 2 pups)

The Mollie's pack started the year with eight adults and lead female 1090F produced a litter of four pups. Long-time lead male 890M, who joined the pack in 2016, disappeared and is presumed dead at 10.5 years old; the second oldest wolf in Yellowstone at the time. The last sighting of him was walking past a trail camera in August, looking frail and with an injured foot. The leadership position was taken up by 1237M, a male the pack adopted as a subordinate in late 2017. By the end of 2021 a young male was harvested in Wyoming and one other adult dispersed or died. Of the four pups produced, two of them survived to the end of the year.

Wapiti Lake (21 wolves: 13 adults and 8 pups)

The leading female of the Wapiti Lake pack disappeared this summer at 11 years old and is presumed dead after

leading the pack for seven years. After her death we guessed the leadership would fall to the oldest daughter and only female unrelated to alpha male 1014M; however, the pack seems to be going through a period of instability and may be splitting into two near the end of 2021. Many of the female adults (new alpha 1203F, 1235F, 1265F, the uncollared oldest gray, another uncollared gray, and an uncollared black) found a new alpha male. This group ranges from six to eight wolves. A younger female (1267F) and the pack's adult males (1014M [last seen in late November], 1234M, 1329M) usually stay with one or two gray adult females and the pack's eight pups. This group ranges from 10 to 15 wolves as some wolves go back and forth between groups. Both groups use the Wapiti Lake pack's traditional territory, and because of the daily shifting between groups, we are counting them as one pack for the end of the year.

Cougar Creek (10 wolves: 5 adults and 5 pups)

The last radio-collared wolf in the Cougar Creek pack dispersed in early 2021, but pilot Mark Packila was able to find the pack occasionally in March by snow-tracking. After the snow melted, we relied on chance sightings and trail camera images of this pack to determine pack size, composition, and reproduction. Five pups and at least three adults were counted over the summer and pack size was confirmed at 10 for the end of the year.

Bechler (estimated 4 wolves: 2 adults and 2 pups)

The Bechler pack has no radio-collars and collaborating technician Aaron Bott spent a third summer trying to determine this pack's current size and reproduction. The pack had five pups and reached a high count of nine wolves in late summer. Two pups were harvested in Idaho and several other wolves disappeared, leaving the Bechler pack with approximately two adults and two pups by the end of the year.

1198F

Wolf 1198F continues to travel alone. By the end of 2021, she had been a lone wolf for more than 30 months.

Other wolves

1155M/1154F

After his new mate in 2020 and possible pups disappeared, wolf 1155M was tracked with female 1154F for several months until he was trapped on private land north of YNP in February. Around the same time 1154F travelled back into the park and started the Rescue Creek pack with males from Junction Butte.

Heart Lake (estimated 10 wolves: 6 adults and 4 pups)

The Heart Lake pack shifted out of YNP in early 2021 but, unlike other packs in the area that would return during the late winter and denning season, the Heart Lake pack stayed in Wyoming. They are now monitored by Wyoming Game and Fish Department.

Transboundary packs, Hawk’s Rest (about 11 wolves: 5 adults and 6 pups) and Pahaska (about 8 wolves: 5 adults and 3 pups), use eastern YNP seasonally, usually from August to early winter, and are monitored by Wyoming Game and Fish Department.

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Publications

Brandell, E.E., N.M. Fountain-Jones, M.L. Gilbertson, P.C. Cross, P.J. Hudson, D.W. Smith, D.R. Stahler, C. Packer, and M.E. Craft. 2021. Group density, disease, and season shape territory size and overlap of social carnivores. *Journal of Animal Ecology* 90: 87-101.

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Capturing and collaring wolves is essential to the research in Yellowstone. Pilot Jim Pope and crew from Leading Edge use nets to restrain the wolves and then bring biologists in to attach the collars and take samples and measurements. NPS Photo: D. Smith

| Volunteer Hours for 2021 | |
|--------------------------|-------|
| Name | Hours |
| Hannah Beroske | 250 |
| Taylor Bland | 1034 |
| Tyler Gerstein | 320 |
| Tyler Greenly | 300 |
| Cameron Ho | 200 |
| Clair Lacey | 250 |
| Dylan Sanborn | 600 |
| Carly Segal | 350 |
| Winston Oppelt | 100 |

BACK COVER: A wolf from the Wapiti Lake pack feeds on a freshly killed elk near the newly constructed employee housing in Yellowstone. In winter the area is quiet with few people yet the wolf moved off by sunrise. Wolves generally return to carcass sites until there is only hide and bones remaining. - NPS Photo: J. SunderRaj

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*All photos are NPS unless noted.