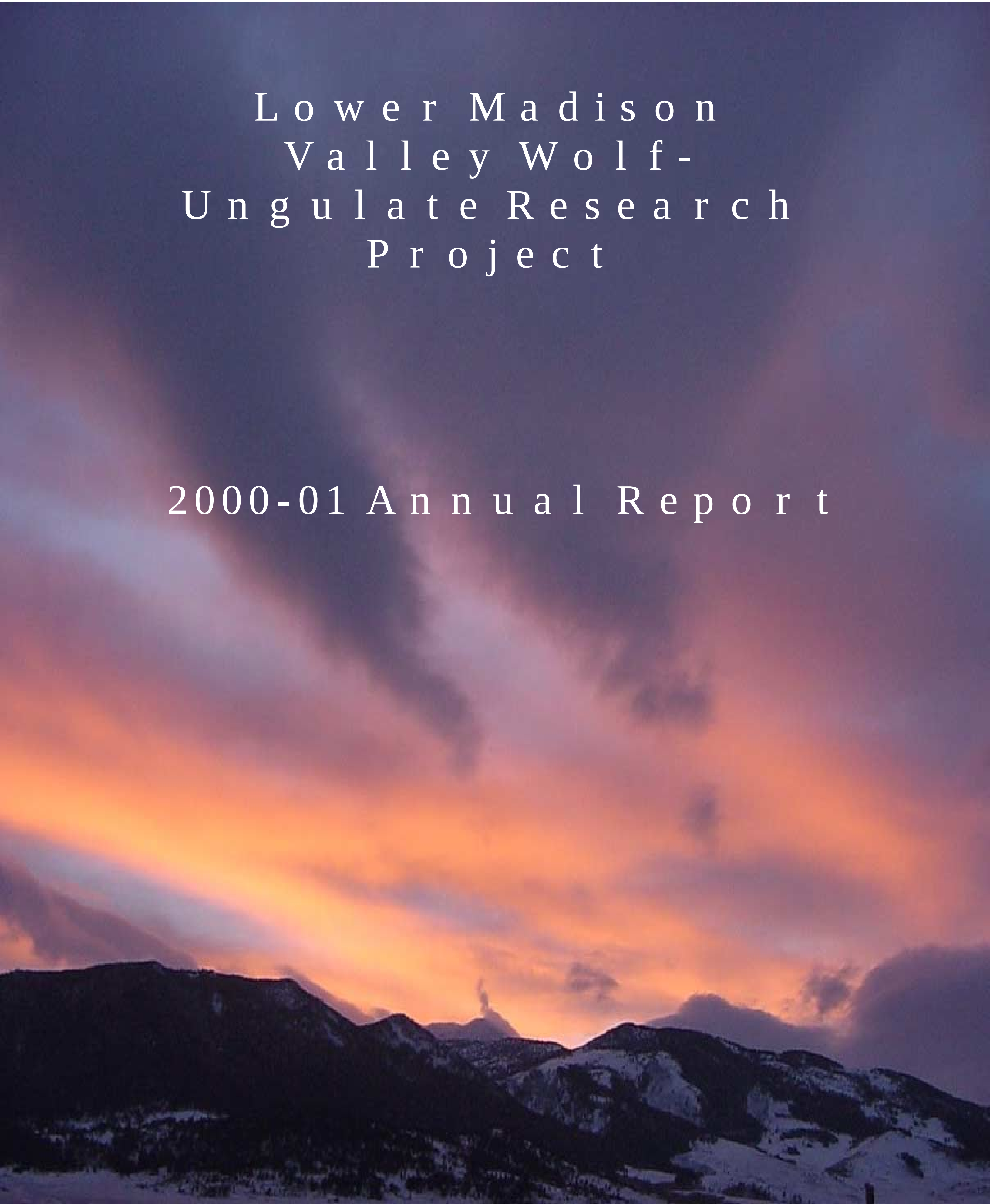

Lower Madison Valley Wolf-Ungulate Research Project

2000-01 Annual Report

The Montana State University research team for the pilot year consisted of:
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The pilot year would not have been possible without funding contributions and logistical support provided by:
Roger and Cindy Lang
Bob and Annie Graham
Montana State University (Bob Garrott and Scott Creel)

The research would not be possible without the advice and collaboration of the following agencies:
Montana Department of Fish, Wildlife, and Parks
United States Fish and Wildlife Service

The owners, managers, and/or caretakers of the following landholdings in the valley have also graciously provided access to their lands as well as other types of aid:
Carroll Ranch
CB Ranch
Corral Creek Ranch
Elk Meadows Ranch
Elkhorn Dude Ranch
High Valley Ranch
Sun Ranch

This report was prepared by Justin Gude with aid and input from Bob Garrott.

Summary

The Lower Madison Valley Wolf-Ungulate Research Project is designed to quantify management-related and theoretical aspects of predator-prey interactions on ungulate winter ranges. In order to address such issues, data collection focuses on wolves, hunters, ungulates, and environmental conditions. During the first year, our major goal was to develop, implement, and revise data collection methods applicable to the Lower Madison study area for use in successive years of the study.

Two wolf packs used the study area this winter. The Taylor Peak pack was located in or around the study area on most days, and the Chief Joseph pack was rarely located in the area. The areas used by the packs overlapped extensively with no documented antagonistic interactions between the packs. Sixty-two wolf-killed ungulates were located over the course of the winter. The vast majority of kills were elk and were located in the flats habitat type. Also, over half of all kills found were elk calves.

We obtained a sample of 78 hunter-killed elk from the late hunting season. Most of these kills were adults, and the exact ages are currently being determined for comparison with wolf kill data.

Elk numerically dominated the ungulate community, particularly in the flats habitat type where approximately 2250 elk wintered. Elk represented 93% of the total number of ungulates present in the flats during most of the winter. Also, approximately 87% of all elk in the study area were located in the flats region until the onset of the spring migration period. Mule deer showed the highest recorded densities in other habitat types during the core of the winter, but elk density became higher than mule deer density in habitat types other than the flats at the end of the field season. Accurate and repeatable methodology to measure juvenile recruitment in all ungulate species is currently being developed using data collected during the first field season, as methods attempted during the field season were not successful. Elk tended to reside in larger groups relative to the number of elk in the study area than did other ungulate species. Individuals in elk groups also tended to be close together, a pattern that was not noticed in other ungulate species. In the coming years, we plan to add methodology to measure ungulate vulnerability to wolf predation as it occurs in live populations versus in wolf kill selections.

Relatively mild temperatures and snowfall, high wind speeds, and an early warming trend marked the first winter field season of the study. Different habitat types had notable differences in snow accumulation. In the coming field season, we will begin a more intense monitoring of environmental conditions as they relate to wolf predation.

The success of the first year of the study can be attributed to outstanding cooperation between the local community, federal and state agencies, and the research team. With continued cooperation, the chances of a successful project are great. We plan to continue the study for a minimum of two more years, as it has been converted into a MS graduate project. Also, the project is currently being integrated with similar projects at two other sites in the Yellowstone area.

Study Purposes and Questions

The focus of the Lower Madison Valley Wolf-Ungulate Study is predator-prey interactions between wolves and big game, or ungulate, species. Because this topic is of interest to many different people and groups, the study has been designed to address a broad range of issues, ranging from management to theoretical science.

In terms of management, the major question is how wolves affect ungulate populations. Answering this question is of interest to sportsmen, guides, ranchers, and outdoor enthusiasts, all of who make up the constituency for the Montana Department of Fish, Wildlife, and Parks (FWP), as well as others. FWP is charged with both managing ungulate populations and devising a wolf management plan, as FWP will gain management authority for wolves when they are de-listed as endangered species in the near future. Because such management depends and is based on populations, gaining information on how wolf and ungulate populations interact will be invaluable for such management decisions and plans. Thus, our major management-oriented goal as scientists is to provide FWP and the general public with objective data on wolf-ungulate population interactions and professional interpretations of those data.

In terms of more theoretical science, the major ecological question is how wolf and ungulate populations respond to each other numerically (demographically), behaviorally, and spatially. The basic idea is that traditional models of predator-prey interactions were developed using small mammals and invertebrate subjects due to the ease of data collection with those animals. The models do not seem to describe the observed interactions between large mammals in most areas, so we believe that new models need to be developed. In order to develop such models, study sites at three locations in the Greater Yellowstone Ecosystem have been identified, and data collection has begun at all three sites. The Lower Madison Valley site is one of these locations, and though a generalized wolf-ungulate model will require many years of data collection to develop, we can begin to collect and analyze data within the next few years.

Considering the two types of objectives, we have created a set of five more specific questions that will allow us to gather the needed information:

1) How do wolves select prey from what is available?

2) How does hunter offtake compare to wolf offtake?

3) How do wolves and ungulates respond to each other spatially?

4) How does wolf offtake affect ungulate demography?

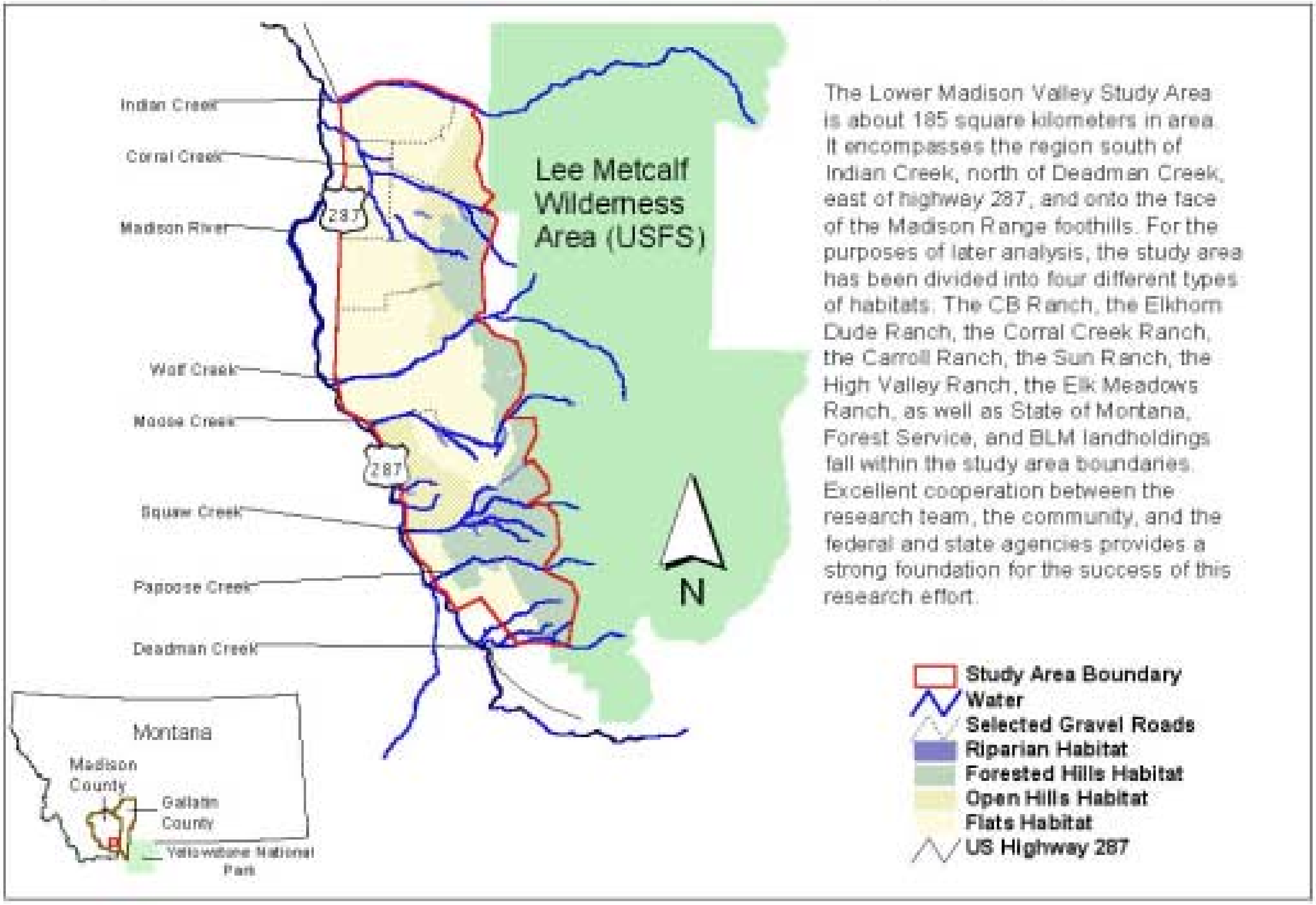
5) How does ungulate demography affect wolf offtake and demography?

The primary goal for this first pilot year of the project was to assess and develop methods to answer these questions. Because of the extreme overlap between management-related and theory-related issues, we should be able to use much of the same data for analysis and consideration of both topics. In order to answer the questions, then, the types of data that we need to collect are data on wolf population dynamics, wolf offtake, hunter offtake, ungulate population dynamics, and environmental conditions. The data that are summarized in this report are presented in this order. Because of logistical and knowledge limitations, we are currently only able to focus the study on the winter months and ungulate winter ranges. No analyses have yet been performed, as one year of data can be misleading and different from other years. It is best to accumulate data for multiple years prior to formal analyses.

Study Area

The study area encompasses about 185 square kilometers (73 square miles) in the region south of Indian Creek, north of Deadman Creek, east of US 287, and onto the face of the Madison Range foothills (Figure 1). This region is highly varied in terms of habitat types, which has the potential to affect wolf-ungulate interactions by affecting the habitats that both wolves and ungulates use, food availability, and environmental conditions. Thus, for the purposes of this study, the region has been divided into Flats, Open Hills, Forested Hills, and Riparian Habitats. All data collection methods are designed to incorporate any variation between these habitat types.

Figure 1: Lower Madison Valley Study Area



The Lower Madison Valley Study Area is about 185 square kilometers in area. It encompasses the region south of Indian Creek, north of Deadman Creek, east of highway 287, and onto the face of the Madison Range foothills. For the purposes of later analysis, the study area has been divided into four different types of habitats. The CB Ranch, the Elkhorn Dude Ranch, the Corral Creek Ranch, the Carroll Ranch, the Sun Ranch, the High Valley Ranch, the Elk Meadows Ranch, as well as State of Montana, Forest Service, and BLM landholdings fall within the study area boundaries. Excellent cooperation between the research team, the community, and the federal and state agencies provides a strong foundation for the success of this research effort.

Field Methods

Fieldwork began on December 3, 2000 and ended on April 30, 2001 during the pilot year of study. Excluding breaks during this time period, the total number of days spent in the field was 123. The first major focus of the pilot year field season was to learn and become familiar with the landscape, and the month of December was spent traveling the terrain and developing ideas for data collection methods. Familiarization with the area was a process that continued throughout the field season, though. The remaining field-oriented goals for the pilot year were to develop methods for data collection, to begin collecting data, and to refine the methods.

Most data collection methods were developed over the course of the winter, but some are in the process of being revised. Data collection methods had four main focuses including wolf data, hunter data, ungulate data, and environmental condition data. Researcher time had to be split between these tasks because only one person was in the field during the first season.

Wolf data collection depends on locating and tracking wolves in the study area. Wolf packs were located at least once on 105 out of 106 days in the field from January to April. Wolves were the focus of fieldwork on 74 of those 106 days, though tracking was not always possible. Approximately 69 of the 74 wolf-focus days were spent tracking. A total of 14 days in January were devoted to sample collection from hunter-killed elk, all of which occurred on the weekends of the late-hunting season. Ungulate data collection consisted of surveys and opportunistic observations. Surveys were completed in varying habitat types for three days out of every 14 (18 total days) from February to April. Data on ungulate groups was also recorded opportunistically during all other field activities. Environmental conditions, such as snow condition, temperature, and wind speed, were recorded in conjunction with other data focuses as well, providing almost a daily record of environmental parameters.

Wolf Data

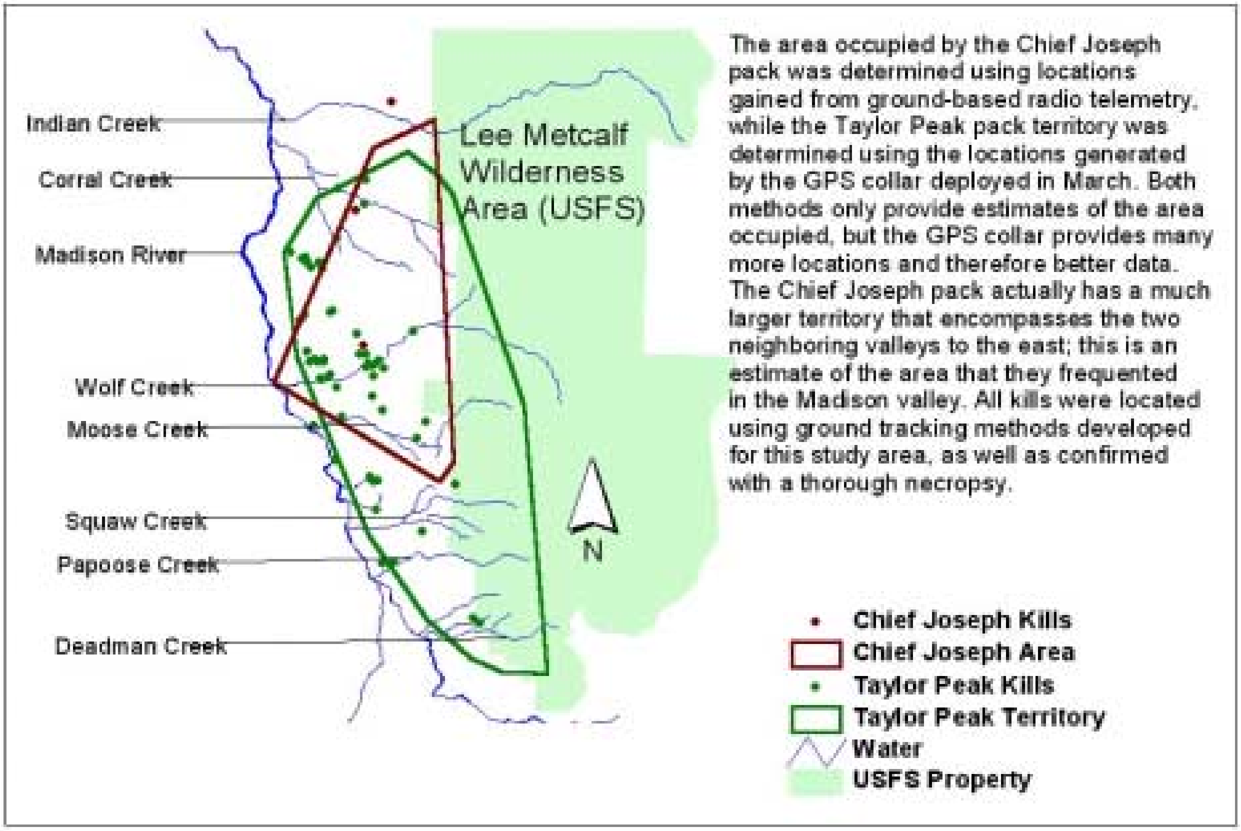
Demographics and Spatial Organization

Two packs used portions of the study area this past winter, the Taylor Peak pack, consisting of five animals, and the Chief Joseph pack, consisting of twelve animals. These pack sizes are from before the denning season, and both packs denned this spring. So, both packs may now contain more animals. The Taylor Peak pack denned in the study area, and the Chief Joseph pack denned in the Gallatin Valley.

The Taylor Peak pack was in or around the study area on most days this winter, although they did make excursions. For example, after the three radio-collared wolves in the pack were located within the study area boundaries on the morning of March 22nd, they were not located in the study area again until the morning of March 23rd. Because one of the collars contained a GPS mechanism, which records and stores locations several times a day using the satellites orbiting above the region, we were later able to learn about their movements during the time in which we lost track of them with ground tracking technology. It turns out that the pack took a foray east up the north fork of Squaw Creek, over Expedition Pass, into the Alp Creek-Moose Butte region in the Gallatin Valley, and then back again within 24 hours. The straight-line distance of the excursion was only about 15 miles, but it was nevertheless considerable due to the snow depth on the Madison Range and the fact that they undoubtedly did not move in a straight-line fashion.

The Chief Joseph pack was only rarely in the study area, and they were not always all present when they were in the area. Although we know they were in the study area during the January late hunting season because of hunter sightings, we did not have the radio collar frequencies and thus were not able to determine how many were present or the length of time they were present. We do know that in early February nine of the wolves in the pack were in the area for four days, on February 21st twelve of the wolves were in the area for the day, and in mid-March twelve of the wolves were in the area for three days. "Wolf-days" are used to keep track of how many wolves are in the study area on a daily basis, and thus provide an index of predation pressure on the ungulate populations residing in the area. A total of 436 wolf-days were recorded in the study area between the end of January and the end of April, with 352 days (81%) attributed to the Taylor Peak pack and 84 days (19%) attributed to the Chief Joseph pack. Keeping track of wolf presence in this way permits us to estimate wolf kill rates more accurately. The Chief Joseph pack has an extremely large territory spanning into the Lower Madison study area, the Gallatin Valley, the Tom Miner Basin, and south into the Madison-Firehole-Gibbon region of Yellowstone National Park. Hence, the Lower Madison area is only a small portion of their range and they spend a small portion of their time there. One of the other wolf-ungulate study sites mentioned previously is located in the Gallatin Valley, where the pack spends most of its time, and another is located in the Madison-Firehole-Gibbon region of Yellowstone National Park, where the pack is occasionally located.

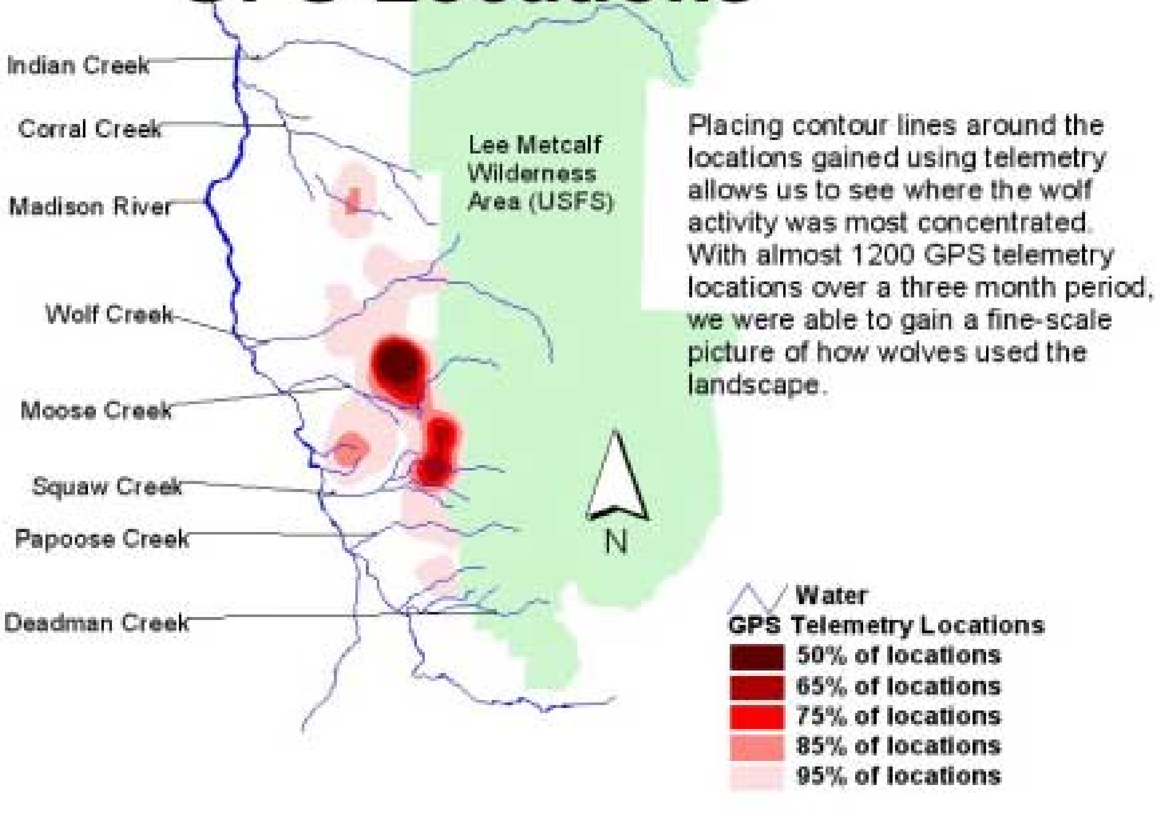
Figure 2: Wolf Spatial Dynamics



The area occupied by the Chief Joseph pack was determined using locations gained from ground-based radio telemetry, while the Taylor Peak pack territory was determined using the locations generated by the GPS collar deployed in March. Both methods only provide estimates of the area occupied, but the GPS collar provides many more locations and therefore better data. The Chief Joseph pack actually has a much larger territory that encompasses the two neighboring valleys to the east; this is an estimate of the area that they frequented in the Madison valley. All kills were located using ground tracking methods developed for this study area, as well as confirmed with a thorough necropsy.

Spatially, the Chief Joseph pack tended to stay in the northern portion of the study area while the Taylor Peak pack territory encompassed most of the study area (Figure 2). The two packs overlapped territories extensively without any documented fatalities this winter, which is somewhat odd for territorial packs competing for access to the same ungulate resource base. In many cases, especially when food is in short supply, neighboring packs act more aggressively toward each other. Perhaps the lack of aggression stems from the fact that wolf #115, the alpha female in the Taylor Peak pack, was born into, and dispersed from, the Chief Joseph pack, and food is in abundant supply in both packs' territories. A couple of anecdotal observations support the idea that the packs have remained fairly friendly with one another since #115 left. First, Ed Bangs of the US Fish and Wildlife Service saw the packs in close proximity to one another from a helicopter and observed no antagonistic behavior. Second, Justin Gude picked up the radio signal of wolf #250 of the Taylor Peak pack with the Chief Joseph pack on a morning when both packs were in the area. The other Taylor Peak wolves were several miles to the south and were joined by #250 later that same night. We did notice a tendency, though, for the Taylor Peak wolves to move to the southern end of the study area soon after the Chief Joseph pack entered the valley, so it will be interesting to observe the relationship of these two packs in the future.

Figure 3: Taylor Peak Pack GPS Locations



Placing contour lines around the locations gained using telemetry allows us to see where the wolf activity was most concentrated. With almost 1200 GPS telemetry locations over a three month period, we were able to gain a fine-scale picture of how wolves used the landscape.

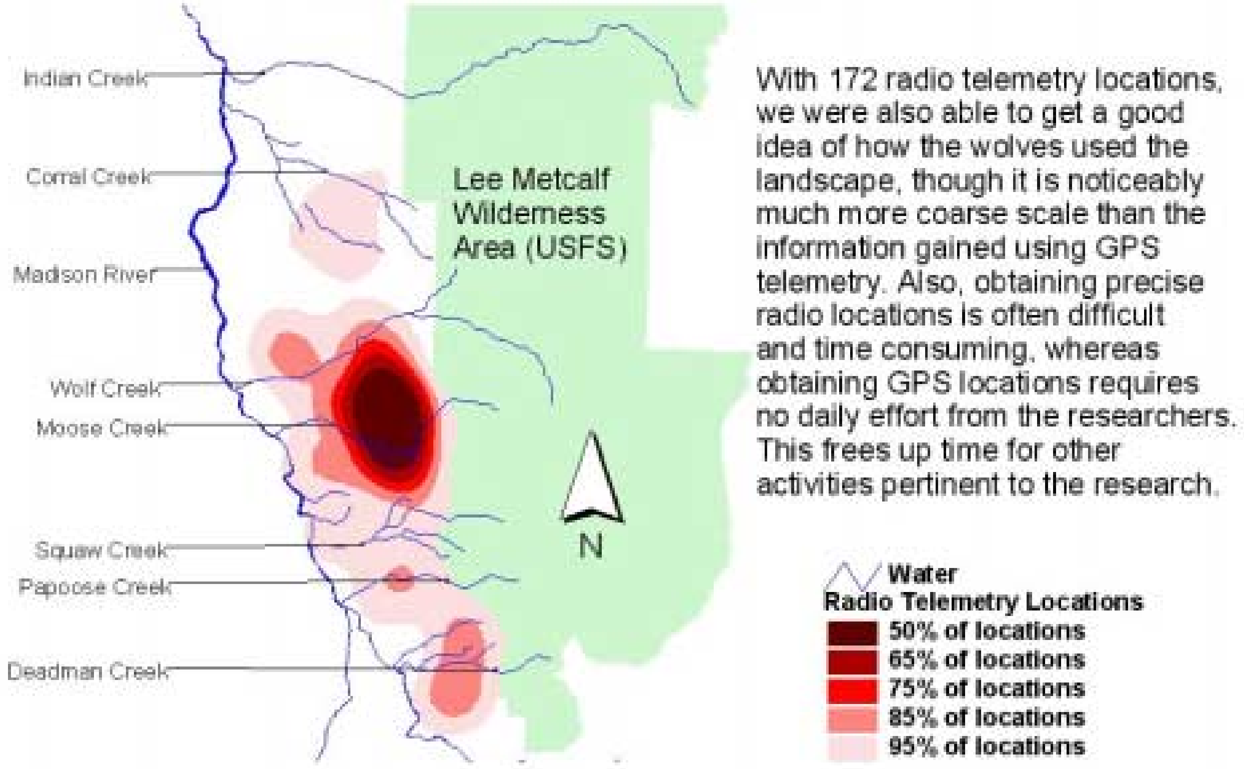
Another aspect of wolf spatial organization is how wolves and ungulates use the landscape with respect to one another. Eventual analyses in this arena include how wolf spatial use patterns affect ungulate behavior and distribution, and how ungulate behavior and distribution affect wolf spatial use patterns. For wolves, this is the area of research where GPS technology will probably be most useful. Because a large part of the study area remains almost snow-free for much of the winter, we cannot rely on snow tracking to provide unbiased information on wolf landscape use, so, we are left with telemetry locations for use in determining how wolves use the area spatially. During the period from March 6th until May 21st, when we had a GPS collar deployed on a wolf in the Taylor Peak pack, we were able to obtain roughly 1200 locations for the pack. These data provide information about wolf habitat and landscape use on a very fine scale (Figure 3), which will be important for analyses. Also, GPS locations are taken independent of researcher activities, requiring no time or effort on a daily basis. By comparison, during the winter study period from January until the end of April, we were able to obtain 172 radio-telemetry locations of the Taylor Peak pack (Figure 4). Such a high number of locations can provide quite a bit of information on wolf habitat and landscape use, but it is easy to see that the scale of the information is much more coarse than

Figure 4: Radio-Tracking on the Sun Ranch

The very cold author locates the Taylor Peak pack early on a winter morning along the main Sun Ranch road in order to begin daily tracking of the pack.

that provided by the GPS collar, which will become important for analyses (Figure 5). Also, obtaining accurate radio-telemetry locations is often time consuming and difficult. The US Fish and Wildlife Service has agreed to deploy GPS collars on both the Taylor Peak and Chief Joseph packs over the next two winter seasons, often a very costly and intricate operation involving aerial darting of wolves in each pack (Figure 6).

Figure 5: Taylor Peak Pack Radio Locations



With 172 radio telemetry locations, we were also able to get a good idea of how the wolves used the landscape, though it is noticeably much more coarse scale than the information gained using GPS telemetry. Also, obtaining precise radio locations is often difficult and time consuming, whereas obtaining GPS locations requires no daily effort from the researchers. This frees up time for other activities pertinent to the research.

Wolf Offtake

Kills were located using tracking methods developed for this study area, which included backtracking between known locations and scanning between known locations using a spotting scope, depending on which habitats the wolves moved through. When an ungulate carcass was found, an investigation of the area and a necropsy, or thorough examination of the carcass to search for signs of the cause of death, were used to determine if wolves killed the animal (Figure 7). A total of 69 carcasses were located along wolf travel routes, but only 62 ungulates were determined to have been killed by wolves during this winter season (Figure 8), as well as two coyotes. Other causes of death included hunter wounding losses, fences, and one unknown. Fifty-eight of the kills found were made by the Taylor Peak pack, and the remaining four were made by the Chief Joseph pack. These are likely not all of the kills that were made by wolves in the study area, but these kills

Figure 6: 2001 Wolf Capture Operation

Ed Bangs of the US Fish and Wildlife Service (left) and Justin Gude of Montana State University transport a large male wolf from the helicopter to the staging area on March 6, 2001, after the wolf was darted and drugged from the helicopter. This wolf was fitted with a radio collar and was tagged as wolf #238. A GPS collar was also deployed on another wolf caught that day, wolf #250. The US Fish and Wildlife Service has agreed to keep animals in the Taylor Peak pack fitted with radio and GPS collars over the next two years, which is a large commitment because this type of capture operation is expensive, difficult, and dangerous.

can be used to monitor kill rate throughout the winter and thus to estimate total offtake of ungulate populations during the winter season. We can do this by keeping track of the wolf-days for a given time period, the dates of the kills, and the tracking efficiency on the kill dates (i.e. what percentage of daily wolf movements were tracked). With this information, kill rates and total offtake can be estimated in later analysis.

Most of the kills found this winter were elk (90%), as were the majority of ungulates wintering in the study area (see ungulate data section). Wolves did seem to show a preference for elk calves in this study area (58% of total number of kills). Also, most kills were found in the flats habitat type (77%, Figure 9), which is also where most of the ungulates in the study area were found.

Figure 7: Examination of Wolf Kills

Researchers came across several ungulate carcasses, such as this one, during winter tracking of wolves in the study area. This carcass was determined to be a wolf-killed elk calf after a thorough examination of the surrounding area and a necropsy. Such methods were performed at every carcass found in order to determine the cause of death.

Hunter Data

We were able to obtain a sample of hunter offtake in the study area during the late elk hunting season in January due primarily to the Sun Ranch hunter check-in/check-out system. Eventually, this data will be used to analyze how hunter offtake compares to wolf offtake and how the combined hunter and wolf offtake affects the elk population. Hunters killed far more adults than wolves, all but a handful of which were females due to the harvest regulations (Figure 10). Similarly, of all the elk that wolves killed, about two-thirds were female (Figure 8). Also, we examined only slightly more hunter kills than wolf kills, though neither sample represents all of the animals killed by hunters or wolves. For further analysis, we pulled an incisor tooth from each of

Figure 8: Wolf Kills Found During the Winter 2000-01 Study Season

Figure 8a: Wolf Kills By Species and Age

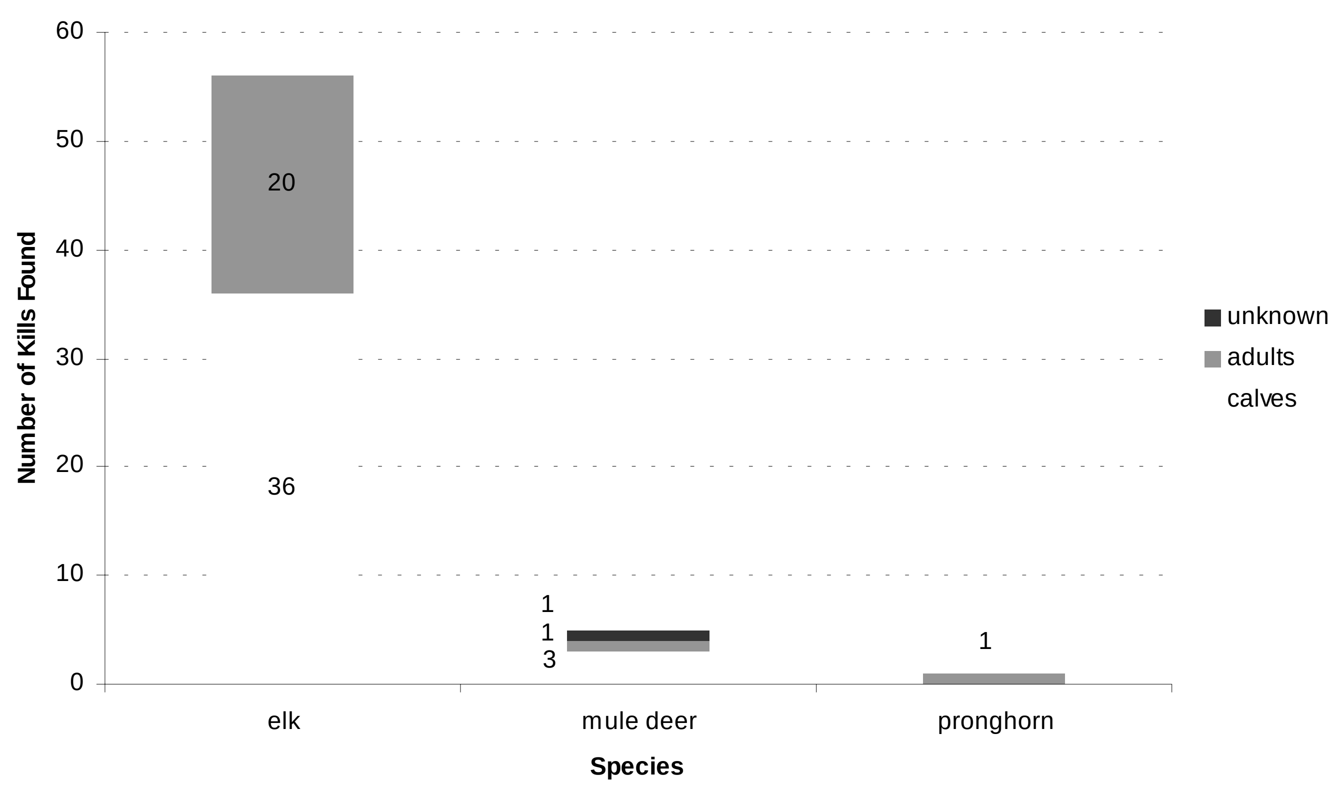
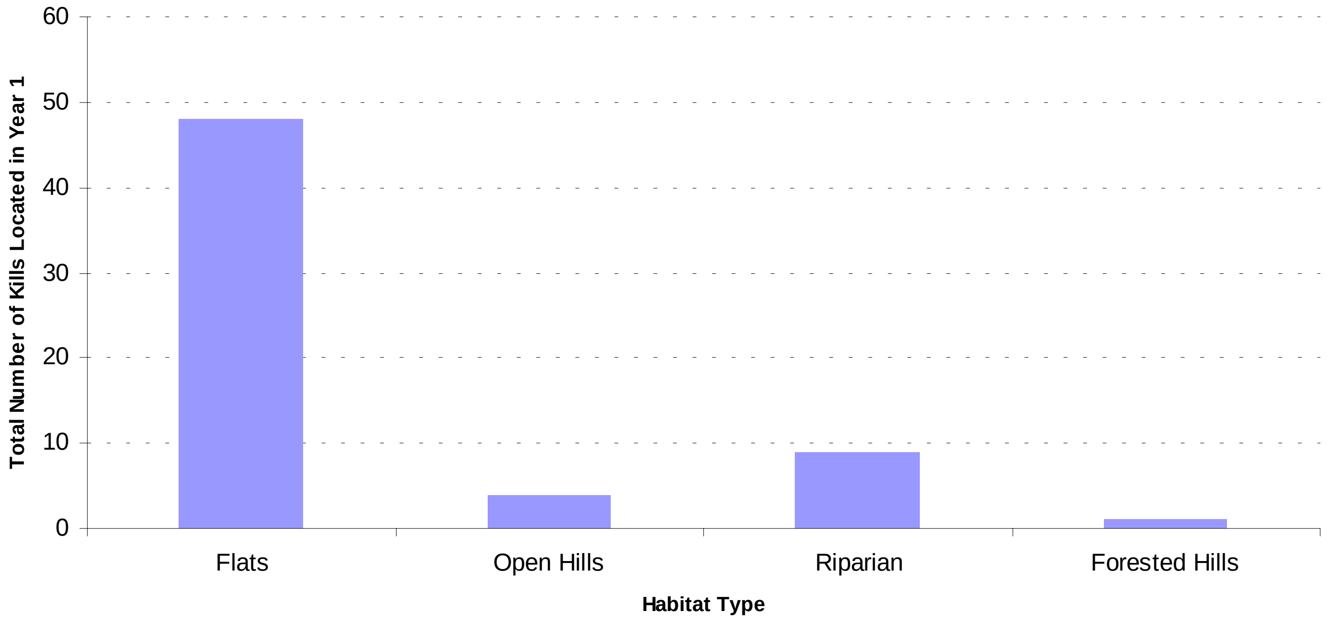


Figure 8b: Wolf Kills by Species, Age, and Sex

elk total	56(90%)	**mule deer total**	5(8%)	**pronghorn total**	1(2%)
adult cow	10	unknown adult	1	adult female	1
yearling cow	3	female calf	2		
spike	3	unknown calf	1		
bull	4	unknown sex/age	1		
adult elk total	20(32%)				
male calf	12				
female calf	23				
unknown calf	1				
calf elk total	36(58%)				

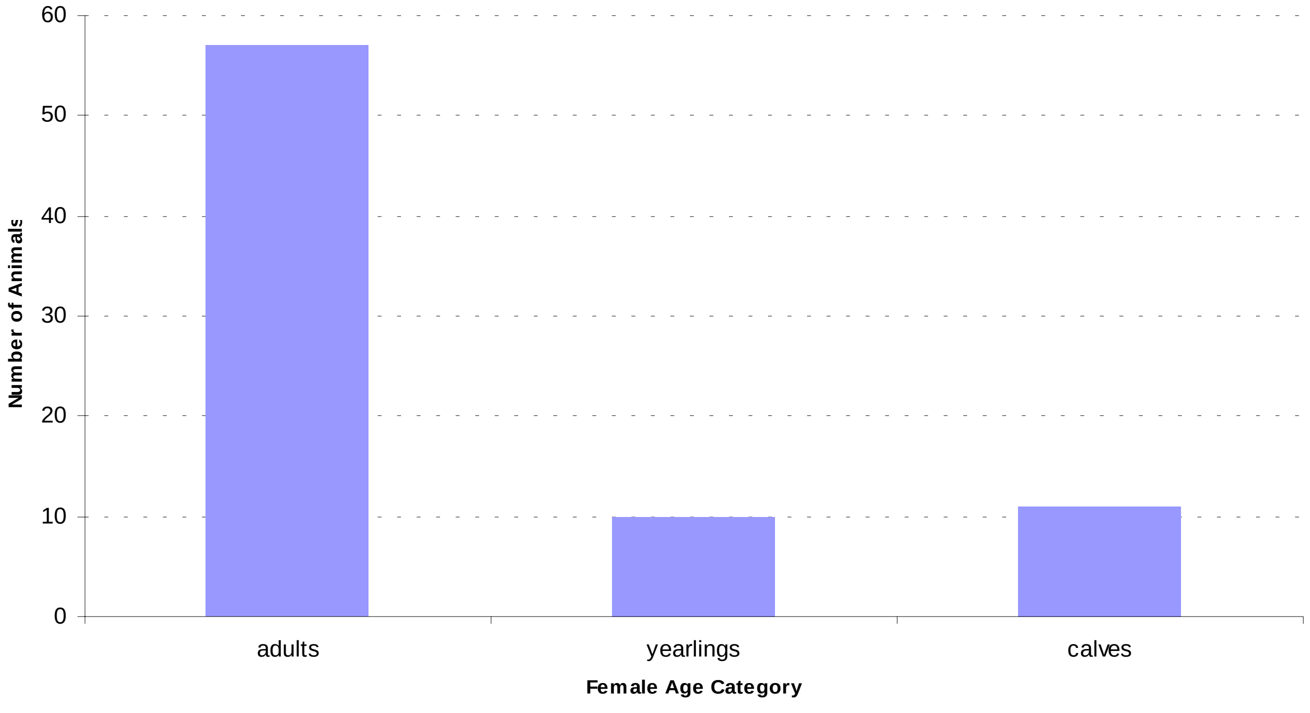
The vast majority of kills located were elk, which is expected because elk comprised approximately 93% of the wintering ungulates present in the study area during survey periods for most of the winter. The wolves seemed to show a preference for calves, as a large portion of the kills located were calves. Satisfying data collection needs for other aspects of the study does not permit all wolves to be tracked everyday, so this does not necessarily represent every kill that was made this winter. However, by keeping track of wolf-days (one wolf spending one day in the study area) and tracking efficiency, we can use the dates of each kill to estimate kill rates for a given time period and thus the overall wolf offtake for the winter.

Figure 9: Wolf Kill Locations During the Winter 2000-01 Study Season



The majority of kills found this winter (77%) were located in the flats region, where 87% of the elk in the study area could usually be found. Because the ungulates in the study area are not distributed evenly, kill locations can eventually be used to determine if wolf offtake has affected different segments of the wintering ungulate populations.

Figure 10: Hunter-Killed Elk Sample From District 362 Late Hunt (n=78)



The majority of hunter-killed elk were adults, as would be expected. This contrasts sharply with the wolf offtake, the majority of which were calves. Similarly, while all but a few of the hunter kills during the late season were females, two-thirds of the wolf kills were females.

the elk that were examined (both hunter and wolf kills), which can be used to precisely age the animals. The teeth have been sent away for examination, and we should obtain the age data within a few months.

Ungulate Data

Demographic Data

Five ungulate species inhabit the study area on a regular basis, including elk (Figure 11), moose, mule deer, pronghorn antelope (Figure 12), and white-tailed deer. Because these ungulates often occupy different habitat types, total ungulate populations in the study area have to be measured using a couple of different methods. In the flats region, where visibility is high, it is possible to make a total count of all ungulates in the area during each survey period. Visibility is poor in the other habitat types, so we must rely on density estimates gained along survey routes in order to index the total number of ungulates present in the habitats. So, the populations in different habitats are reported differently here. Also, FWP conducts yearly total elk aerial survey counts of the region from Indian Creek to Earthquake Lake, which we can use to compare to our estimates gained from groundwork (Figure 13).

Figure 11: Small Elk Group

Small elk groups, such as this one, were common in some habitat types within the study area, but much larger groups were also present.

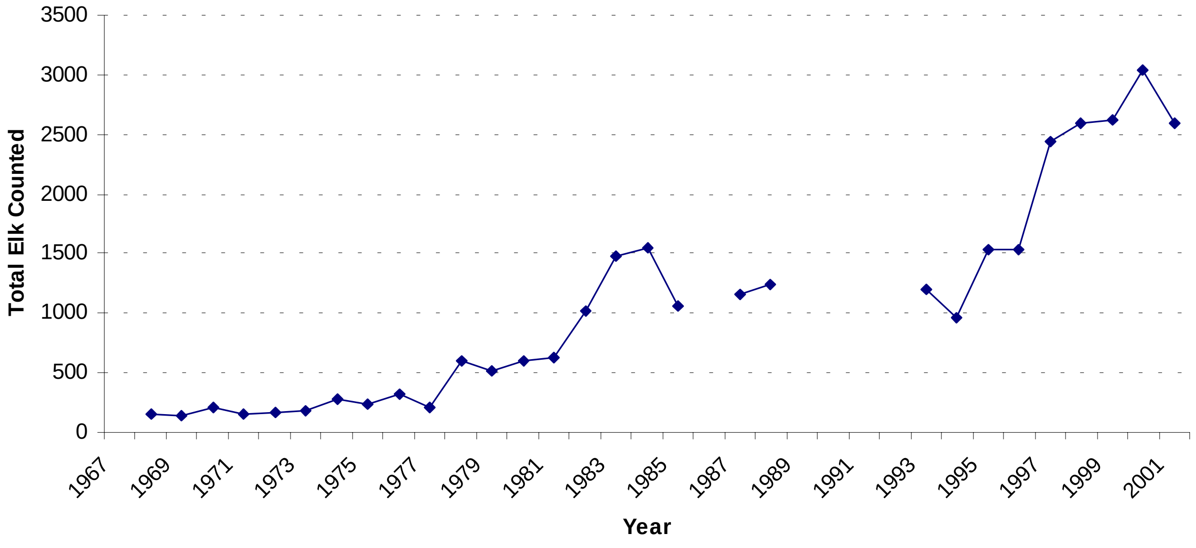
Figure 12: Pronghorn Group

Pronghorn antelope were fairly common in the study area.

Elk numerically dominate the ungulate community in the flats region (Figure 14). In fact, most of the elk in the study area are located in the flats region. The FWP total elk count from Indian Creek to Earthquake Lake this past winter was 2588, while the number of elk counted in ground surveys for this research project was approximately 2250 during the core of the winter. This represents 87% of the total FWP count, and their survey areas extend south and east of the study area boundaries. So, the number of elk in the flats likely represents more than 87% of the elk in the study area. Monitoring the total elk population in the flats also allows us to keep track of elk migration back to summering areas, which is indicated by the sharp decline in numbers toward the end of the season. A slow pronghorn migration is also visible, as they moved through the study area over the length of the study season. Interestingly, no pronghorn were observed outside of the flats region at all during ungulate survey periods. Lastly, it is important to note that very few mule deer and white-tailed deer were observed in the flats over the winter season.

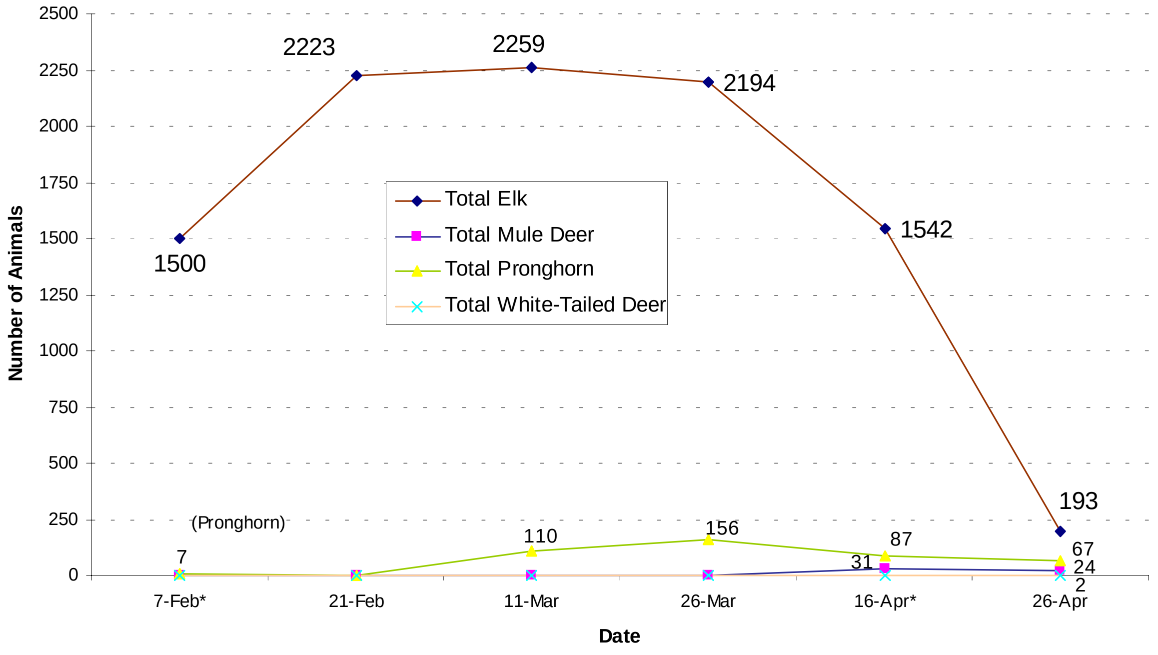
Monitoring density in habitat types other than the flats provides an index of the total ungulate population sizes in those habitats. Monitoring density is not as sensitive as counting the total population, which means that observing the overall density trend is somewhat more meaningful than observing the absolute density numbers. In any case, densities provide for two major types of comparisons within this system. First, we can monitor coarse-scale changes in ungulate distribution over time (Figure 15). For example, elk moved from the flats into other habitat

Figure 13: Fish, Wildlife, and Parks Total Elk Counts in the Indian Creek to Earthquake Lake Survey Block



The Montana Department of Fish, Wildlife, and Parks has been conducting elk surveys in the region including and surrounding the study area for many years, and have graciously made this data available to us. Though some years were missed, this represents a large amount of elk population data from before wolves recolonized the valley. These data will become extremely useful as we accumulate comparative data on elk populations over the years since wolves have recolonized the study area. As is evident, the number of elk in the area has been increasing rather steadily for some time now, so it will be interesting to see how this compares to what happens with wolves inhabiting the valley.

Figure 14: Estimate of Total Number of Ungulates Present in the Flats Region During Winter 2000-01



Elk were by far the most abundant ungulate in the area for most of the winter, with numbers ranging from 193 to 2259 on survey dates. On survey dates marked with an asterisk, however, many members of a large elk group could not be counted by the observer due to their position in the landscape. Pronghorn were the second most abundant ungulate in the flats, with counts ranging from 0 to 156. Mule Deer and White-Tailed Deer were far less abundant in the flats, with numbers ranging from 0 to 31 and from 0 to 2, respectively, on survey dates. Two migrations are evident in this data: the migration of pronghorn onto the wintering ground and eventually further south, and the spring migration of the elk back to the summering ground.

Figure 15: Density Trends Between Habitats for Elk and Mule Deer

Figure 15a: Elk Densities by Habitat Type

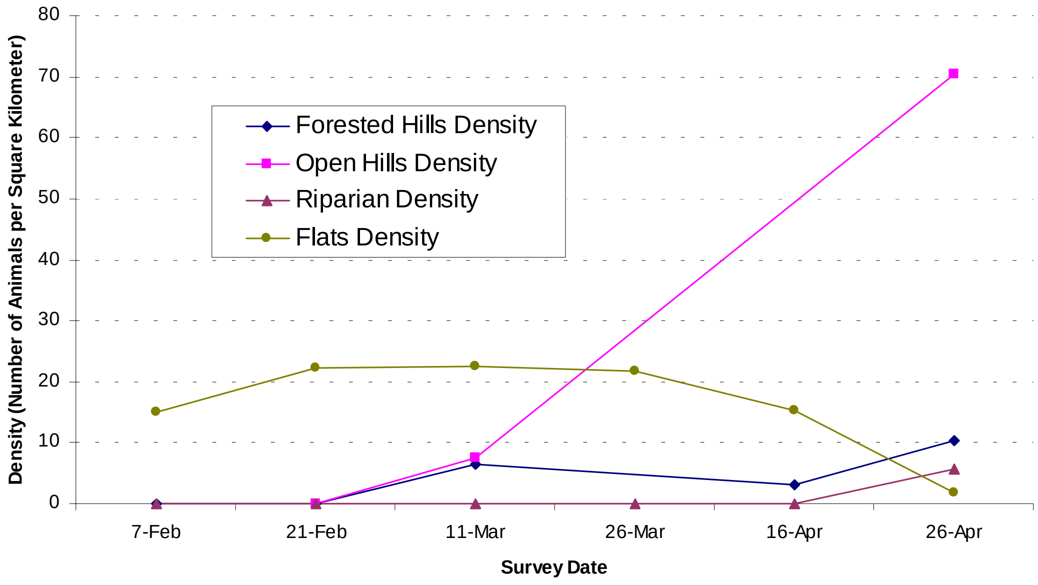
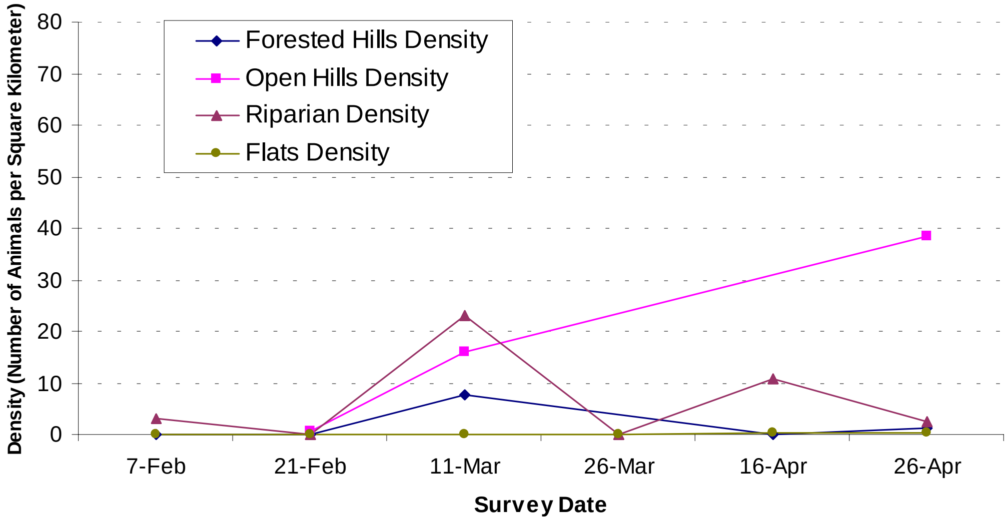


Figure 15b: Mule Deer Densities by Habitat Type



(a) Elk moved from the flats habitat into other habitats at the end of the winter. Although the number of elk in the flats was far greater than the number ever seen in any other habitat type, elk became very dense in the open hills habitat type, which is about a fourth the size of the flats habitat. (b) Mule Deer also became very dense in the open hills habitat at the end of the winter, though not as dense as elk did. Mule deer moved into the open hills from forested hills and riparian areas. Though the decline in density in the forested hills appears rather small, this habitat represents about twice the area of the open hills. So, in terms of absolute numbers, a relatively large number of mule deer left the forested hills for the open hills.

types, primarily the open hills, at the end of the field season. Also, mule deer moved from the forested hills and riparian areas into the open hills at the end of the winter. Density can be a bit misleading, though, in relation to overall numbers of ungulates. For instance, the number of elk in the open hills never approached the number in the flats, but the elk were more packed into the open hills at the end of the winter than they ever were in the flats because the area of the open hills habitat is much smaller than that of the flats habitat. On the same note, the area of the forested hills is about twice as large as that of the open hills and about three times as large as that of the riparian areas. Thus, it took a relatively large number of mule deer leaving the forested hills, accompanied by some from the riparian areas, to cause the increase in mule deer density in the open hills.

The second comparison that can be made in the study area using densities is between species in the same habitats. For example, mule deer were more common in the riparian area and forested hills than were elk for much of the winter, and elk became more concentrated in the open hills at the end of the winter than did mule deer. The density of both moose and white-tailed deer in the study area were very small, as less than ten individuals of each species were observed in the study area during the winter season. Moose were only observed in and around riparian areas, and white-tailed deer were observed mainly in riparian areas and open hills. The densities of both species will be monitored for between-year comparisons in population sizes.

Ungulate recruitment is also a demographic factor that is being monitored for this research. Recruitment is defined as the number of calves that successfully survive a certain time period, which in this case is the winter study period. Because it is not always possible to keep track of the total population or the total number of calves in a population over a period of time, recruitment is measured using a time-series of ratios, for example the ratio of calves to cows in a certain sample of elk or, for mule deer and pronghorn, the ratio of juveniles to adults, as males cannot readily be distinguished from females. Taking this into account, it is easy to see why measuring recruitment in this study area is not an easy task due to the large groups of elk in the flats region. In fact, the

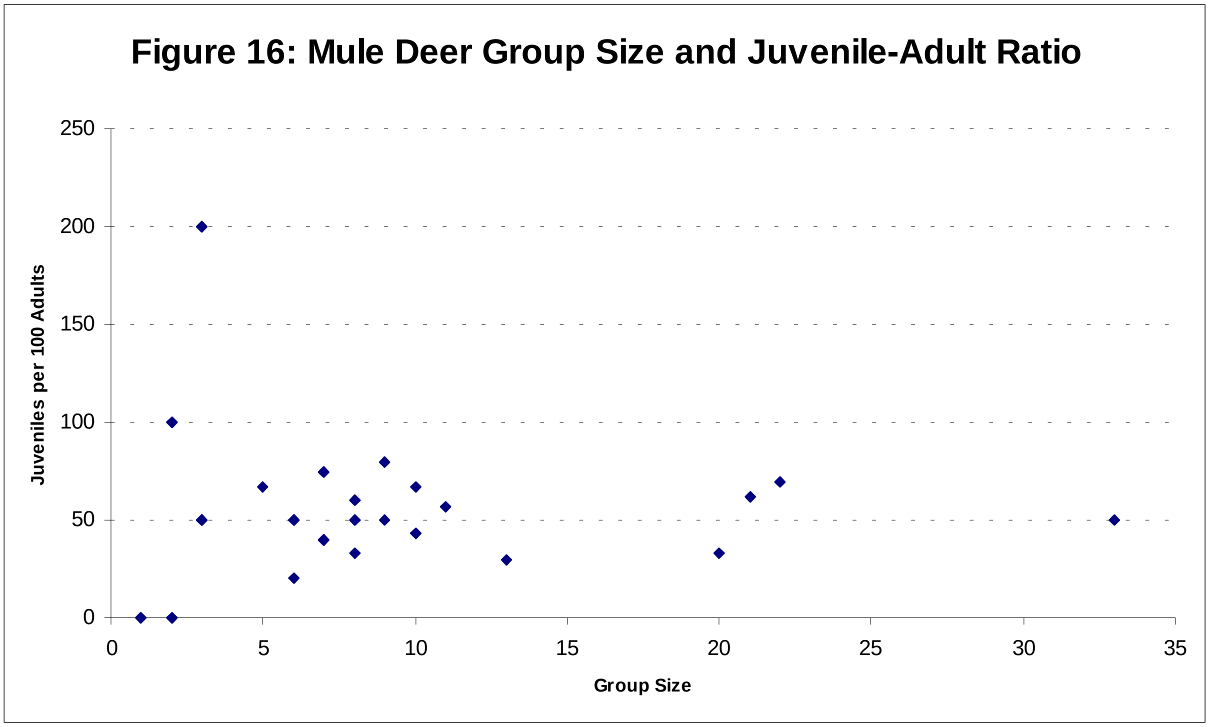


Figure 16: Mule Deer Group Size and Juvenile-Adult Ratio

Ungulate groups tend to contain a more variable number of calves the smaller they are. This same pattern holds for elk in the study area, but not for pronghorn. So, in terms of developing a method of monitoring recruitment, the idea is to classify both smaller and larger ungulate groups, with an emphasis on smaller groups in order to take as much variation into account as possible.

methods that were employed during the pilot season were not successful, but the major purpose of the pilot year was to assess and refine methods for use in successive years. The major problem in our area is devising a way to classify (determine the age and sex of) such a large number of elk while still classifying other ungulate species in a limited time frame. We did collect some data this year that will help us to design such a method. First, ungulate group size can play a role in the number of calves that are observed (Figure 16). Smaller groups tend to be more variable in the number of calves they contain, so the more small-group samples obtained, the more this variation will be captured within the sample. Also, the variation does not seem to taper off with increasing group size for pronghorn, so the more pronghorn groups that are sampled, the better. So, the idea is to sample groups of all sizes with an emphasis on the number of smaller groups for classification counts. Second, the way that groups of different sizes can be chosen for sampling is by concentrating sampling efforts in different habitat types (Figures 17, 18). Sampling the flats at the correct time to classify the easily visible large elk groups is the key. This would also allow for sampling of some smaller elk groups as well as pronghorn groups. Sampling other habitat types will allow for more small elk group observations and mule deer classifications. Also note that classifying ungulate groups using a habitat sampling design will allow for monitoring of the proportion of other age-sex classes in ungulate populations as well. For example, adult elk bulls were primarily located in groups in the forested hill habitat. Monitoring these groups will permit us to assess the proportion of bulls in the total population.

Keeping track of moose and white-tailed deer recruitment in the study area is a bit easier. Very few of these ungulates reside in the study area, which makes it possible to monitor the fate of individual calves. For example, three moose in the study area were consistently seen with calves, and all three calves survived the winter.

Behavioral Data

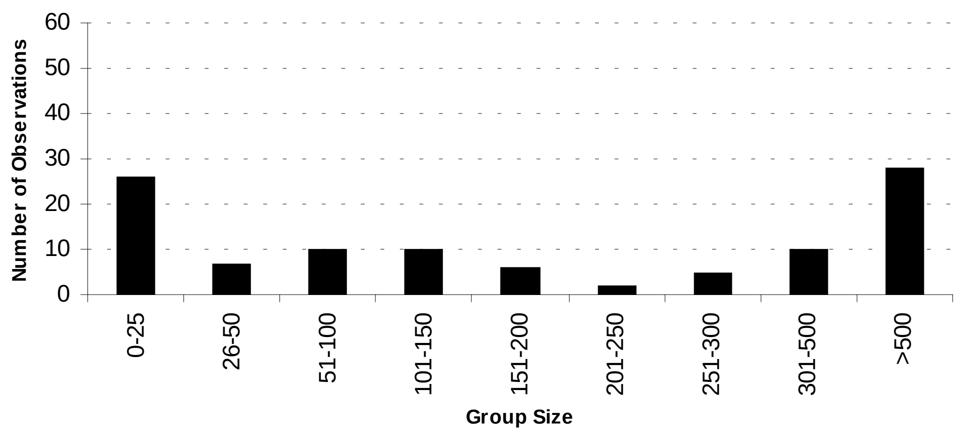
The primary reason for the collection of ungulate behavioral data is for comparisons with environmental conditions and wolf landscape use. Conditions and/or predators may affect several ungulate behavioral characteristics, a few of which are presented here.

First, larger ungulate groups are hypothesized to help protect individual animals from being killed by predators for several reasons. For example, each individual in smaller groups has a better chance of being chosen as prey by predators than individuals in larger groups, larger groups have more eyes to watch for predators, and large groups can offer better defense against predators. In the flats, where most elk kills were found, most elk are found in large groups (Figure 17a). Such large groups are not common in other habitat types within this study area (Figure 18a) or in other study areas. Further, large pronghorn groups were fairly uncommon during this past winter, even on a scale pertinent to the number of pronghorn wintering in the study area (Figure 18b). Pronghorn made up the smallest portion of the wolf offtake for all species killed by wolves, and they are social ungulates. This information might indicate that they are not as wary of wolf predation as are elk.

Because larger groups are hypothesized to provide more safety for individual animals, we can look how behaviorally responsive animals in different group sizes are to predation (Figure 19). Whenever an ungulate group was spotted, the dominant behavior category (feeding, bedded, vigilance, walking, or running) was noted. Though no major patterns were observed, elk in larger groups were bedded a little more often than elk in smaller groups, and smaller elk groups were observed moving (walking and/or running) slightly more often than larger groups. Vigilance was an uncommon behavior for all groups, though, which is probably a function of the observation method. The entire group has to be alert and vigilant for a behavior to be noticed using this method, and such an occurrence is rare. Groups only exhibit such behavior in the presence of an immediate threat;

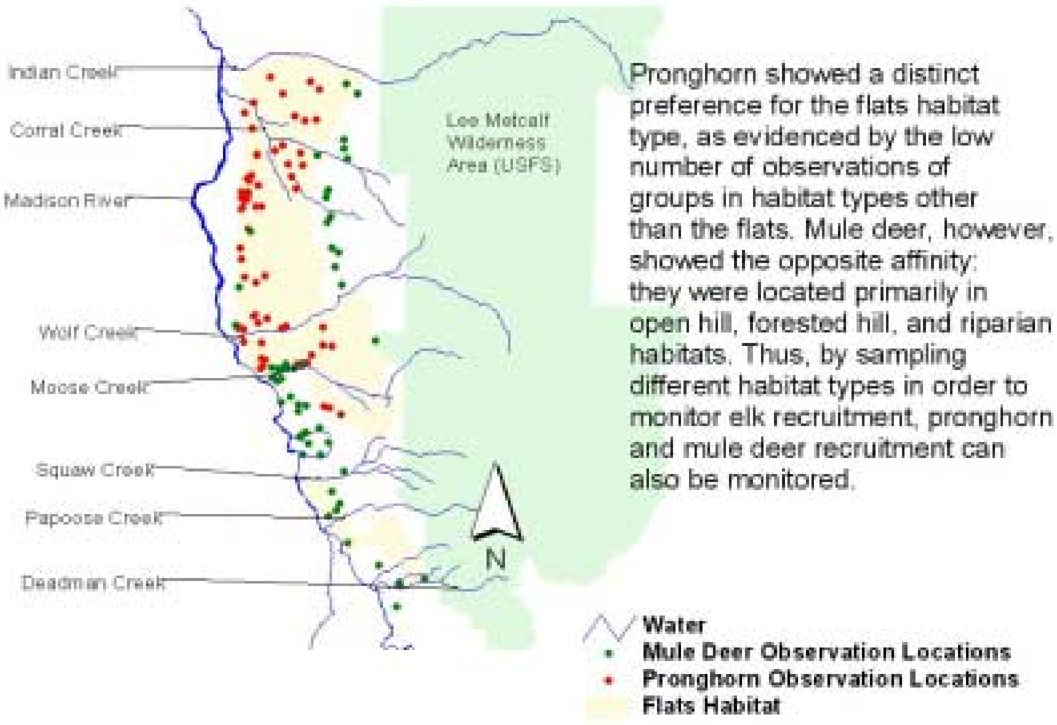
Figure 17: Ungulate Group Distribution in Different Habitats

Figure 17a: Elk Group Size Distribution for the Flats Habitat



Large elk groups are common in the flats, and they are easily visible. The best-laid plan, then, is to classify the larger groups when they are in a position on the landscape where they can be counted. By focusing on the flats region in order to count larger groups, we will also be able to count some smaller elk groups. Also, larger ungulate groups are hypothesized to provide more protection against predation than smaller groups. This idea that ungulates use their behavior in order to avoid predation may be supported here because most of the elk predation occurred in the flats, where most elk (numerically) were in large groups. Because smaller groups were equally as abundant as larger groups, it was not possible to tell if larger groups in fact did protect against predation, as wolves may have chosen their elk prey from either small or large groups in the flats.

Figure 17b: Mule Deer and Pronghorn Observation Locations



Pronghorn showed a distinct preference for the flats habitat type, as evidenced by the low number of observations of groups in habitat types other than the flats. Mule deer, however, showed the opposite affinity: they were located primarily in open hill, forested hill, and riparian habitats. Thus, by sampling different habitat types in order to monitor elk recruitment, pronghorn and mule deer recruitment can also be monitored.

Figure 18: Ungulate Group Distribution in Different Habitat

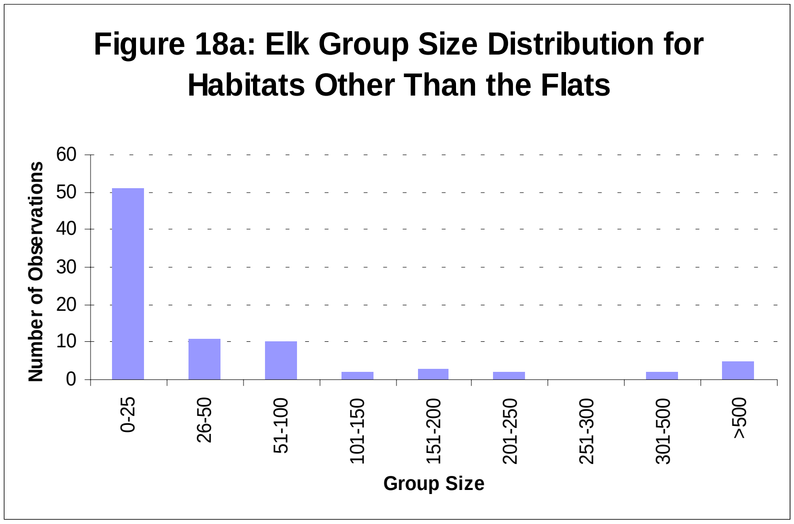


Figure 18a: Elk Group Size Distribution for Habitats Other Than the Flats

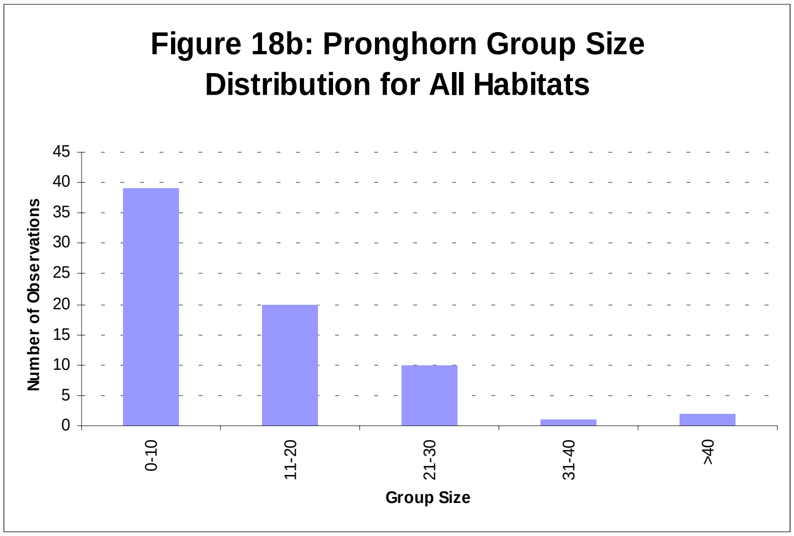
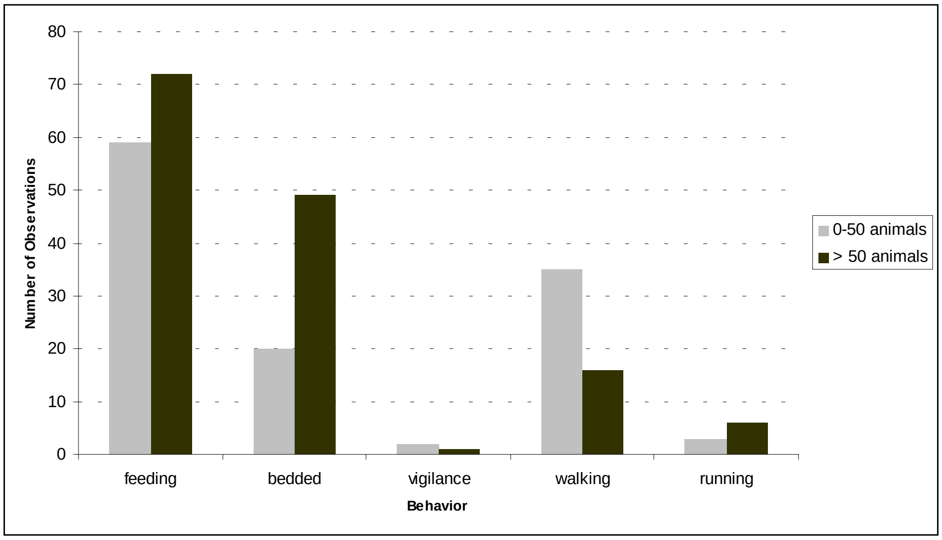


Figure 18b: Pronghorn Group Size Distribution for All Habitats

Large elk groups (a) are uncommon in habitats other than the flats. So, by surveying these habitats, we can add more small elk groups into our composition surveys. Also, the high frequency of smaller groups in habitats other than the flats, where wolf predation on elk was minimal, hints that the large groups in the flats might indeed be a behavior used by individual elk to minimize the chance of predation in that habitat. Large pronghorn groups (b) are also uncommon in the lower Madison Valley, even on a scale appropriate for the number of pronghorn present in the study area. Pronghorn thus might not be attempting to decrease the chance of being killed by wolves. This idea is supported by the observation that pronghorn received the lowest amount of predation pressure of any species that wolves killed.

Figure 19: Elk Behavior in Different Group Sizes



Another reputed advantage of larger group sizes is that animals in larger groups tend to be less alert to predation pressure because they have more comrades that have an interest in looking out for predators. No patterns vividly support this hypothesis in these data. However, animals in larger groups were observed bedding down more often than animals in smaller groups, and smaller groups were seen moving (walking and running) a little more often than larger groups, which could possibly indicate a certain level of unrest in smaller groups.

otherwise, most individuals will be engaged in other activities while a small number of individuals are alert for predators.

The amount of space between group members can also be used to index the relative responsiveness to predation for different ungulate groups (Figure 20). The concept is that groups that are spread out are less aware of a risk of predation. For elk, tightly packed groups were the norm, and groups that are spread out were relatively rare. Such an observation would be expected, as elk made up the largest portion of the wolf offtake. For pronghorn, there seemed to be no real pattern in terms of group spacing, and they experienced the lowest amount of wolf predation pressure.

Looking at the above measures of behavior, it appears that elk are attuned to the predation pressure exerted by wolves, which only recently returned to this system. This observation is concurrent with a recent hypothesis that ungulates are able to respond to new predators very quickly with behavioral changes that reduce the chance of predation [see Science volume 291 (February 2001), page 1036]. Other ungulates, however, do not seem to be too wary of wolf predation, which might be anticipated because they experienced such a small amount of predation pressure.

Figure 20: Spacing Within Ungulate Groups

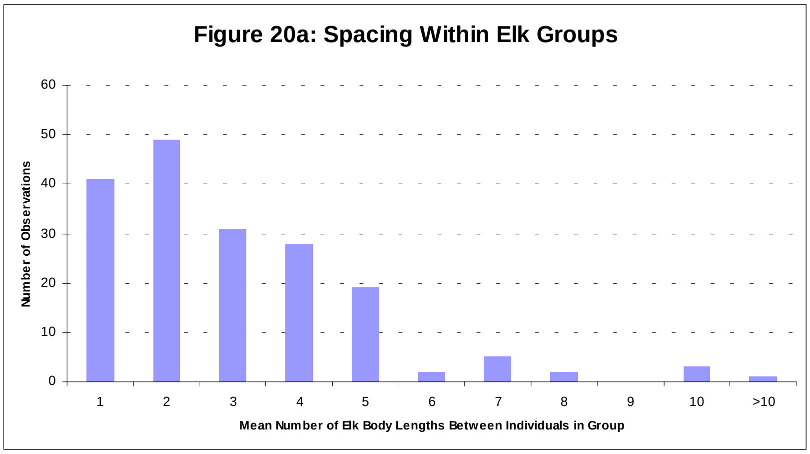


Figure 20a: Spacing Within Elk Groups

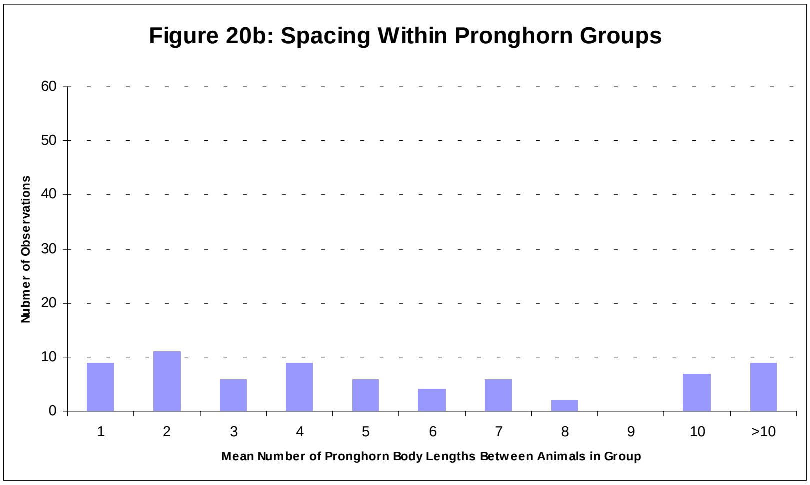
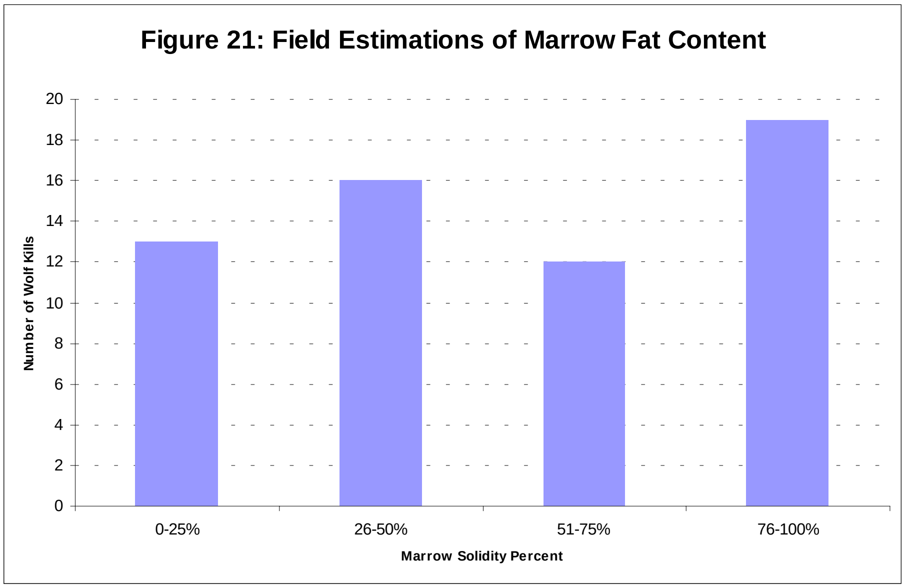


Figure 20b: Spacing Within Pronghorn Groups

Another measure of a potential behavioral response of ungulates to wolf predation is the amount of spacing within groups, which can be used as another index of the alertness or responsiveness to predation. (a) As expected, a tendency toward elk groups dwelling in close contact was observed for elk in the lower Madison valley, as elk made up most of the wolf offtake during the pilot year. (b) Pronghorn, which were exposed to minimal wolf predation pressure during this past winter, showed no real tendency toward tightly packed groups.

Vulnerability Data

Several factors might contribute to ungulate vulnerability to predation. For example, nutrition, stress, parasites, disease, and environmental conditions all may play a role in making certain individuals more likely to be chosen by wolves than others. Few data of this type were collected in a useful way this first winter. Environmental conditions are discussed in the next section, and data was also collected on the nutritional status of killed ungulates, as indexed by the fat content of the bone marrow (Figure 21). No real pattern jumps out from the marrow fat content of animals killed by wolves, which could mean that nutrition was not a major factor that wolves were able to key in on when selecting prey from all of the available animals during this past winter.



No strong pattern exists between the amount of bone marrow fat content as indexed by field estimates of marrow solidity (marrow with a higher percent solidity contains more fat) and the prey that wolves chose. This could mean that the nutritional status of individual ungulates did not factor into how wolves choose their prey in the Madison Valley this past winter, but several problems related to using estimations of marrow fat content make it so that we cannot be sure. We hope to resolve these problems by measuring the actual fat content of the samples in a lab and employing different methods in the coming years.

However, this conclusion would be a bit hasty because using this method to assess the condition of dead ungulates has a few problems. First, it tells us nothing about the nutritional condition of the animals in the live populations, so we have nothing to compare the data to in terms of what factors drive wolf prey selection. Second, it is not a very sensitive measure of actual nutritional condition, in that an animal might have depleted almost all of its body fat reserves while still maintaining a relatively high marrow fat content. Last, estimating the percent solidity of the marrow in the field in order to index fat content may lead to mistakes due to misclassification. We are currently addressing this last problem in an MSU laboratory by determining the actual fat content in a marrow sample taken from every ungulate examined. We hope to address the first two problems in the coming years by changing our methods to include samples from both live and wolf-killed portions of the population and by using a more sensitive measure of nutritional status. Beginning next field season, we also hope to add field methods that will allow us to better address how vulnerability in the live population relates to the prey that wolves select, including measures of all the vulnerability factors listed above. Some of these data can be collected in the field alone, but other samples will have to be collected in the field and taken to MSU for further lab analysis. This is a very important topic not only for predator-prey theory, but also potentially for ungulate management. If certain factors are determined to lead to increased ungulate vulnerability to predation, those factors might be able to be monitored by managers of areas where ungulates and predators coexist in order to help predict the wolf offtake for use in management decisions.

Environmental Condition Data

The pilot study year was marked by relatively mild winter conditions. Certain condition factors were monitored in order to provide an index of winter severity. Eventually, these data will be compared to wolf and ungulate data for analysis of the role of environmental conditions in wolf-ungulate dynamics. As mentioned above, we plan to begin more intense monitoring of environmental factors in the coming field season.

The ambient temperature and wind speed were recorded every time that an ungulate group was observed. Looking at the first temperature record and last wind speed record for successive days can provide an index of day-to-day temperatures in the study area, though it does not provide an index of temperature extremes (Figures 22 and 23). Obviously, the temperature and wind were often more severe than the figures dictate, but in such cases ungulates were not always observed. The temperatures during the pilot season were relatively mild with a few sharp dips, while winds were often gusty. Also of note is the relatively early warming trend (and thus snowmelt) seen this winter.

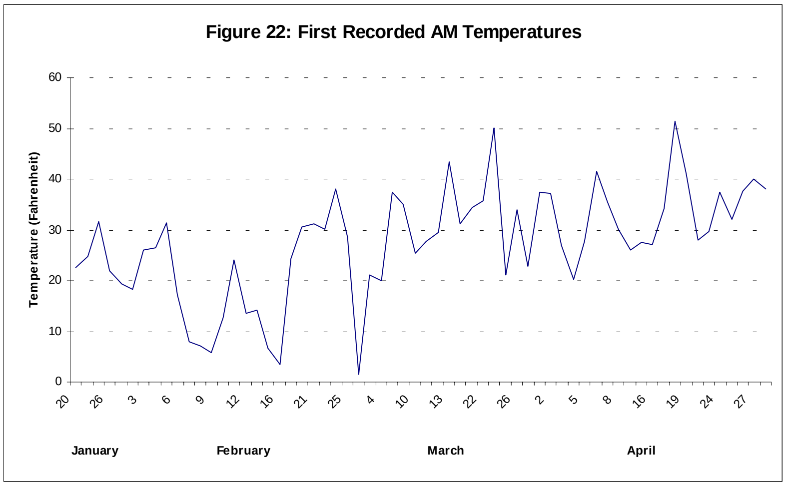


Figure 22: First Recorded AM Temperatures

Relatively mild temperatures and an early warming trend marked the 2000-01 winter. These are not the temperature extremes, as it was often colder than this record indicates. Such records can be useful in looking at year-to-year trends, but in the coming years we hope to add better measures of how temperature interacts with wolf predation.

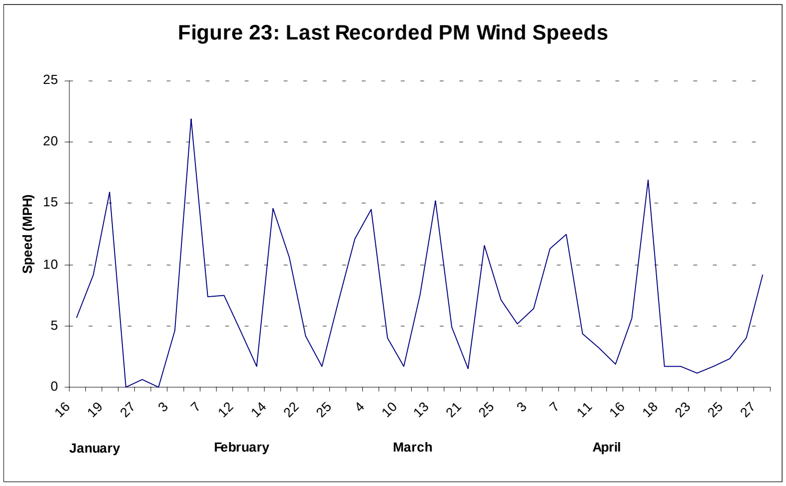
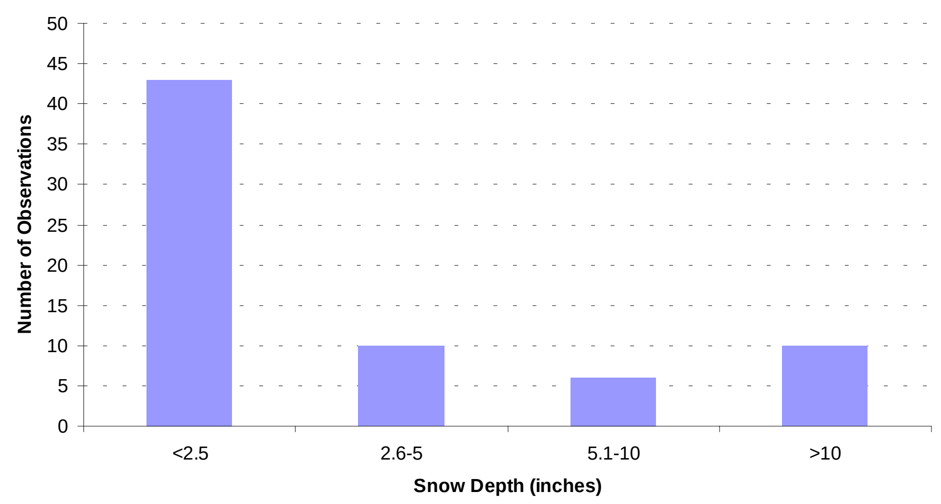


Figure 23: Last Recorded PM Wind Speeds

Winds in the valley were gusty this winter, often making the mild temperatures seem frigid.

Snow depth was recorded during the examination of every ungulate carcass found (Figure 24). Because of the different habitats and snow conditions in the study area, presenting the data in a time-series fashion would not describe the conditions in the entire study area accurately. The data do show, however, the difference in the snow pack between habitat types, as most kills were made in the flats, where the wind usually kept the land bare of snow. Deep snow conditions were present in other habitat types until the early thaw, accounting for deep snow conditions at those kill sites.

Figure 24: Snow Depth at Carcass Examination Sites



The high number of ungulate carcasses located in areas of little snow is indicative of the difference in conditions between habitats. Most of the kills were found in the flats, where the wind usually keeps the area relatively snow-free, while some carcasses were found in the deeper snow of other habitat types.

Conclusions

Considering that this was the pilot year, we were very successful at addressing wolf-ungulate interactions in the Lower Madison Valley. Most data collection methods that were used worked well, though we now realize that certain methods need to be revised and others need to be added to the study. The reason that the project has been a success thus far is because of the cooperation between the community, agencies, and the researchers. Obtaining the data requires spending time in the field and having logistical support, which would not be possible without permission and support from landowners, managers, caretakers, and community in the valley. The fact that landowners have financially supported the work done thus far goes above and beyond the already unusual amount of cooperation for this type of study and is the reason that the pilot year was completed. Also, without support from the US Fish and Wildlife Service in terms of putting collars on wolves for the purpose of this study, we would be unable to proceed. We are grateful for this amount of cooperation and pleased to be a part of it.

We plan to continue the study for a minimum of two more years beginning this fall, and the study is being converted into a Master's level graduate project for Justin Gude. Wolf and hunter data collection methodology will remain similar in the coming years. Ungulate data collection will be modified and expanded in several ways, most of which have been discussed. The new methodology will require increased effort from the research team, and FWP also plans to increase their ungulate monitoring effort to provide more information on elk distribution, numbers, and recruitment. Environmental condition data collection will also be expanded in the coming years, as well as further intertwined with wolf and ungulate data collection procedures. All of the Lower Madison data collection and analysis methods are being integrated and compared with the two other field sites in the Greater Yellowstone Ecosystem, which will provide more data and therefore more powerful comparisons. At the end of each field season an annual report, such as this one, will be produced. Future reports will also become available to all interested parties in July or August.

Continued success for the project depends on several factors. First, continued and expanded cooperation is a must. Second, we need the ability and personnel to put time in the field and the logistical support for fieldwork. Data collection of this type is often difficult and time-consuming, such that adding another technician to the project will allow for better and more efficient fieldwork. Third, the project depends on financial support for GPS collar rebuilding and lab equipment costs.

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Wolf tracks in the snow as the sun rises over the Madison Range after a winter storm.