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Examination of Scavenging Associated with Wolves

By

JAMIE N. BANKAITIS

Bachelor of Arts, North Carolina State University, 2009

Thesis

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Approved By:

Sandy Ross
Associate Dean of the Graduate School

Dr. Randall Skelton, Chair
Department of Anthropology

Dr. Ashley McKeown
Department of Anthropology

Dave Dyer, MS
Division of Biological Sciences

Bankaitis, Jamie, M.A., Spring 2012 Anthropology

Abstract

Chairperson: Randall Skelton

Forensic anthropologists often confront external influences on a body, whether they are human, animal, or environmental. One of the major and most common confounding factors for forensic anthropologists is animal scavenging and the damage this inflicts on the skeleton. The types of scavengers present vary from region to region, and in the Northwest, large carnivores such as bears, mountain lions, and canids are abundant. These types of carnivores can not only inflict incredible trauma to a skeleton, they can also disperse the remains over very large areas, making it difficult for forensic teams to recover all of the skeletal elements for identification. Research has been done on tooth mark and bite mark patterns so that scavengers can be differentiated, but there is very little research on how an animal's behavior may affect the context of a deposition site. The purpose of this research is to closely examine the scavenging patterns of a large carnivore common in the Northwest, wolves, by presenting a carcass to a captive wolf pack and visually observing their behavior, especially scavenging behaviors such as targeted areas of the body, the dispersal of remains, and caching. The hypothesis is that if a scavenger is able to be identified at the scene, then based on the animal's typical scavenging behavior, forensic professionals can narrow the parameters of their search and hopefully recover more skeletal elements that could be crucial to reconstructing the context of the scene. The results of this study reject the null hypothesis that scavengers cannot by distinguished from one another based on their patterns of behavior when encountering a carcass. The scavenging behavior of a wolf pack varies significantly from that of bears or mountain lions, given the differences between pack hunters and solitary hunters. It will be considerably harder to distinguish between wolves and other canids, especially coyotes, although differences in tooth and jaw morphology may assist with this.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

The determination of taphonomic change is one of the most crucial components to consider when handling a forensic scene (Haglund, 1997). Environmental conditions such as climate, topography, animal, and insect activity can heavily influence a site by dispersing remains over great distances or otherwise modifying them (Haglund and Sorg, 1997). Of these conditions, animal scavenging can be one of the most damaging. Large scavengers are capable of carrying skeletal elements over large distances, crushing bones into miniscule fragments, and may even bury remains. This can create significant issues with identifying the remains, but can also severely limit forensic anthropologists' ability to reconstruct the scene (Haglund and Sorg, 1997). Haglund (1997) writes that a more holistic comprehension of animal scavenging can prove vital in forensic investigations. This is true for locating dispersed skeletal units, interpreting the general times that the scavenging occurred during the postmortem interval (PMI), and differentiating animal artifacts and other soft tissue and bone modifications. A better understanding of animal scavenging could also help in establishing the relative PMI through the examination of dispersion and other damage to a skeleton by animals. It could provide an additional view on the ecological and environmental circumstances under which disarticulation occurred, as disarticulation exposes bones to environmental damage, such as weathering

The goal of this research is to examine the scavenging behaviors of a large carnivore and apply it to the forensic context. For this study, a pack of wolves (*Canis lupus*) was utilized. Wolves were selected for a variety of reasons. Given their recent reintroduction in the Northwest region, the probability that forensic cases in which wolves are a factor is increased (Boyd and

Pletscher, 1999). Also, the proximity of wolf habitats to humans and their wide distribution means that they will more likely be the responsible agents of scavenging on human remains. Wolf biology could provide insight into how a dynamic element of taphonomy (animal behavior) affects the overall site.

Identifying Scavengers

Identifying a scavenger is one of the more difficult tasks that forensic anthropologists face. At the scene, often it may not be immediately apparent exactly what kind of animal scavenged the remains beyond distinguishing between rodents and carnivores. The point of this research is to try and identify scavengers based on distinct scavenging behaviors combined with visual observations on scavenging manifestations on the bones.

Coard (2007) conducted a study with the purpose of developing a method to identify predators by placing the carcasses of four sheep and one foal in the Cambrian Mountains in the United Kingdom. His analysis focused on the damage done to hard skeletal tissues by an unknown predator through visual examination by the eye and a light-powered microscope, casting, and measurements of the length and breadth of tooth pits. Tooth scores, which are defined as any furrow or groove where the length is three times longer than the width, were measured and examined under a microscope with electronic sliding calipers. Tooth pits were defined as marks falling under this measurement, including individual cusps and crowns. The results showed that a medium-sized felid and fox were the responsible taphonomic agents, and that tooth pits should be a more reliable method for identifying predators than scoring. Coard (2007) found that the larger a tooth pit or the wider a score is, the larger the predator is. This conclusion is supported by the results of a study done by Dominguez-Rodrigo and Piqueras

(2003) using samples of fleshed bones gnawed on by lions, jackals, bears, and defleshed bones chewed upon by hyenids, dogs, and baboons. The lion, jackal, and hyena samples were collected from Africa. The bear and baboon samples were gathered from Spain, and the dog samples were obtained from feeding experiments with German Shepherds. Dominguez-Rodrigo and Piqueras (2003) found a distinct correlation between the length and breadth of the tooth pits, and tooth size was shown to be the central factor that accounts for this correlation. However, more data are needed to narrow this down to specific taxa. Cusp spacing and patterning may provide the necessary data to accomplish this, but the problem with this lies in the fact that the larger a scavenger or predator is, the more damage they can inflict, making measuring distinct cusps and cusp spacing difficult. Cusp patterns in wolves are unique due to the anterior position of the protocone and the relative narrowness from the protocone to parastyle in the carnassials (Coard, 2007). Unfortunately, distinguishing these subtle variations may only be able to be done in a lab under a magnifier once the bones are clean, not at the scene.

Differences in arch shape and bite mark shape also vary between animal groups (Murmann, *et al*., 2006). In the canid family, the anterior arch is deeply curved relative to other animals, especially cats, which have linear arches. When analyzing bite marks, intercanine width is frequently considered, although this tends to be more helpful for superficial bites, while mesial bone length is likely more accurate for deep bites (Figs. 1 & 2).

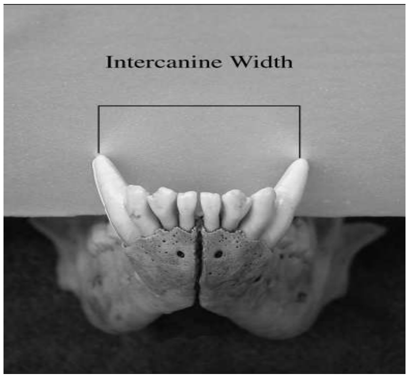

Figure 1 : Intercanine width measured at the canine cusp tips, as in shallow bites (Murmann, *et al*., 2006, pg. 847)

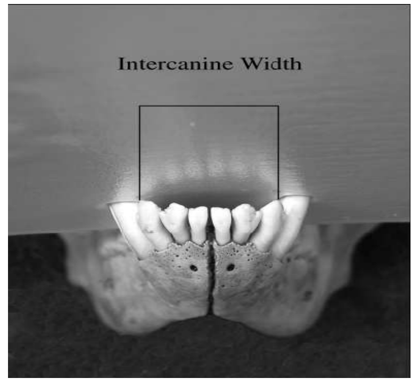

Figure 2 : Shows the appropriate canine width measured on the most mesial aspect of the canines in the cases of deep bites (Murmann, *et al.*, 2006, pg. 848)

One of the main issues confronting the identification of carnivore tooth marks is the capability of the analyst to distinguish between marks produced by animals, marks produced by humans, and other causes of bone modification (Blumenschine, *et al*., 1996). The results of two blind tests performed demonstrated that even unobtrusive carnivore tooth marks could be identified with near-perfect accuracy depending on the analyst's experience and available instrumentation. This indicates that an analyst needs at least a 10-16 power handlens or low power microscope to make these distinctions, as naked-eye diagnoses are unreliable.

There are many variables that factor into how an animal scavenges a body, such as anatomy and environmental conditions. Haglund (1997) suggested that anatomy of the scavenging animal affects the ease or difficulty of the removal of certain body parts by scavengers, that the architecture of joints and ligaments of the dead animal influences the overall resistance to scavenger-assisted disarticulation, and even that standard scavenging behaviors can be modified when body parts are in sheltered conditions, such as the presence of clothing or plastic, or if the remains are buried. Haglund (1997) also notes that observations of canid-scavenged remains in the Pacific Northwest show a relatively consistent pattern for dogs and coyotes, typically involving five stages (Table 1).

Table 1: Stages of Canid-Assisted Scavenging (N=37) (Haglund, 1997, pg. 368)

Stage	Condition of Remains	Range of Observed Postmortem Interval
0	Early scavenging of soft tissue with no body unit removal	4 hours to 14 days
1	Destruction of the ventral thorax accompanied by evisceration & removal of one or both upper extremities including scapulae & partial or complete clavicles	22 days to 2.5 months
2	Lower extremities are fully or partially removed	2 to 4.5 months
3	All skeletal elements disarticulated except for segments of the vertebral column	2 to 11 months
4	Total disarticulation with only cranium & other assorted skeletal elements or fragments recovered	5 to 52 months

Crania are usually found in nearly all cases involving canid scavenging, and damage is usually limited to punctures of the mastoid processes, perforations of the orbits and maxilla, and chewing on the borders of the nasal aperture. The bones of the upper extremities, including the scapulae and clavicles, are generally recovered less often than the lower extremities (Fig. 3).

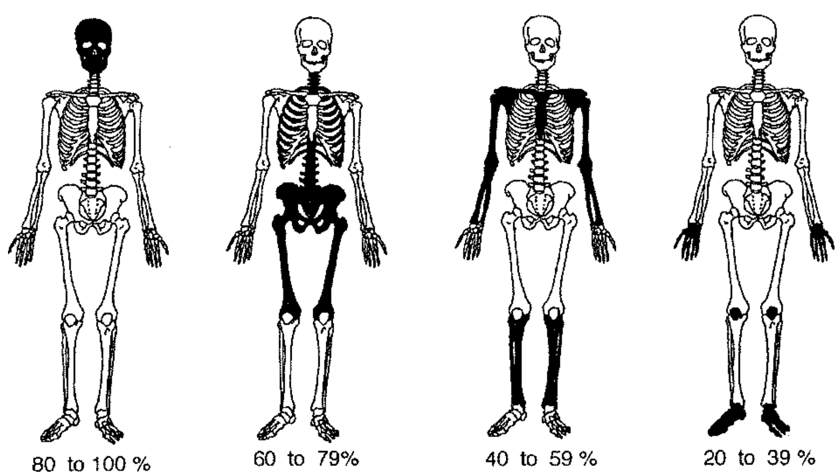

Fig 3: Frequency ranges for the recovery of skeletal units from all cases in the sample of scavenged remains (N=53). (Haglund, 1997, pg. 376)

Movement of the body by scavengers can be distinguished by the presence of drag marks or disturbed ground cover, although this can be influenced by things such as topography and vegetation (Haglund, 1997).

In summary, much of the current research on animal scavenging examines tooth marks and bite patterns, a useful and vital component to identifying the responsible agents. However, this can be limited in the field when bones are dirty, and perhaps still somewhat fleshed. It can be difficult to obtain an accurate identification until the bones are removed from the site and properly cleaned. By examining different behavioral patterns of large carnivores (wolves), researchers may be able to identify responsible scavengers at the scene while it is still intact.

Hypothesis

The working hypothesis is that the scavenging patterns of large carnivores may be distinguished from one another based on the behavior of the animal(s). This hypothesis may be accepted if I can reject the null hypothesis that the scavenging and trauma patterns inflicted by large carnivores cannot be distinguished from one another. This hypothesis will be tested by presenting a fresh pig carcass to a pack of five captive wolves located just outside of Missoula, MT. Observation of their scavenging behaviors will focus on elements such as hierarchal rank, sequence of evisceration and distarticulation, and the time frame in which these activities occur. These observations will then be compared to what has been documented in previous wolf scavenging studies, as well as the scavenging patterns of other large carnivores.

CHAPTER 2

LITERATURE REVIEW

The significance to studying wolf behavior so intensively is that it demonstrates how a wolf or wolves react to resources in their environment, such as carcasses they scavenge. While there has been abundant literature on wolf behavior in regards to their movements, social structure, and general diet, very few have focused on how a pack alters the state or location of carcasses they did not kill. Reviewing wolf behavioral patterns is thus necessary in order for wolf activity on a carcass, potentially human remains, to be recognized.

Willey and Snyder (1989) found that there is a fairly consistent pattern of carcass reduction and disarticulation in canids, with consumption of the hindquarters and ribs, and opening of the thoracic cavity occurring first, followed by destruction of the limb bone ends, rib heads, and vertebral column. Disarticulation typically occurred between 24 and 48 hours, with the forelimb usually being disarticulated before the hind end.

Wolf Social Behavior

Kleiman (1967) states that canids are relatively social animals, and express this in the amount of physical contact and communal activity, including hunting, feeding, and sleeping. Wolves are unique in that they also engage in communal howling, a rarity in canids. Wolves also tend to have more developed social interactions, as well as more specialized behaviors for expressing dominance and subordination, including more agonistic actions such as attack, defense, and flight. A wolf pack's ranking order is crucial to their survival, as wolves rely on a stable social hierarchy to maintain a functional hunting group.

Wolves are the largest members of the canid family, with adult males averaging around

95-100 pounds, and adult females averaging around 80-85 pounds. Wolves have a total of 40 adult teeth, with 12 incisors, 4 canines, 16 premolars, and 8 molars. Their ecological niche is that of *the* northern predator on larger mammals, with their only other major source competition being the mountain lion (Mech, 1970). Black bears are rarely observed in large, non-forested areas, far from forest cover as seen in Yellowstone National Park (Gunther and Smith, 2004). Black bears are smaller in body size, putting them at a competitive disadvantage with other large carnivores. Grizzly bears do occasionally interact with wolves, and interspecific killing between species has been documented. However, grizzly bears are usually displaced from a carcass by a wolf pack, especially if it is a mother grizzly with her offspring.

Packs

The strongest personality trait of the wolf is its ability to form emotional connections to other individuals (Mech, 1970). This ability results in the formation of packs, the basic element of wolf society. Wolves are able to exist in packs due to their aversion to fighting, as well as their adaptability to changing conditions. Social bonds are formed very early, usually beginning around three weeks of age (Fig. 4).

Fig 4: A male and female pair in Wolfkeep pack

After wolf pups pass a certain point in their growth, they become resistant to forming friendly relationships with unfamiliar wolves (Woolpy and Ginsburg, 1967).

It is important to distinguish between a wolf *population* and a wolf *pack*. A population consists of packs that occupy adjacent or overlapping ranges (Mech, 1970). Most wolf packs contain eight members or less, made up of a breeding pair, the pups, and a few extra adults that also may breed. Temporary relationships between two or more packs sometimes occur, which can result in very large groups, but this is rare. Packs maintain their composition fairly rigorously. They will sometimes chase off nonmembers, or in some cases, accept one member from another group and reject the other nonmembers. The most important aspect of a pack, however, is the strong social bonds that are required to hold a pack together. If these bonds did not exist, every wolf would simply go their own way.

The central unit to any wolf pack is the mated pair (Mech and Boitani, 2003). There are usually two ways a pack is formed: pack budding and pack splitting. Pack budding occurs when a dispersed wolf and mate try to establish their territory along the borders of a natal pack territory. Pack splitting is when a group of wolves splinter off and form new, completely separate territory. It is also important to note that pack size is not necessarily equivalent to hunting group size, as established packs will sometimes split further into smaller hunting parties temporarily. Largest pack sizes are typically seen in the winter, while summer brings about smaller groups and lone wolves (Mech, 1970). There are three main reasons why packs are larger in the winter: conditions for observation are best at that time, pups are able to hunt with the pack, and packs are nomadic in the winter, meaning the social center is no longer the summer den, but the pack itself.

Peterson, *et al*. (2002) found that in packs of gray wolves, dominant individuals successfully control the behaviors of the others, while pack leaders control pack movements. This means that a dominant wolf may not necessarily be a pack leader, although this situation is not well-documented in wild wolves. They discovered four probable behavioral indicators of leadership: scent-marking, frequency and time at the lead while packs were moving (frontal leadership), initiation of pack behavior, and nonfrontal leadership. The strongest predictor of leadership found in this study was high social rank, which Peterson, *et al*. (2002) hopes will resolve the misconception that packs are led by a single Alpha male. Instead, a male and female of high rank usually form the primary breeding pair and provide the most leadership to the pack, although leadership responsibilities may be shared in order to take advantage of communal experience in an area, thus lessening the energy expenditure for the dominant pair. Mech (1970) writes that there are two separate dominance lineages within each pack, a male one and a female one. However, these dominance orders can cross sexual lines in juvenile animals, and do not divide into male and female groups until sexual maturity is reached around 22 months.

Pack sizes will vary, but are not limited in terms of numbers. These variations can be attributed to differences in factors like mortality and reproductive rate, but there are four main influences that affect pack size (Mech, 1970). The first is the smallest number of wolves required to hunt and kill prey efficiently and safely. The second is the largest number of wolves that can be fed sufficiently on prey. The third is the number of other pack members that each wolf can form a social bond with, and the fourth is the amount of social pressure that each pack member could accept. The last two are especially important as pack size is more heavily dictated by social factors rather than food due to the constancy of pack size.

In the past, lone wolves were thought to have been either older individuals whose mate had died or dispersed individuals looking to form a pack or a territory (Thurber and Peterson, 1993). These solitary wolves usually stayed on the border of known pack territories, hunting smaller prey and scavenging kills made by large packs. Thurber and Peterson (1993) hypothesized that there may be two reasons for solitary wolves or small packs. The first is that if population density is high in relation to available resources, more pack members may disperse to avoid intrapack conflict or to find more abundant food resources. The second is that if population density is low in relation to resources, pack members may disperse to form several smaller breeding packs, increasing the population. This means that transient relationships in wolf packs do exist, usually because younger wolves travel to and from their natal pack before permanently separating to form their own pack and territory. This flexibility in pack size helps cushion the constant fluctuations in the wolf's social and ecological factors (Mech and Boitani, 2003).

Dispersal

Wolves are generally highly nomadic, typically dispersing over areas that can exceed 600 kilometers (Boyd and Pletscher, 1999). Dispersion can occur as a response to pressures such as food competition, mating, environmental disturbances, social hostility, and the availability of suitable habitats. Wolf dispersal occurs when a wolf permanently leaves its natal area. This can be a gradual process, with a wolf separating itself for days or weeks before permanently departing. The immediate reason for this departure is unclear, but could be due to factors such as nutritional deficiencies and social stresses. In the central Rockies, dispersing wolves may have a lesser chance of encountering prey or potential pack mates to help with hunting versus wolves in the more homogenous mid-western United States. Due to the difficult terrain, wolves in the Rockies would have a greater need to conserve energy as they must travel farther between widely dispersed ungulate winter ranges. Messier (1985) stated that wolf dispersal is a lengthy and dynamic development that spans many months or even years in a saturated population in a relatively homogenous area. Boyd and Pletscher (1999) found the exact opposite: that wolves engaged in very few extraterritorial movements and that once wolves permanently parted from their pack, they dispersed relatively quickly.

Offspring tend to stay with their parents from anywhere between 10-54 months, depending on the environment, and except under extenuating circumstances, all will eventually disperse (Mech and Boitani, 2003). Wolf dispersal occurs as a continuum, graduating from single, short absences from the natal pack to moderate and multiple extended leaves to permanent departure. Wolves usually engage in directional dispersal, or the tendency to move a greater distance in a more or less single direction, with the focus of dispersion being the maximization of breeding opportunities instead of locating optimal resources.

Movements

Boyd and Pletscher (1999) established that wolves are very nomadic, and this is one of their most distinguishing traits. The wolf's ability to travel serves the two essential roles of a wolf's life: obtaining food and maintaining their territory (Demma and Mech, 2009). A wolf pack's annual cycle consists of two seasonal movements: home-site based summer travel (April to late fall) and nomadic winter travel. During the summer months, wolf movement mainly centers on the pack's present den or another rendezvous location from which every adult will go out to search for food and then return to feed the pups. Breeding males will spend less time in den areas than breeding females, although all breeding wolves demonstrated extensive and habitual use of the homesite. Breeding wolves were also usually present on a daily basis while non-breeding wolves used the homesite erratically. The spatial distribution of wolf travel was determined by the repetitive use of one homesite intermingled with movement to other areas of the pack's territory.

Packs can travel up to 35 miles overnight, and 45 miles in a day (Mech and Boitani, 2003). A wolf's build can allow it to travel steadily at around 8 kilometers per hour. When moving over land, wolves usually travel single file, allowing the greater number of pack members to conserve their energy (Mech, 1970). Wolves tend to travel to wherever the prey is, avoiding areas that contain no prey such as conifer swamps and mountains in the winter, as their prey prefer to stay in the valleys. However, wolves will utilize easy travel routes situated in prey-free regions, such as frozen lakes and shorelines. In regions with high mountain ranges and very deep snow accumulation, such as the Rockies of North America, wolves will shift their activities to lower elevations during the winter.

Territory

An animal's territory is defined by the area that the animal(s) will defend against others of their own kind (Mech, 1970). Wolves are generally highly territorial, depending on competition pressures, economic defensibility of resources, and the adaptive cost of aggressiveness (Mech and Boitani, 2003). Territories can cover large areas with high numbers of prey, and as wolves circulate their territory to hunt, they rarely come across their neighboring packs. Territories are highly variable in size, with about 33% of this variation due to prey biomass.

Dens/Rendezvous Sites

Den selection is critical to the pack because its affect on reproductive success (Kaartinen, *et al*., 2010). The type of den a pack selects can depend heavily on the habitat available to them. Wolves tend to den more or less at random throughout their territory, although they will avoid the outer one kilometer or so of their territory boundaries (Mech and Boitani, 2003). There is evidence that the larger the territory, the closer to the center the den will be. Since rendezvous sites are typically located in the general denning area, den location is usually the strongest determinant of a pack's location in a territory. In Finland, dens were identified based on marking left by wolves, trampled vegetation, and the presence of scat and hair (Kaartinen, *et al*., 2010).

Pregnant female wolves may concentrate around a den site for up to a month before birth (Mech and Boitani, 2003). Most natal den sites are located near water, and can be located in a variety of places based on the landscape. In the tundra, wolves may den in crevices, caves, or rocky scrapes, while in forested areas, dens can be dug under tree roots. Several dens may be dug by the females and other pack members in close proximity to one another, or as far apart as ten miles. The entrance to the den tends to measure approximately 14-25 inches in diameter, and is typically oval in shape (Mech, 1970). The tunnel can run about the same size or larger, and generally extends 6-14 feet in, with an enlarged chamber at the end. Each den can contain several passageways and entrances, but a large mound of dirt is usually present at the main entrance (Fig. 5). Adult wolves usually prefer to lie on elevated areas overlooking the den, and if undisturbed, a pack may reuse a den site year after year.


Fig. 5: Den photographed at Wolfkeep

Once the pups are born, they stay in and around the den for their first 8 weeks or so, although the mother may move them from one den to another during this time (Mech and Boitani, 2003). When pups are 8 to 20 weeks, they inhabit a "nest" located above the ground. The mother remains with her pups a majority of the time in their first 3 to 4 weeks of life, but afterwards, the amount of time in which pups are left alone varies. During the pups' first few weeks of life, they are fed predigested food obtained through regurgitation. Pups are fed this way not only by their parents, but by other members of the pack as well. At around 3 months of age, the pups begin learning how to hunt with the pack. At 4 to 10 months, adolescent wolves are mobile enough to join the adults in the hunt, although they are not full-sized yet. It is important to note that at 26 weeks or so, the adult incisor, canine, and carnassial teeth have fully erupted, even though the wolves are still growing (Gipson, *et al*., 2000) (Fig. 6).

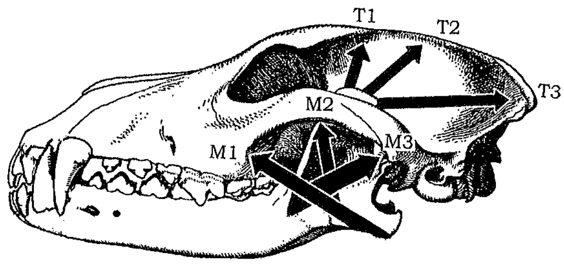

Fig. 6: Orientation of the temporalis (T1-T3) and masseter (M1-M3) muscles (Mech and Boitani, 2003)

Rendezvous sites are activity areas around the den site that are used by wolf litters once they abandon their den (Mech and Boitani, 2003). These sites are characterized by networks of trails, beddings, and activity areas. Evidence suggests that some of these sites seem to have originated as locations where adult wolves had made a kill, usually of a large animal. It appears that rather than bring the food back to the pups, the wolves simply brought the pups to the food.

Wolf Diet

The wolf is an opportunistic animal with an excellent ability to locate food (Mech and Boitani, 2003). This ability is characterized by flexibility and opportunism, as wolves are able to survive on any prey

"large enough, abundant enough, and catchable enough" (Mech and Biotani, 2003).

In North America, wolf prey in the wild have continuously occupied desirable habitats with relatively low human densities, as they experience drastic seasonal shifts, including a long winter season in which they are more vulnerable to wolf predation. In the winter, the wolf diet consists mostly of ungulates while in the summer, their diet becomes more diverse with the inclusion of beavers, snowshoe hares, and juvenile ungulates.

When a kill is made, devouring the carcass as rapidly as possible is a clear priority for wolves, but there are limitations as to how much a wolf can consume at once (Mech and Boitani, 2003). The average per capita consumption of a carcass would be 22 pounds on the first day, and 13 pounds on successive days. It is the privilege of the dominant pair to feed first, (although this can vary), but in general, the wolves of high rank can finish their initial feeding on a fresh kill in an hour or less. Subordinate wolves will then feed while the dominant wolves rest, even searching out ridgetops or treetops to eat in seclusion. Low ranking members of the pack may also run to the carcass, tear off a limb, and drag it away to feed safely. Wolves typically rest less than 100 meters from their kills, but depending on seasonality, parts of their kill may be distributed amongst dens tens of kilometers away or in caches.

The standard consumption pattern is as follows: 1) opening of the body cavity and removal/consumption of the lungs, heart, and liver, 2) consumption of the stomach lining and intestinal wall, 3) consumption of the kidneys, spleen, and smaller internal organs, and 4) areas of large muscle masses are consumed, usually the extremities (Mech and Boitani, 2003). Bones are also required by wolves in their diet as a major source of calcium and phosphorus for maintenance of their own bones. The bones and hide of an animal are usually the final parts of a carcass to be eaten as they are not very digestible. More often than not, the skull, mandible, vertebral column, long bones, and hide are left, although these bones are almost always gnawed clean of flesh (Mech, 1970). In exceptionally large prey, such as moose, leg bones are typically left articulated, but the legs are widely separated. Additionally, half of the vertebral column is usually attached to the skull, while the other half is attached to the pelvis. Chewing is normally apparent on ends of the long bones, the edges of the pelvis, the scapulae, and the mandible.

When environmental conditions shift, so does the relationship between wolves and their prey (Mech and Boitani, 2003). When conditions are favorable to prey, this hinders the well-being of the wolves, but when conditions are unfavorable to prey, this promotes it. This means that in spring and summer months, when food is abundant and large ungulates are able to move around more freely, wolves are probably less successful in their hunts. However, in the colder winter months, vegetation has become less plentiful, and snow cover hinders movements of ungulates. It is in these months that wolves may be more successful in their kills. In general, however, wolves will eat just about any meat available, including carrion and garbage.

Caches

Once a wolf has eaten its fill, it may begin caching its food. These caches may contain anything from an intact ungulate calf weighing 6-8 kilograms covered in snow to regurgitated meat chunks in a shallow hole dug into the ground (Mech and Boitani, 2003). This type of behavior is important in the summer as it can secure excess food resources left from a large kill and reduce to amount lost to other scavengers and maggots. Wolves also tend to distance themselves from the kill before they begin caching, most likely to reduce the risk of theft from other animals. Mech and Boitani (2003) wrote that although they suspect that wolves will cache in the winter, there appear to be no clear cases of this. Mech (2003) stipulates that wolves would have little reason to cache in the winter, as packs tend to easily devour an entire kill at once.

Snow

It is no mystery that foraging for food is one of the primary activities of a wolf pack. However, there are several factors that can influence wolf foraging behavior, such as prey selection, search distance, and spatial use (Kunkel, *et al*., 2004). These factors also act as crucial parameters in wolf-prey interactions. In a study conducted by the University of Montana-

Missoula, Kunkel, *et al*. (2004) found that snow depth tended to be the primary influence in search distance, as increased snow depths can increase encounters with potential prey. Although no significant relationship was discovered between wolf density and search distance, wolves in Quebec have been observed to hunt more intensely when prey densities are low.

Huggard (1993) examined snow's heavy influence on wolf-prey interactions, finding that while deep snow limits the movements of both wolves and ungulates alike, wolves have a lighter foot loading which allows them to travel on top of a snow crust that would otherwise not support their prey. Huggard (1993) followed two packs of approximately five to eight wolves, with one to four wolves in each pack fitted with a radio-collar. Snow depth was recorded daily, and the packs were examined intensively in the winters of 1989 to 1990. The packs were observed returning to old kills several times for up to two months. The average snow depth when scavenging occurred was shallower than when kills were made and scavenging tended to occur more often in both early and late winter versus mid-winter when the snow was at its deepest. The results of this study failed to indicate that wolves avoided scavenging, suggesting that in periods where prey densities may have decreased, wolves would actively scavenge old kills instead of hunting. This is supported by the observation that in winters with deep snow, wolves traveled shorter distances between kills, yet scavenged a higher percent of known carcasses.

Interactions with Other Predators

When prey is sparse in the winter, the diets of similar species have the potential to overlap, especially when the primary food source is the same. This has been observed with wolves and coyotes, as both species' diets depend heavily on ungulates (Arjo, *et al.*, 2002). While it is common knowledge that scavenging can serve as a reliable method for obtaining food at a relatively low expenditure of energy, some of the costs of this can be aggressive encounters with larger predators. Competition for food can occur when diets are similar, however, different species are able to coexist with a relatively high overlap if variety is high in at least one species's diet, or if prey is plentiful. In more northern latitudes, prey variability is restricted, which can lead to an increase in dietary overlap between similar species, such as wolves and coyotes. Arjo, *et al*. (2002) found that while the diets of wolves and coyotes overlapped more frequently in the winters, coyotes tended to avoid larger predators both spatially and temporally, most likely to avoid conflict.

Aside from coyotes, the recent reintroduction of wolves to certain parts of the Northwest region has also lead to interspecies conflict with grizzly bears, another predator whose diet consists heavily of ungulates. Green, *et al*. (1997) conducted an examination of wolves and grizzly bears in Yellowstone National Park, noting that the wolves' integration into the area will most likely create competition with bears for carrion in the spring months. However, the scavenging behaviors of bears differ greatly from those of wolves. The authors write that a high quantity of carcasses scavenged by bears occurred within three days of the death of an animal, reasoning that the probability of finding edible material decreased significantly if the bear did not find the body within the first few days. This is different from wolves, which have been known to return to carcasses several times to feed (Huggard, 1993). Also, the likelihood of a bear scavenged ungulate in the spring increases with elevation. Grizzlies tend to den at around 2000-3050 meters, where there are fewer competing scavengers.

It has been documented that in areas where grizzly bears and wolves are sympatric, intraspecific killings by both species does occur (Gunther and Smith, 2004). Most of these interactions that occur involve defending young or competition over carcasses. In eight interactions documented between wolves and female grizzly bears with cubs, five occurred at carcasses, two were at wolf rendezvous sites, and one was at a neutral site. In the five instances where interactions occurred at a carcass, wolves displaced the bear family three times. This may be due to the slow reproductive speed of grizzly bears, and so mothers are less willing to endanger their cubs in competition for food.

Bauer, *et al.* (2004) examined the scavenging patterns of *Puma concolor* on mule deer carcasses in Peninsular Ranges of San Diego County in California. Forty-four deer carcasses were placed at twenty-three different sites. The carcasses were discovered and scavenged by pumas from one to fourteen days, with the average being five days, after deposition. Carcass conditions varied from frozen and fresh to rotting and infested by maggots. Bauer, *et al.* (2004) found that pumas treated carcasses they scavenge much like they would their own kills, exhibiting behaviors such as dragging carcasses to favored sites, caching, depositing scat, and scraping the area. Pumas are recognized as opportunistic predators, and this attitude seems to extend to scavenging as well. Scavenging may be a vital part to a puma's survival, as it meets the animal's nutritional needs while reducing the danger of injury while attempting to make a kill. Like wolves, pumas may scavenge more often in the winter, when cold temperatures reduce spoilage. While puma scavenging patterns encompass many traits that are similar to that of wolves, the fact that they are a solitary hunter and often kill their prey through stalking may cause enough differentiation between the two species' scavenging behaviors that they may be distinguished from one another.

Wolf – Human Interactions

A widespread belief about wolves among humans is that wolves are dangerous to people (Mech, 1970). Mech (1970) reported on a wolf attack on a person in 1968 in Turkey, but stated that in North America, there is no scientifically acceptable evidence available to support the idea that healthy, wild wolves pose a threat to humans.

However, after 1970, an increase in aggressive wolf-human incidents in Alaska and Canada occurred as a growing wolf population joined with an increase in human activity in wolf habitats (McNay, 2002). Until 1996, all of these encounters of unprovoked attacks resulted in low-level threats or superficial bites. After 1996, four of five of these cases involved serious human injury. McNay (2002) writes that wild wolves that have very little or no contact with humans pose little threat to human safety. However, as human populations encroach further into wolf territory, wolves become habituated and thus become fearless. This is further encouraged when wolves receive food directly from people, and they begin to develop aggressive behavior when approaching people. A wolf's response to fear is typically flight or controlled aggression, but as wolves become conditioned to humans, these responses can decrease.

Wolf movement is usually influenced by humans, as wolves will use features such as trails or roads to move around their territory as it provides a path of least resistance (Musiani, *et al*., 2010). However, although trails and roads are appealing as they allow for easier navigation, wolves will discontinue using them if the encounter rate with humans increases. In general, wolves tend to be very shy of humans and will usually try to avoid them as much as possible (Mech, 1970). Humans have also taken some action to avoid encounters with wolves. When wolves were reintroduced to Yellowstone National Park and Idaho, US Fish and Game established the option of closing off to humans a 1.6 kilometer area around active wolf dens and rendezvous sites located on public land during the denning season (Mech and Boitani, 2003).

In recent years, recorded incidents of wolf aggression towards humans appear to have increased in North America (Mech and Boitani, 2003). Most of these encounters were attributed to wolf self-defense, defense of other wolves, rabies, or aggression towards people accompanied by dogs. It is obvious now that even healthy, non-rabid wolves sometimes attack people, yet these attacks are rare and almost never fatal. It is important to keep in mind that much of the time in a wolf attack, it somehow feels threatened by a human's presence and will seek to defend itself or its pack, but healthy wolves do not actively hunt or stalk people with the intent to kill them for consumption.

CHAPTER 3

MATERIALS AND METHODS

Analysis of wolf scavenging was carried out to assess if wolf scavenging patterns can be distinguished from other large carnivores. The overall goal of this research is to provide an initial understanding of the pattern of scavenging exhibited by wolves, using a deceased pig as a proxy for human remains. This particular study focused specifically on the behaviors of the wolves in relation to how they scavenge a carcass. Wolves are present in this region of the United States, and it is highly probable that they will scavenge human remains if given the opportunity. Analysis of their particular scavenging behaviors could theoretically lead to more complete recoveries of human remains, especially in cases where disarticulation has occurred.

Research Area

This study took place at the Wolfkeep Sanctuary, approximately 16 miles from Missoula. This sanctuary is located off of Highway 200 E, and is maintained by Carl and Christina Bock. The enclosure in which the pig was deposited is wooded, and about 10 acres in size (Fig 7). Five wolves live in this enclosure, 2 males and 3 females. All 5 wolves are approximately 10-12 years old. Four are arctic wolves (*Canis lupus arctos*), and one male is a gray wolf. The four arctic wolves consist of the Alpha male, the Alpha female, and two low ranking females. The arctic wolves are also all siblings. The wolves’ regular food was withheld during the course of this study, and no new carcasses were introduced into the enclosure.

Fig. 7: The Wolfkeep Sanctuary's main enclosure

Specimen Placement and Data Collection

The specimen used for this study was a female pig weighing approximately 260 lbs (Fig. 8). It was purchased from a rancher located in Great Falls, MT. A pig was chosen as a proxy to a human body given anatomical similarities such as lack of fur, overall organ tissue composition, and bone composition. The pig was shot on site at 5:10 PM on November 11, 2011 with a .22 caliber rifle prior to acquisition. The pig's internal temperature at time of death was 102 degrees Fahrenheit. The pig was then wrapped and transported back to Missoula, where it was kept on a trailer overnight. The air temperature that night was approximately 30 degrees Farenheit, although it was not cold enough to freeze the pig.

Fig. 8: The pig

The pig was deposited in the enclosure at 10:00 AM the next day, and was left uncovered. Cold temperatures likely hindered decomposition and insect activity. A time lapse camera was set up against a tree just outside the fence of the main enclosure with a photographic interval of one minute to record the wolves' interactions with the pig, and closer images were taken, focusing on the areas of wolf activity. Daily logs were kept for 14 days before research was concluded due to prior commitments of the sanctuary's manager. The data collected included daily scavenging activity of the wolves, areas on the pig that showed scavenging behavior, and other activity patterns not associated with the pig carcass.

CHAPTER FOUR

RESULTS

The results presented in this chapter consist of visual observations made of the course of 14 days. A time lapse camera recorded images every minute from 10:00 AM to 8:00 PM every day during the course of this research. Closer images of wolf activity were also recorded every day with a digital camera.

Day One

The pig was deposited at 10:00 AM on November 12, 2011. Its ambient temperature was 70 degrees Farenheit. Upon deposition, the wolves exhibited some curiosity, flipping the pig over and rolling on it (Figs. 9 & 10).

Fig. 9: The wolves investigating the pig

Fig. 10: Blood smeared on the wolf's fur from rolling on the pig

After about one hour, the Alpha male (Woody) began to tug heavily at the hind end, focusing on the thin skin of the joint of the hind leg (Fig. 11), while the Alpha female (Mariah) and other male (Teton) began working at the abdominal wall and armpit (Fig. 12).

Teton was able to feed with the Alpha male and Alpha female without conflict, which is atypical of wild packs. The reason for this is that Woody and Mariah are brother and sister. They are the dominant pair, but not a breeding pair. Since Teton is not related to Mariah, they form a bonded pair, although they do not breed as Teton is neutered. Teton ranks below Woody, but his alliance with the Alpha female allows him access to the carcass, and he is able to feed alongside the Alpha male without conflict.


Fig. 11: The alpha male begins pulling at the joint of the hind leg


Fig. 12: The alpha female working at the armpit

This activity occurred for about half an hour, then the wolves bedded down for the afternoon. At around 4:19 PM, heavy activity of the three top ranking wolves was captured by the time lapse camera (Fig. 13).

Fig. 13: Tearing of the abdominal wall

The three topmost wolves were able to feed together without much conflict (Fig. 14), although the Alpha female did snap at her packmate, the male that ranks below her (Fig. 15). This is interesting in that this male is her “mate,” although they do not actively breed. This female ranks above her “mate” in this pack, which allows her to deny him access to the remains. In the wild, the Alpha pair are equal to one another, as the male holds no more dominance than the female since they are also a breeding pair (Mech, 1970). However, since a majority of the Wolfkeep pack is related, this has an effect on their social behavior.

Fig. 14: Communal feeding between the three top ranking wolves

Fig 15: The alpha female snapping at her packmate, a lower ranking male

At approximately 4:30 PM, 6 ½ hours after deposition, evisceration of the pig was evident on the time lapse camera (Fig. 16). This activity continued into the night.

Fig. 16: Evidence of evisceration beginning

Day Two

Visual observation the next morning showed that the pack had torn heavily into the abdominal wall (Fig. 17). Evisceration had begun, as the stomach was spilling out, but none of the other organs had been exposed or removed. Some small tears in the stomach lining revealed the contents, which consisted of a kind of grain, but none of the stomach was eaten. Based on observations, the wolves seemed to have actively eaten around the stomach, instead of removing it from the body and consuming it. This suggests that the wolves found the organ unappealing, perhaps due to the processed food inside the stomach.

Fig. 17: 24 hours after deposition

The time lapse camera did not capture any significant activity during this day, possibly due to the amount consumed by the wolves the previous night.

Day Three

There was little change to the pig this day (Fig. 18). There was some tearing at the hide covering the rump, shoulder and back, exposing the muscles there, but little consumption of the meat. It seemed as though the wolves were removing the hide very carefully, as opposed to tearing into it and consuming it. The organs remained intact.


Fig. 18: Three days after deposition

Day Four

By this time, the hide had stiffened due to exposure, and was much tougher. The meat itself remained unfrozen, but there was still minimal activity from the wolves. The stomach contents remained in the stomach, and none of the other organs were removed. Bits of meat and hide were observed around the pig, most likely resulting from the tearing and pulling of the hide. At this point, the wolves expressed much more interest in the hind legs and flank than the forelimbs and shoulder.

Day Five

On the fifth day, the temperature had dropped to below freezing overnight, enough to freeze the pig solid (Fig. 19).

Fig. 19: Five days after deposition

As seen in the figure above, the pack had pulled back the hide along the back, rump, and shoulder. Activity seemed to be most heavy at the ribs and hind end. The organs still had not been removed, which is unusual, and the animal has been dragged a few inches from its original deposition site.

Day Six

There was some light snow accumulation overnight. This kept the pig frozen, although this did not seem to deter the wolves. Activity patterns showed chewing at the hind end and at the ribs (Fig. 20). The organs remained intact, although the stomach had dried out due to exposure to the open air.

Fig. 20: Male wolf chewing at the hind end

Day Seven

After one week, it appeared that the wolves favored the hind end over the shoulder, as the rump showed much heavier activity. The hide along the back had been peeled away more, and the ribs were slowly being exposed. The organs remained intact, and the pig had not been moved more than a few inches from the original deposition site (Fig. 21). This was unusual for this pack, as it is typical for them to move a carcass to another part of their enclosure if they feel it is being interfered with by people. The daily activity of closely photographing the carcass and removing snow cover would be seen as interference, yet the pack left the carcass at its original deposition site. This may be further evidence of the pack's general disinterest in this carcass.


Fig. 21: One week after deposition

Day Eight

Images on the eighth day exhibited much heavier activity at the hind legs than had been seen in the previous week. There was evidence of tearing at both hind legs, exposing muscle (Fig. 22). The meat covering the ribs was also becoming more exposed, but there was little activity at the shoulder. Scoring from the teeth was also present in the muscle at the hind end (Fig. 23), and pig hair was present in the scat, based on visual observation. The scat had also become somewhat loose and runny, suggesting that the composition of the pig meat is significantly different than their usual diet.

Fig. 22: Evidence of consumption at hind end

Fig. 23: Scoring from the teeth in the muscle

Day Nine

More activity at the hind legs was evident this day (Fig. 24). An interesting observation was of the tiny scraps of meat surrounding the back of the pig. This most likely resulted from Teton's chewing, as this wolf is missing his canines. There was no further activity at the abdominal wall, and minimal chewing at the shoulder.

Fig. 24: Nine days after deposition

Day Ten

On this day, the temperature was much warmer, around 35 degrees Fahrenheit, which allowed the pig to thaw significantly. Activity at the rump included removal of the tail and further consumption of the muscle covering the hind bones (Fig. 25). A small portion of the stomach had been removed and eaten. The femur of the left hind leg was also exposed, indicating that there is not much biomass left on that area of the pig. Behaviors observed on this day included pawing at the hide (Fig. 26), and using a paw to brace against the pig while feeding (Fig. 27).

Fig. 25: Alpha male feeding on the hind end

Fig. 26: Wolf pawing at the hide as a means of peeling it back

Fig. 27: Feeding on the hind limb, using a paw as a brace

Day Eleven

The temperature had increased significantly on this day, averaging at about 43 degrees Fahrenheit. This thawed the pig out almost completely. Nevertheless, there was minimal activity from the wolves, other than some additional chewing at the hind end.

Day Twelve

Some apparent chewing to the back of the head and neck was observed (Fig. 28), but it was difficult to assess the exent of it as access to the main enclosure was not available this day.

Fig. 28: Twelve days after deposition

Day Thirteen

More hide had been removed from the back of the head and neck (Fig. 29). This is evidence of the wolves' shifting focus from the hind end to the fore end. Removal of the hide indicates possible interest or curiosity, as no significant amount of meat had been consumed. This also may be due to the wolves' continued activity at the hind end. The proximal aspect of the femur had been exposed at this time, but there was still a large portion of meat left on the thigh of the pig.


Fig. 29: Thirteen days after deposition

The abdominal cavity has also been eaten down to the stomach, but the stomach itself had not been consumed. Some scoring was evident in the meat at the rump, and the hide had been peeled away more along the backstrap. The left femur had been eaten around, loosening the left hind limb significantly, although disarticulation had not occurred.

Day Fourteen

There was light snow accumulation overnight. There was minimal activity from the wolves during the night (Fig. 30), other than some chewing on the neck and back. The wolves received two turkeys yesterday, as it was Thanksgiving, so that most likely influenced the lack of activity. This was the final day of observation.


Fig. 30: Two weeks after deposition

After fourteen days of visual observation, this research concluded. Approximately two months after, I returned to Wolfkeep Sanctuary to collect the bones of the pig. Four bones were recovered, as snow cover from the previous night made finding any others difficult. A vertebra, the left humerus and scapula, and the mandible were recovered from the denning area of the enclosure. All exhibited fracturing from the wolves. The vertebra exhibited a shearing fracture down the midline, with very little chipping or splintering. The humerus showed a spiral fracture down the shaft, also with little splintering. The scapula exhibited gnawing on the medial border of the scapular blade, and the mandible showed gnawing on the ascending ramus, with fractures along the inferior aspect of the mandibular body.

Upon the completion of this research, I observed five clear stages of scavenging behavior with the pack, as summarized in Table 2.

Table 2: Stages of wolf scavenging observed in Wolfkeep pack

STAGE	**DURATION**	**EVENTS**
Initial Stage	1-2 hours after deposition	The wolves investigated the remains by rolling the carcass over and rubbing their cheeks on it
Stage One	1-5 days after deposition	Evisceration of the abdominal cavity
Stage Two	5-12 days after deposition	Consumption of the hind end and back
Stage Three	12-14 days after deposition	Consumption of the shoulder and back
Stage Four	~ 2 months after deposition	Complete consumption of the entire carcass

CHAPTER FIVE

DISCUSSION

The purpose of this study was to observe the scavenging behavior and patterns of wolves on a pig carcass during the early winter months in Montana. This study is similar to that completed by Willey and Snyder (1989). They presented road-kill deer to a captive pack of five wolves, one adult female and four adult males, held in a 38 by 15 m wooded enclosure. A total of fifteen carcasses were presented over a course of two years, with the wolves having unlimited access to them. Their regular food was withheld during the course of this study when a carcass was presented.

The current research in this study examined the scavenging patterns of a captive wolf pack in Montana during the early winter month of November. The hypothesis sought to determine if the scavenging patterns of large carnivores may be distinguished from one another based on the behavior of the animal(s). Over the course of two weeks, daily observations, photographs, and logs tracked the sequence of scavenging of a pack of five wolves, consisting of three adult females and two adult males.

Pattern of Scavenging By Wolfkeep Pack

Although the wolves did not completely consume or disarticulate the pig carcass, there was a pattern in their feeding. There were three wolves that fed most frequently on this carcass, the Alpha male and Alpha female, as well as a lower ranking male. The two females of lowest rank did not seem to feed on the carcass. The pack immediately went for the abdominal cavity, where the hide was thinnest and easily torn away. The first organ exposed was the stomach, an organ typically eaten by lower ranking wolves. The stomach was left nearly intact and untouched, suggesting that it was unappealing to the pack. This may be due to the pig's diet, as its stomach contents consisted of a mixture of processed material, most likely grains. From this initial feeding, the three wolves that fed most frequently on the carcass focused on the hind leg. Wolves typically tear into the hind end of a carcass from the anus as it is the easiest point of entry, but this pack did not. This may be due to the tighter muscles of the rump on a pig, similar to that of a human. The pack instead ate down into the leg, eventually exposing the proximal end of the femur. During this time, the pack also began to pull back the hide along the side and back, again eating down into the carcass. They ate slowly along the left side of the carcass, exposing the muscle covering the ribs. They did not expose the vertebral column or ribs, nor did they remove any of the organs. Although the left hind leg became very loose, none of the extremities were removed. This may be due to the fact that in wild packs, the low ranking members run up, tear off a limb, and quickly drag it a safe distance away (usually a few meters) to feed while the higher ranking members remain at the body's core, as it contains the choicest organs such as the liver and heart. In this case, the two lowest ranking females were kept away from the carcass by the higher members of the pack, and so disarticulation was not necessary.

The pattern of feeding demonstrated by this pack did not match the expectations set based on typical scavenging patterns, as it took much longer than expected for this pack to consume this carcass. Overall, the pack showed a general disinterest in this carcass, appearing to eat only out of necessity as they were not receiving any other kind of food. The pack even removed remains from other carcasses, all ungulates, from their caches to feed on. This suggests that the wolves did not like this type of meat, perhaps due to its fattier composition. The wolves' manager even stated that the wolves were demonstrating very atypical behavior to what they normally display. The wolves were not territorial about this carcass, even when photos were taken at close range. For this pack, it is typical for them to move the carcass several meters from where it is originally deposited if they feel it is being interfered with. It is also unusual that it would take a pack of five so long to consume a 260 pound animal. When given deer or elk carcasses, the pack would fully consume and disarticulate them within a few days. This pig remained nearly intact after two weeks, suggesting further that the wolves found this carcass unappealing.

Scavenging Pattern Comparisons

When the scavenging pattern observed at Wolfkeep is compared to that observed in Willey and Snyder's (1989) study, significant differences are apparent. Disarticulation did not occur during the two weeks that the pig carcass was present in the enclosure, and more activity was observed at the hind end rather than the forelimb. The organs of the pig were not removed, and activity at bleeding areas, such as the nose, did not occur. This may be due to the difference in the type of carcass presented to the packs. Willey and Snyder used road-killed deer. This type of animal is more typical of a wild wolf's diet, given their predation of ungulates. Pigs are encountered much less frequently, which may explain why the Wolfkeep pack showed less interest in this carcass.

Haglund (1997) presented a time period much more extensive than Willey and Snyder (1989). Haglund's (1997) time table ranged from 4 hours to 52 months, beginning with early scavenging of the soft tissue and ending with complete disarticulation. During the two weeks that the pig was present at Wolfkeep, the soft tissue was mostly removed on the left side, with heavier activity occurring the hind limbs than the forelimbs. There were significant differences between the results of this study and those of Haglund. While this study used a pig carcass and observed wolf scavenging, Haglund examined human remains that exhibited signs of scavenging by coyotes and dogs. It is worth noting that despite these differences, the pack at Wolfkeep showed more similarities in their scavenging behaviors to Haglund's research, rather than Willey and Snyder's (1989).

The reason for why the Wolfkeep pack's scavenging behaviors were more similar to those presented in Haglund's (1997) study of dogs and coyotes most likely lies with the type of carcass present. A pig was used as a proxy to human remains given their anatomical similarities such as lack of fur, as well as general organ tissue and bone composition. Deer are ungulates, something that is very prevalent in a wild wolf's usual diet. They are herbivores, and most likely contain leaner muscle than pigs or humans, given their highly mobile lifestyle. A higher fat content in pigs may make them less appealing to wolves, as a wolf's digestive system may be less capable of processing fat given the amount of time a pack spends traveling. The scat from the Wolfkeep pack became runny and loose after a few days of feeding on the pig, supporting this idea.

Differentiation from Other Large Carnivores

Wolves are pack animals, and the scavenging behaviors demonstrated by pack animals can greatly differ from that of solitary carnivores, such as mountain lions or bears. Wolves' diets are similar to that of bears and mountain lions, as all three species tend to consume mostly ungulates. However, differences in their behaviors cause distinctions between their individual patterns of scavenging. Previous studies showed that bears will not typically feed on a carcass if a significant amount of time has passed since that animal's death (Green, *et al.*, 1997). Given that a bear's young travels with them, as they have no pack to help watch over the cubs, it is possible that a human scavenged by a bear with cubs would not be dispersed over a large area. Bears also tend to remain at higher elevations when scavenging for food, as they typically den at around 2000-3050 meters, where interspecific competition is less. However, bears are large, solitary creatures that are also capable of transporting remains a great distance. In a case of bear-scavenged remains in California, the only skeletal elements recovered was a portion of calvarium and mandible, as well portions of the femurs, tibias, humeri, right radius, and left innominate (Murad and Boddy, 1986). These elements were all recovered within a 70 yard radius of the abandoned vehicle located at the scene. Bears are also capable of ingesting smaller skeletal elements such as hands and feet, and so those parts of a body may be absent. The long bones of the skeleton would also likely exhibit heavy chewing as a means of obtaining the marrow from these bones, but differences in bite mark patterns can help forensic anthropologists distinguish between bears and wolves.

Mountain lions are also solitary animals, but their scavenging patterns could be more difficult to distinguish from a wolf pack's, as they bear strong similarities. Pumas are opportunistic scavengers, and exhibit behaviors such as caching, depositing scat, and dragging the carcasses to favored sites (Bauer, *et al*., 2004). In this case, it is likely that elements of the axial skeleton would be in close proximity to one another, while the extremities would be disarticulated. This is similar to wolves, however, pumas have a different dental formula that would result in a distinctive bite mark pattern. Comparisons of dentition between wolves (Figs. 31 and 32) and pumas (Figs. 33 & 34) can be seen below.

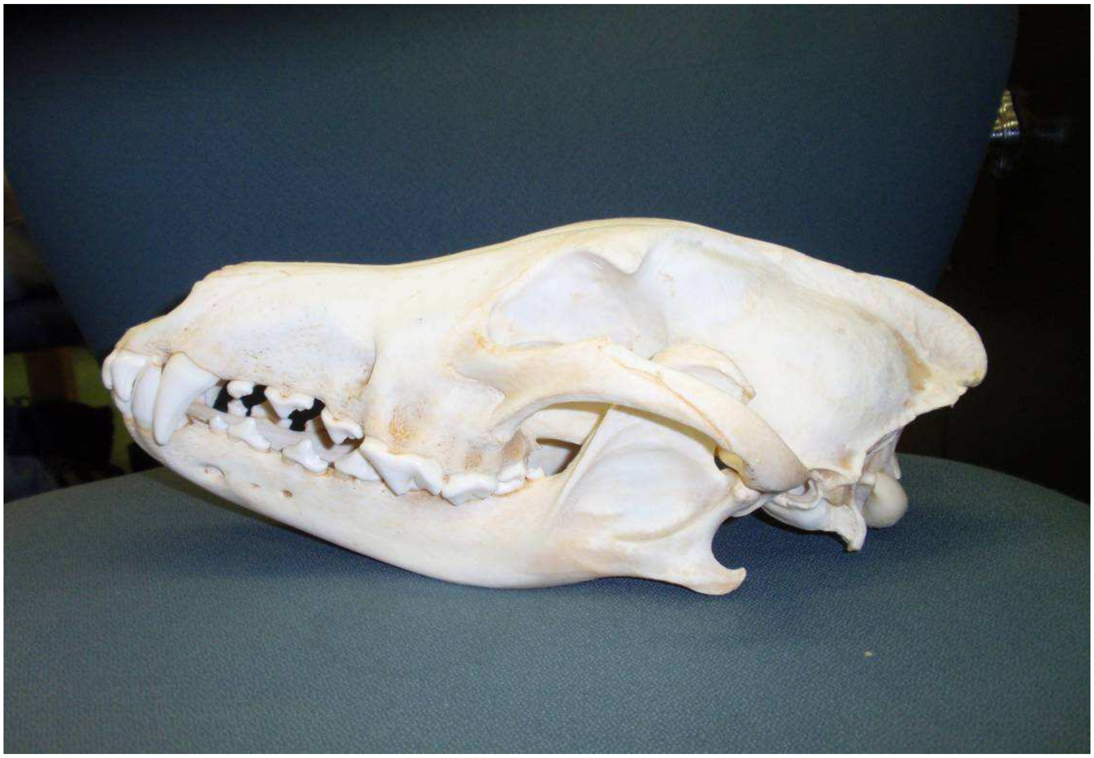
Fig. 31: Side profile of an adult wolf skull

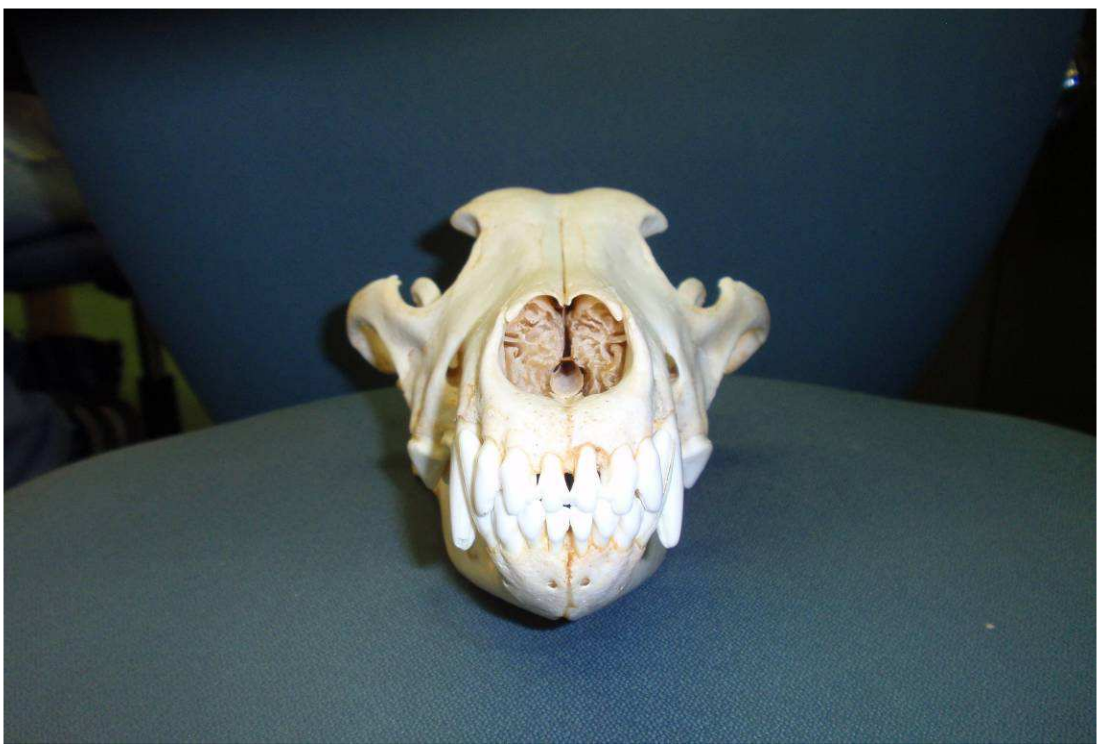
Fig. 32: Front profile of an adult wolf skull

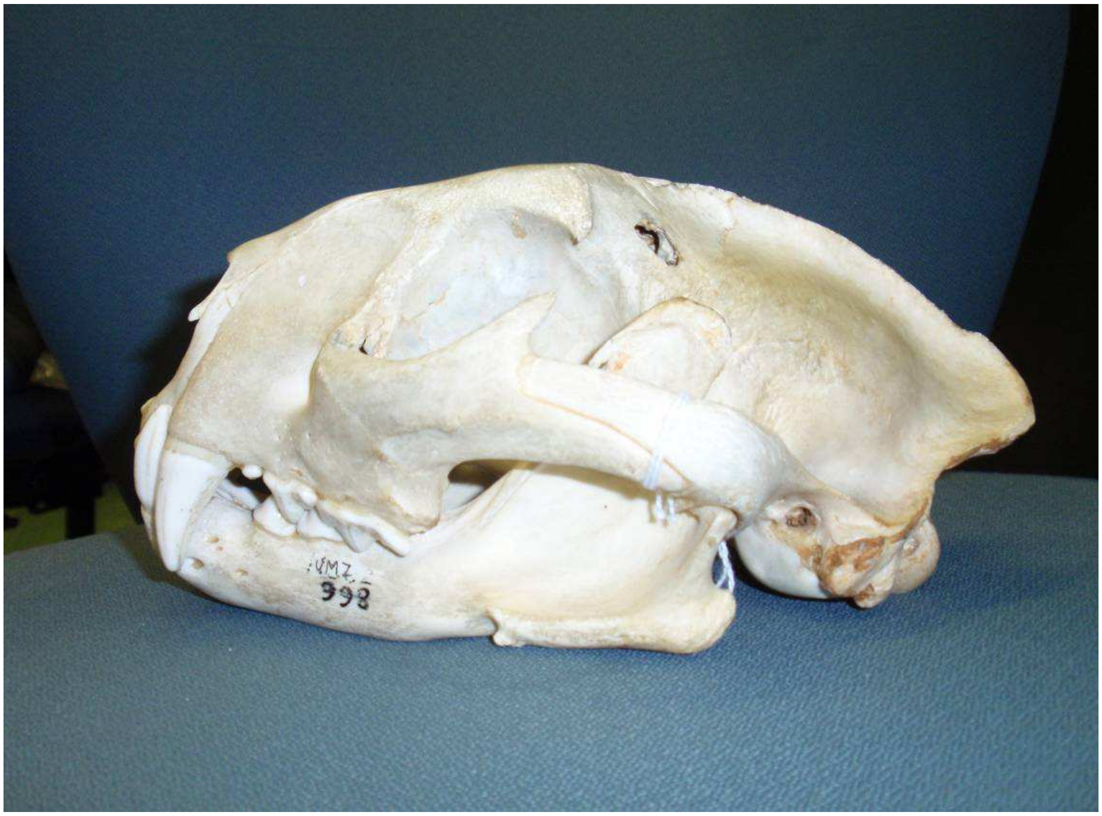

Fig. 33: Side profile of an adult mountain lion

Fig. 34: Front profile of an adult mountain lion skull

It would be particularly difficult to distinguish the scavenging patterns of wolves from other canids, especially coyotes. These species of carnivore are pack animals, and their scavenging patterns are very similar. In this case, distinguishing between canid species may at this time be limited to recognizing differences in tooth and jaw morphology, including intercanine width, tooth pitting, arch shape, and bite mark shape.

What to Look for When Encountering Remains Scavenged by Wolves

The typical pattern of consumption for a pack is typically: 1) opening of the body cavity and removal/consumption of liver, heart, and lungs, 2) consumption of the stomach lining and intestinal wall, 3) consumption of the kidneys, spleen, and smaller internal organs, and 4) consumption of areas of large muscle mass, usually the extremities (Mech and Boitani, 2003). Given this pattern, it is likely that elements of the axial skeleton will be scattered in close proximity to the original site of deposition. Once disarticulated, the extremities can be picked up and moved as a unit. These are the elements of a body that are most likely to be cached or transported back to the denning area. Based on Haglund's (1997) study of 53 individuals scavenged by coyotes or dogs, the cranium is typically recovered 80 to 100% of the time, with the vertebral column, pelvis, ribs, and femora recovered 60 to 79% of the time. The tibiae, fibulae, radii, ulnae, scapulae, and sternum are usually recovered 40 to 59% of the time, and the hands and feet are recovered 20 to 3% of the time.

The scavenging patterns of wolves can be strongly influenced by season. In the summer (April to late fall), especially during whelping season, the pack has to carry food back to the denning area for the pups. Also, caching is more prevalent as a means to slow decomposition and protect their food from other potential scavengers. If a human body is found in the summer and it is determined that wolves scavenged the remains, one could expect to find the cranium, vertebral column, ribs, and sternum scattered in close proximity to the original site of deposition, as this part of the skeleton is usually eaten by the high ranking wolves, and so would not be scattered far from where the body was found by the pack. It is probable that the smaller skeletal elements such as the ribs and vertebrae would show heavy fracturing due to crushing by the wolf's jaws. The extremities, if disarticulated, would be more difficult to locate. Lower ranking wolves tend to tear these pieces off and drag them safely away to feed, but will not stray far from the carcass. In this case, the extremities would typically be within 100 meters or less from the site of the carcass.

Cached remains tend to be more frequent in the summer, when decomposition rates are increased due to warmer temperatures. Caches are typically distanced from the body to prevent theft from other animals, and are recognizable as mounds of disturbed ground. Cached remains tend to be buried about 6 to 8 inches below the surface, and are frequently located under the beds of the wolves, which are usually situated against bases of trees or other types of wind breaks (Fig. 35).

Fig. 35: Beds of Wolfkeep pack

In the case of human remains, the extremities are the units most likely to be cached. An important thing to note, however, is that a single wolf can consume up to 22 lbs in one feeding. In an average pack of five to six wolves, a 200 lb. human could potentially be consumed by a pack in one encounter. In order to be cached, the body must be large enough to sufficiently feed the entire pack, including the subordinate members, with enough left over that the wolves will return, thus rendering a cache necessary to prevent theft and decomposition.

In the summer, when pups are too small to hunt with the pack, disarticulated remains are most likely to be transported back to the denning area. Given the vast amount of territory a pack can have, one would need to know where the denning site is, something that may only be accomplished through collaboration with a department such as the state's wildlife division or the National Park Service.

In the winter, the pups are large enough to actively hunt with the pack, and caching is much less frequent due to the drop in potential prey. When encountering wolf-scavenged human remains in the winter, it can be expected that the axial skeleton would be scattered around the area where the pack found the body, with the extremities disarticulated and lying within a 100 meter range. However, potential snow cover could make recovery of disarticulated elements very difficult.

CHAPTER SIX

CONCLUSION

The results of this research represent the findings of a two week-long examination of the scavenging patterns and behaviors of a captive wolf pack in Montana. The aim of this study was to determine if the scavenging patterns of large carnivores may be distinguished from one another based on the behavior of the animal(s), for the purpose of more accurately analyzing and reconstructing a forensic scene in which carnivores are a factor.

Based on the results of this study, I cannot reject my null hypothesis that the scavenging patterns and behaviors of wolves cannot be distinguished from that of other large carnivores. Bears and pumas are a wolf pack's strongest competition for food, and their patterns of scavenging bear strong similarities to that of wolves that cannot be distinguished based on this study. However, these animals are solitary carnivores, and so some variations can be expected. More intensive research into the scavenging behaviors of bears and pumas could provide much needed insight as to these differences. Coyotes would likely be the hardest species to differentiate from wolves, given their obvious similarities, but differences in tooth size and morphology may help make this distinction.

These results have provided a baseline for determining scavengers responsible for consuming human remains at the scene, using their behavioral patterns as indicators. This will hopefully serve to help forensic anthropologists in analyzing scavenged remains at the scene, while context is still intact. It will also assist forensic professionals in locating dispersed skeletal elements, establishing relative PMI, and provide another view on the ecological and environmental conditions under which disarticulation occurs.

Further research on large carnivore scavenging is warranted, especially in regions where their interactions with humans are greater. It is hoped that this study will be used in future studies on this topic to supplement the knowledge of animal activity on human remains in the forensic context. It would be ideal for this research to be used to better comprehend animal behavior when encountering a carcass, as this could lead to better recovery and overall analysis of human remains that have been scavenged by large carnivores.

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Appendix A: Fractures Commonly Seen in Remains Scavenged by Wolves

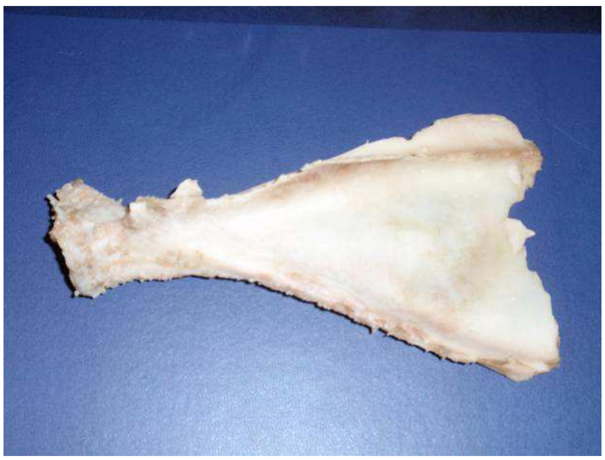
The following photos exhibit the bone and its corresponding fracture caused by the Wolfkeep pack.

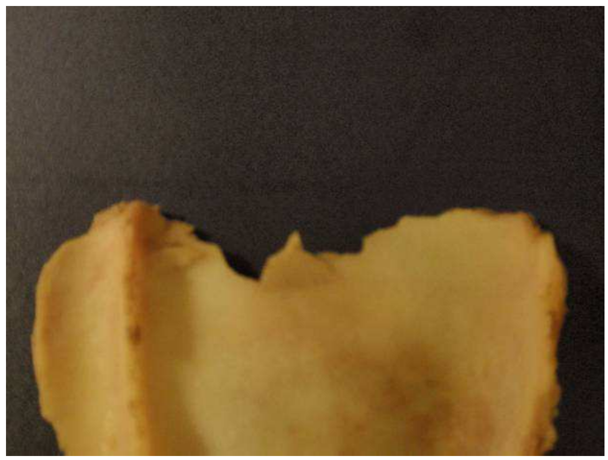
Bone 001 – Vertebra of ungulate exhibiting a shearing fracture along the right aspect of the vertebral body.

Bone 002 – Vertebra of pig exhibiting a shearing fracture on the midline of the vertebral body.

Bone 003 – Left humerus of pig exhibiting a spiral fracture along the shaft.

Bone 004 – Left scapula of pig exhibiting gnaw marks on the medial aspect of the scapular blade.





Bone 005 – Mandible of pig exhibiting gnaw marks on the ascending ramus and inferior aspect of the mandibular body.