FOOD RESOURCES FOR GRIZZLY BEARS AT ARMY CUTWORM MOTH AGGREGATION SITES IN THE GREATER YELLOWSTONE ECOSYSTEM

by

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DEDICATION

I dedicate this thesis to my grandfather Robert Lozano, for showing me the beauty of the great outdoors. He passed away in 2021, and he was a very big part in my love for the outdoors and wildlife. He took me fishing when I was younger and talked about the importance of fish. He truly appreciated the outdoors and passed it down to his grandchildren. He is one of the reasons I wanted to work with wildlife, and he was very excited and supportive of my work. I truly wish he was here to see this. Thank you, Popo!

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ABSTRACT

Army cutworm moths (*Euxoa auxiliaris)* (ACM) migrate annually to peaks on the eastern edge of the Greater Yellowstone Ecosystem (GYE). Grizzly bears (*Ursus arctos horribilis)* feed on these moths from mid-to late summer. The Shoshone Forest is preparing a management plan to address the conservation of these sites and foraging bears. Increased human use and GYE-wide changes in grizzly bear food availability and related foraging patterns are concerns prompting plan preparation. This study addresses grizzly bear diet and vegetation foraging locations on a prominent moth site ("South Site"). A 1991 study identified 4 forb genera utilized by bears at ACM sites. A 2017-2018 study identified 5 more and postulated that biscuitroot (*Lomatium* spp.), found in high elevation meadows, was an important resource for grizzly bears. During 2020-2021 we clarified these findings using scat collection and descriptions of available vegetation. We determined the frequency and volume of food items in 298 scats. We quantified vegetation at peak meadows (elevation: 3,078 – 3,657-m) and in cirque basins (elevation: 3,658 – 3,931-m) to record the percent cover of nine forb genera. We also described the density of biscuitroot and craters where bears excavated roots to determine if biscuitroot influences foraging site choices for grizzly bears. We confirmed use of 7 of the 9 previously identified forb genera. The most frequently consumed foods by grizzly bears were ACM (23% volume) and roots and tubers (38% volume). Similarly, the 2017-2018 study found 20% ACM by volume and 45% roots and tubers by volume. There was a positive, linear relationship between the density of flowering biscuitroot and craters from grizzlies digging roots in several peak meadows ($p < 0.001$). Rather than foraging solely on ACMs, grizzly bears on this moth site relied highly on vegetation in their diet, specifically roots and tubers from biscuitroot and clover. Our findings suggest grizzly bears have a diverse diet at this moth site that may allow them to adjust to variations in ACM abundance. They focused foraging on roots and tubers at 5 peak meadows near talus where moth foraging occurs; information that can potentially help mitigate human-grizzly bear interactions involving climbers.

CHAPTER ONE

LITERATURE REVIEW

Introduction

The grizzly bear, *Ursus arctos horribilis*, is an iconic carnivore in North America because it is a large, charismatic apex predator. Since 1975 when the species was placed on the threatened species list, grizzly bears have become a controversial topic (USFWS 1975; 1993). To recover the grizzly bear population in the lower 48 states of the United States, a recovery plan was created and approved in 1982 (USFWS 1993). In 1993, a recovery zone for the Greater Yellowstone Ecosystem (GYE) grizzly bear population was established (USFWS 1993). Over the past 50 years, the occupied range of the grizzly bear has expanded past the recovery zone (Bjornlie & Haroldson 2018a) (Figure 1). The recovery and management plans indicated that an emphasis should be placed on habitat monitoring, which includes observing food abundance (USFWS 2007a).

The GYE grizzly bear is an opportunistic omnivore capable of shifting its diet. That is, its diet is highly variable, and it can adjust to seasonal and annual changes in food availability (USFWS 2007b). This species will prey or scavenge on food that is available, including grasses, shrubs, roots, insects, fungi, fish, and small and large mammals (Mattson et al. 1991; Mealey 1975; 1980; USFWS 2007b; IGBST 2013). Grizzly bears prefer foods that are easily digestible and are high in sugars, protein, stored fat, and starch. The foods that are consumed must have enough nutrient value to survive denning and post denning (USFWS 2007b; IGBST 2013).

Moth Aggregation Sites in the GYE

The first documentation of bears foraging through alpine talus for army cutworm moths (*Euxoa auxiliaris)* (ACM) during the summer was in 1952 in Montana within the Mission Mountain Range (Chapman et al. 1955; Klaver et al. 1985). The Interagency Grizzly Bear Study Team (IGBST) first observed the GYE grizzly bear population foraging through alpine talus looking for ACMs in 1986 (Mattson et al. 1991). However, French et al. (1994) stated that hunters in the Yellowstone Ecosystem observed this behavior as early as the 1950s. In the early 1900's, garbage dumps were located throughout the GYE. Within Yellowstone National Park's (YNP) boundaries these garbage dumps became popular viewing areas for park visitors. It is believed that access to these garbage dumps kept the majority of the population at a lower elevation and therefore prevented earlier notation of grizzly bears foraging for ACMs at aggregation sites (Herrero et al. 2005; Penteriani et al. 2017). After garbage dumps were closed in the GYE in the mid-late 1970's and in addition to bears being hunted outside of the YNP area, the grizzly bear population declined. During this time the GYE grizzly bears were not believed to be utilizing moth aggregation sites (O'Brien and Lindzey 1994).

Since 1986, management agencies for the GYE have documented 31 ACM sites and 21 additional sites where grizzly bears have exhibit the foraging behaviors consistent with moths in the area (Bjornlie & Haroldson 2018b). However, more information is needed at these moth aggregation sites in the GYE, due to the increase of grizzly bear foraging activity at these sites, and this lack of information was first referenced in the Final Conservation Strategy for the Grizzly Bear (USFWS 2007b).

Currently, there is no site-specific management plan for moth aggregation sites in the GYE. Management for the Shoshone National Forest (SNF) was tasked with collecting more information about the ecology of ACMs and grizzly bears as well as the use of the aggregation sites by both species so that an informed management plan can be created (USFS 2015). There are currently five moth-site studies specific to the GYE two were food-habit studies, but none focused on the vegetation that grizzly bears forage on at moth sites (Mattson et al. 1991; French et al. 1994; O'Brien & Lindzey 1994; Robinson 2009; Nunlist 2020).

Nunlist (2020) focused on both human and bear use at two moth aggregation sites in the GYE. To determine grizzly bear use of these moth aggregation sites, they repeatedly visited predetermined sites to observe bear behavior and completed a resource selection function (RSF) analysis (Nunlist 2020). They noted grizzly bears were heavily foraging in five vegetative areas on what has been called the South Site. This was believed to be due to the presence of biscuitroot (*Lomatium cous*). In addition, during this study they completed a diet analysis that indicated that vegetation was one of the primary food sources grizzly bears were consuming other than ACMs (Nunlist 2020). Therefore, the U.S. Forest Service (USFS) has collaborated with Montana State University (MSU) to gain more information about ACM aggregation sites.

My study aims to collect data that will clarify and contribute to the knowledge of food resources grizzly bears use at moth aggregation sites to help guide management efforts. I focused on identifying food resources that are being consumed by grizzly bears at moth aggregation sites and compared the results with previous food-habit studies completed at moth aggregation sites. In addition, I aim to establish the biodiversity and distribution of the vegetation grizzly bears are foraging on at the ACM aggregation sites.

Grizzly Bear Feeding Behaviors in the GYE

Four main foods the grizzly bear feeds on for high caloric intake

When grizzly bears emerge from their dens, during the late spring to early summer, the bear will move to lower elevations where the vegetation is no longer under snow and will later follow the emergence of plants as the snowpack melts (USFWS 2007b). In addition, grizzly bears will scavenge for ungulates that have deteriorated in health or have died during the winter, and from spring until mid-summer they will predate ungulate neonates (Craighead & Craighead 1972; USFWS 2007b). In late summer to fall, the grizzly bear favor fruits, whitebark pine seeds, alpine plants, and ACMs (USFWS 2007b). Bear movement will change due to variation in weather, food abundancy, and if nutrient requirements are met (USFWS 2007b).

Food resources that are high in protein and carbohydrates are important to the grizzly bears diet because they are needed for denning (Mattson et al. 1991; Mealey 1975, 1980; USFWS 2007b). Four foods that are important for grizzly bears because of the high calories they provide include ungulates, spawning cutthroat trout (*Oncorhynchus clarkia*), whitebark pine seed (*Pinus albicaulis*), and ACMs (USFWS 2007b, USFS 2015). Habitat loss and human activities are affecting the abundance and distribution of these foods (USFWS 2007b). Whitebark pine seeds are decreasing because of the mountain pine beetle, *Dendroctonus ponderosae* (IGBST 2013). Within the YNP the cutthroat trout population is decreasing due to the introduction of lake trout (*Salvelinus namaycush*) (Koel et al. 2005). These four seasonal food sources are important to the GYE grizzly bear population and it is a part of the Conservation Strategy for the Grizzly Bear in the GYE to monitor these food resources (USFWS 2007b; IGBST 2013).

Food Resources in the GYE

Invertebrates

Grizzly bears feed on invertebrates. They have been observed feeding on more than 36 species of invertebrates, including 33 insect species, one annelid species, one mollusk species, and one spider species (Gunther et al. 2014). One prey species, ants, are not high in energy value; ants are 2.27 kcal/g (Craighead et al. 1995), but are high in protein (34%)(Yamazaki et al. 2012).

Vegetation

Throughout the year, vegetation is a primary food source for the grizzly bear. Graminoids (i.e., grass and grass like plants, which include: grasses, sedges, rushes, and arrow-grasses), including the roots and stems, are the main food resource for grizzly bears because of their abundance and availability each year in their home range (French et al. 1994; Gunther et al. 2014; Mealey 1980). Gunther et al. (2014) noted that 100% of collected grizzly bear scat contained graminoids.

Vegetation is only 40% digestible by the grizzly bear, whereas it is 75% digestible for deer and elk (Pritchard & Robbins 1990; White et al. 2017). Gunther et al. (2014) noted grizzly bear diets consist of more than 162 plant species, which include 85 species of forbs, 31 species of graminoids, 31 species of shrubs, 7 species of trees, (i.e., catkins, nuts, and seeds), 4 species of aquatic plants, and 4 species of ferns. Grizzly bears have a large selection of vegetation on which to feed compared to other food items, but most vegetation is low in calories. Plants can provide protein, fat content, and carbohydrates, but grizzly bears must consume large amounts of vegetation to receive necessary levels of protein, fat, and carbohydrates. Some vegetation such as seeds of the white bark pine (3.99 kcal/g) and clover, *Trifolium* spp., (4.83 kcal/g) have a high caloric content for grizzly bears, making it possible for bear to store fat from these species (Gunther et al. 2014).

Mammals

Grizzly bear diets typically have a large amount of protein and calories from ungulates such as elk, deer, and bison. Ungulates have a gross energy value of 6.80 kcal/g (Gunther et al. 2014), which is important in the grizzly bear diet because ungulates are 90% digestible (Pritchard & Robbins 1990; White et al. 2017).

Elk are present throughout the GYE and grizzly bears feed on them throughout their foraging season. They hunt for ungulates during spring and early summer more frequently than in late summer and fall (IGBST 2013; White et al. 2017). Grizzly bears also consume carcasses from wolf kills or ungulates that died from other causes (White et al. 2017). In addition, grizzly bears are opportunistic feeders and will feed on smaller mammals such as pocket gophers, voles, marmots, and pikas (French et al. 1994; Gunther et al. 2014).

Fish

Gunther et al. (2014) observed that grizzly bears in the GYE consumed 4 fish species, but cutthroat trout was the primary fish species consumed. Grizzly bears intake 6.10 kcal/g from cutthroat trout and feed on the spawning trout in the shallow streams that flow into Yellowstone Lake (Haroldson et al. 2005; Koel et al. 2005; White et al. 2017). Although cutthroat trout are one of the main food sources for grizzly bears, decreasing spawning in recent years due to the increase of lake trout and whirling disease resulted in a decrease of fish available for grizzly bears (Koel et al. 2005; Haroldson et al. 2005; White et al. 2017).

Feeding Behaviors at Moth Aggregation Sites in the GYE

Army cutworm moths

The army cutworm moth is a migratory species that flies from the Great Plains to the Rocky Mountains each summer. Only one generation is produced each year and the adult will die shortly after oviposition (Cooley 1916; Burton et al. 1980). Larvae hatch from the egg mid-to late fall and feed on emerging plants for a short period before hibernating for the winter (Burton et al. 1980). During the following spring, they forage in an area until the food is depleted, and when new resources are needed larvae may move in masses to a new location. This behavior during population outbreaks is why the species is called the “army” cutworm moth (Burton et al. 1980). The mature larvae will then burrow into the soil where pupation will occur (Burton et al. 1980). The pupal stage will last between 25-32 days (Walkden 1950) or 43-63 days (Cooley 1916) depending on temperature.

Adult ACMs will begin to emerge at the end of spring, however depending on where the population is located they can emerge during early summer (Burton et al. 1980). The moths will then migrate west to higher elevations after emergence to escape the high summer temperatures in the Great Plains and to access nectar sources (Burton et al. 1980; Pruess 1967).

Migration to the Rocky Mountains occurs over numerous nights during late spring and early summer (Robison 2020; Burton et al. 1980; Pruess 1967). The moths begin to arrive in the Rocky Mountains late June to early July (Burton et al. 1980; French et al. 1994; Robison 2009). Once the moths reach the high elevations of the Rocky Mountains, they will seek cover and congregate in alpine talus fields of the mountain slopes (French et al. 1994; White 1996; O’Brien & Lindzey 1994).

Moths will remain on the mountain slopes from late June through September foraging on nectar from alpine flowers where they accumulate fat for the migration back to the Great Plains. Moths typically feed at night and hide during the day in the talus (French et al. 1994; White 1996).

During the summer months, moths will be consumed by predators, including grizzly and black bear (*Ursus americanus*), coyote (*Canis latrans*), bats, mice, and birds. The moths provide 7.91 kcal/g for the predators, and because they are rich in fat and in large abundance grizzly bears favor this species (French et al. 1994; White et al. 1998).

A portion of the grizzly bear population in the GYE relies on the ACM. White et al. (1998) observed grizzly bears consuming as many as 40,000 moths/day, or about 2,500/hr. The grizzly bear forages on ACMs on talus deeper than 15 cm (O'Brien & Lindzey 1994). Moths seem to be most available to bears during early morning hours because they are hidden in large numbers in the talus (O'Brien & Lindzey 1994).

French et al. (1994) analyzed 284 grizzly bear scats collected in summer 1991 from the Absaroka Mountains in Wyoming and found that they preferred ACMs and graminoids. These two resources were found in high frequency in the scat: 79.23% of scats contained ACMs and 85.21% contained graminoid species (French et al. 1994).

Female bears with cubs or yearlings use the moth aggregation sites more than lone adults and sub adults (O'Brien & Lindzey 1994). Females with young most likely use these sites, in part, as an advantage to easily spot other bears and avoid them (French et al. 1991; O'Brien & Lindzey 1994). Large males do not seem to visit these sites as often (French et al. 1994; O'Brien & Lindzey 1994). Nunlist (2020) noted that there were 62 females with cubs, 29 subadults, and

175 lone adults. At the targeted moth aggregation sites there were more lone adults using these moth aggregation sites (Nunlist 2020).

In the fall, ACMs begin to migrate back to the Great Plains. Rabbitbrush are in bloom during this time, so moths may use rabbitbrush nectar to maintain fat and energy for flight through the migration (Cook 1927).

Other food resources

Nunlist (2020) documented during their opportunistic sightings that they observed grizzly bears foraged for vegetation 31% of the time, and during the observations they noted they were foraging heavily for vegetation at five specific vegetation areas at one of the moth aggregations sites. It is believed that they were foraging on biscuitroot and other vegetation. In addition, Nunlist (2020) analyzed 376 bear scats collected in 2017-2018 and found that grizzly bears are eating significant amounts of roots and tubers (38% volume).

Biscuitroot

The grizzly bear has large muscle mass in their shoulders called the suprascapular muscle and long claws that are well adapted for digging (Craighead & Mitchell 1982; Herrero 1978) giving them the ability to excavate roots (Herrero 1978). Biscuitroot (*Lomatium* spp.) is a common plant excavated for consumption of the roots by grizzly bears (Mattson 1997; Mattson et al. 1991). Biscuitroot roots are high in starch and highly digestible (Mealey 1975; Mattson 1997).

Biscuitroot can make up most of their diet during the hyperphagic period (Mattson et al. 1991). Mattson (1997) observed grizzly bears selecting biscuitroot sites to excavate by the size of root and dig-ability of the soil. Although grizzly bears are built for digging, it can become costly and it is worth the effort for them to find soil that is easy to dig to help preserve energy (Mattson 1997). At one of our study sites, “South Site,” bears have been observed excavating biscuitroot (Nunlist 2020; Dan Tyers personal communication).

There are not many studies conducted on the biology and ecology of *Lomatium cous*. Therefore, the following information is on both *Lomatium cous* and *Lomatium dissectum*, fernleaf biscuitroot, which is the largest of the *Lomatium* species and found at lower elevations. *Lomatium* species are members of the carrot family (Apiaceae) and a perennial, herbaceous forb (Scholten et al. 2009). Peak bloom for biscuitroot at lower elevations occurs mid-May (Mueggler 1983), and at alpine elevations blooming can occur as late as July and August (Mattson 1997) after snow melt (Scholten et al. 2009).

Fernleaf biscuitroot is found in areas that receive as much as 360 mm of mean annual precipitation, and in course-to-fine-textured soils with pH levels from 6.5 to 7.5 (Scholten et al. 2009). Once this species is established, it is very competitive against other plants because of its large taproots (Scholten et al. 2009). This perennial species can live 20 to 30 years and reach critical size in 3 to 4 years (Utah et al. 2003). In the first year of establishment, it can only produce a few leaves and will not produce flowers or seeds until the fourth year of production (Scholten et al. 2009). Cous biscuitroot is an alpine biscuitroot and the growth rate for these forbs is unknown and can be longer because of the harsh conditions they grow in.

Research Needs and Objectives

Out of the 31 moth sites in the GYE six were identified as more accessible to humans. Based on SNF personal and Nunlist (2020), two moth aggregation sites in the GYE were identified due to the concern for human safety and bear disturbance (referred to as the “North

Site" and "South Site"). Human activity has increased substantially more on the South Site than the North Site and has had more human and bear interactions (Nunlist 2020). Therefore, our field efforts were focused on the South Site. More detailed information is need at moth aggregation sites in the GYE, to create a specific-site management plan.

In 2017-2018, Nunlist (2020) observed bears heavily foraging on vegetation in five vegetative plots at the South Site, and believed the foraging was due to the presence of biscuitroot. In addition, Nunlist (2020) conducted a scat analysis that suggested that roots-and-tubers (i.e., biscuitroot (*Lomatium* spp.), clover (*Trifolium* spp.), vetch (*Astragalus* spp.), and locoweed (*Oxytropis* spp.)), in addition to ACMs and graminoids, were eaten by grizzly bears at these sites. My research extended this analysis to confirm and provide greater resolution on their diets at these two important sites. In addition, I wanted to understand where food items found in the scat analysis were located at on the South Site.

Therefore, my study had three objectives: 1) through scat analysis, identify the food resources grizzly bears are consuming at the North and South moth aggregation sites; 2) determine if the presence of biscuitroot influences whether grizzly bears dig in certain vegetative areas at the South Site; 3) focusing on the nine-forb genera identified in grizzly bear scat, quantify the alpha- and beta-diversity between the mountain peak and cirque-basins of the South Site. This reflects the high elevation area where grizzly bears are foraging in comparatively high density; and 4) establish the relative abundance of the nine-forb genera identified in scat across the vegetated part of the South Site where grizzly bears forage.

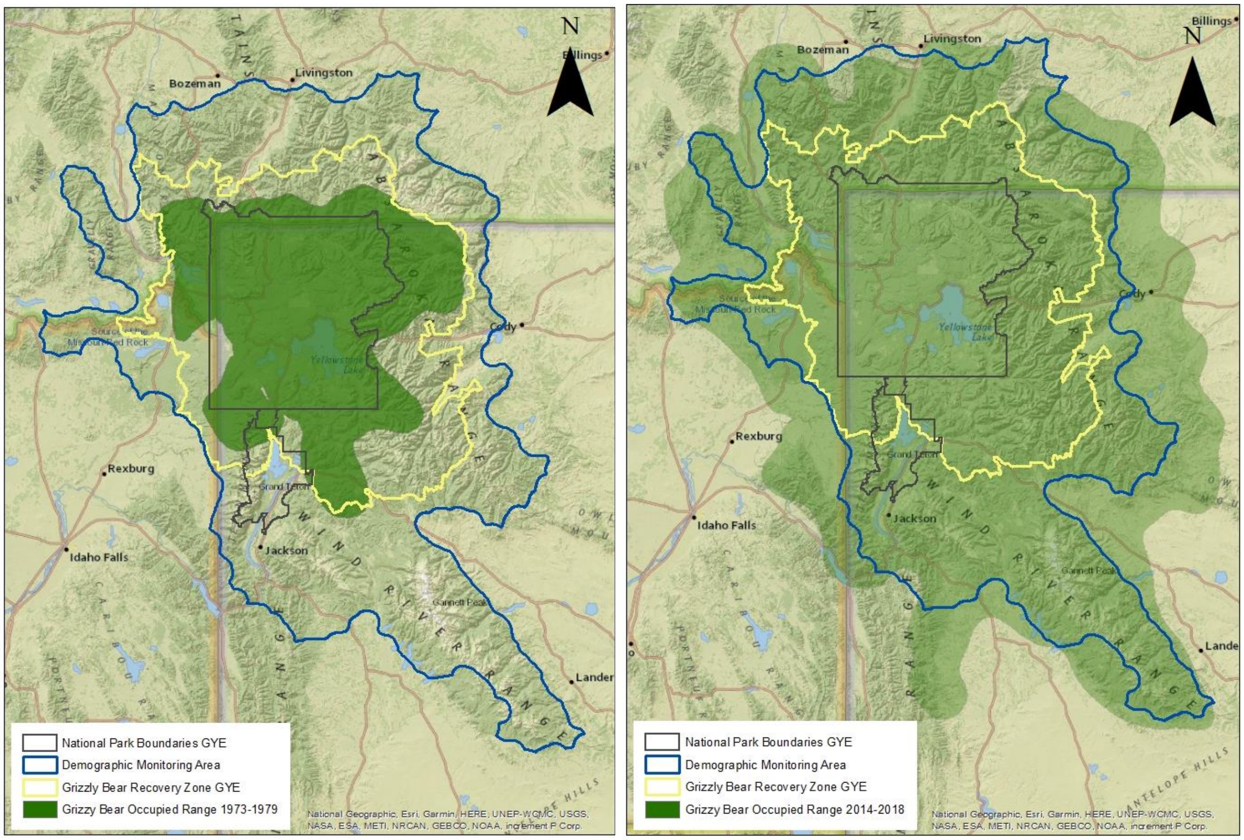

Figure 1. Grizzly bear occupied range from 1973 – 1979 (left) and 2014 – 2018 (right), demographic monitoring area, and recovery zone in the Greater Yellowstone Ecosystem (Bjornlie & Haroldson, 2018a).

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CHAPTER TWO

FOOD RESOURCES FOR GRIZZLY BEARS AT ARMY CUTWORM MOTH AGGREGATION SITES IN THE GREATER YELLOWSTONE ECOSYSTEM

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CHAPTER TWO

FOOD RESOURCES FOR GRIZZLY BEARS AT ARMY CUTWORM MOTH AGGREGATION SITES IN THE GREATER YELLOWSTONE ECOSYSTEM

Introduction

The Greater Yellowstone Ecosystem (GYE) grizzly bear (*Ursus arctos horribilis*) is an opportunistic omnivore. It is capable of diet shifting, meaning that its diet is highly variable and grizzly bears can adjust to seasonal and annual changes in food availability (IGBST 2013). This is a necessary adaptation because access to food items can vary spatially and temporally, especially those that are calorie rich (IGBST 2013). Many studies have confirmed that the diet of the grizzly bear consists primarily of vegetation, ungulates, whitebark pine seeds (*Pinus albicaulis*), spawning cutthroat trout (*Oncorhynchus clarkii*), and army cutworm moths (*Euxoa auxiliaris*) (ACM) (USFWS 2007b; IGBST 2013). Securing these items requires searching across a large landscape accompanied by seasonal or annual foraging adjustments based on food availability (IGBST 2013).

Vegetation, is a primary food source for grizzly bears and it is consistently available ecosystem-wide (Gunther et al., 2014; Mealey, 1975; IGBST 2013). However, other food items are less predictably accessible to grizzly bears, but they offer more calories, which is important during fall hyperphagia a period prior to entering hibernation when grizzly bears gain substantial body fat. As a general pattern, depending on what region they occupy, grizzly bears in the GYE typically have access to at least one calorie rich food source, levels and foraging on vegetation augments energy needs (IGBST 2013).

Ungulates, especially bison (Bison bison) and elk (Cervus elaphus), are generally accessible to grizzly bears in the spring as winter-killed carcasses or neonates, but they are also killed or scavenged in late summer and fall commensurate with the rut when ungulates may be weakened, injured, or killed during mating competition. However, ungulate populations are unevenly distributed across the GYE (IGBST 2013). Moreover, ungulate numbers within populations have varied over time with the influences of hunting, habitat loss, and predation (IGBST 2013). Grizzly bears also use the edible nuts in whitebark pinecones in late summer and early fall. Similarly, cone crops vary annually and spatially in the GYE. Whitebark pine trees have decreased significantly GYE-wide as a result of fires and pine beetle infestations (IGBST 2013). Spring use of spawning cutthroat trout by grizzly bears is primarily associated with Yellowstone Lake where they are accessible in the shallow tributary streams they navigate during spawning. With the introduction of lake trout, a cutthroat trout predator, annual numbers of spawning cutthroat have declined markedly (Koel et al. 2005; IGBST 2013).

Grizzly bears feed on migratory ACMs on high mountain aggregation sites along the eastern edge of the GYE in mid to late summer (French et al. 1194; O'Brien % Lindzey 1994). Whereas the other primary food items have no doubt been consistently available to some measure for bears, migratory ACMs were only recognized as an essential food item for GYE grizzly bears in the mid-1980s (Mattson et al. 1991). ACM migrations may have begun before this time but the presence of foraging grizzly bears on the destination peaks was the first signal of their role in the diet of GYE grizzly bears (French et al. 1994). The effects of early management practices on grizzly bear distribution in Yellowstone National Park (YNP) and on adjacent public lands may explain why the connection between migratory moths and grizzly bear foraging patterns in the GYE was not noticed until about 35 years ago (IGBST 2013). In the early 1900s, open-pit garbage dumps were maintained at YNP visitor facilities and the communities at the park's entrances. This was a matter of trash disposal convenience for the visitor hotels and the gate-way municipalities. This focused grizzly bear feeding activity at dump locations. Bears were also hand-fed along roadsides and anywhere visitors gathered (O'Brien & Lindzey 1994; IGBST 2013). These practices provided a consistent food source for bears in YNP and the human communities along the park's boundary. In addition, since the inception of YNP, grizzly bears not protected within the park were shot or trapped indiscriminately and later legally hunted when State game management agencies were organized (Leopold 1963; IGBST 2013). Presumably, grizzly bears removed outside YNP included individuals who would have utilized the moth aggregation sites, if moths were indeed available (IGBST 2013).

Whereas grizzly bears outside of YNP were often killed by humans, those inside the park associated humans with food. At a few dumps this even had a spectacle dimension with scheduled bear viewing opportunities for visitors (IGBST 2013). The result in YNP was an unacceptable pattern of human-bear encounters with injuries and property damage (Leopold 1963; IGBST 2013). The 1963 Leopold report highlighted the inappropriateness of these YNP management practices. Named for its principal author, the famed zoologist and conservationist A. Starker Leopold, it was presented to the US Secretary of the Interior. It provided the first concrete plan for managing park visitors and ecosystems under unified principles based on science (Leopold 1963). The report recommended weaning the bears off the garbage dumps to reestablish natural ecological processes. (O'Brien & Lindzey 1994; Leopold 1963).

However, following the dump closures, which occurred from the 1960s until the late 1970s, the rate of human-bear conflicts increased as displaced bears gravitated to human settlements for food (IGBST 2013). Consequently, as a result of management removals of bears habituated to human foods and starvation because of an inability to transition to natural foods, the YNP grizzly bear population was at risk of extirpation (USFWS 1975, 2007a; IGBST 2013). In response, in 1975, the grizzly bear was placed under Endangered Species Act protection (USFWS 1975; 1993; 2007a). Under federal protection the GYE grizzly bear population has recovered, and criteria have been met for delisting (USFWS 2007a; Bjornlie & Haroldson 2018a).

GYE grizzly bear distribution is no longer dump-centric. In fact, over the past 47 years the distribution of the GYE grizzly bear population has expanded in numbers and range ecosystem-wide, including the eastern mountains where the moth aggregation sites are located (Bjornlie & Haroldson 2018a). Therefore, sightings of grizzly bears foraging on moths on the high peaks on the eastern edge of the GYE in the mid-1980s is likely the result of this sequence of agency management actions (Mattson et al. 1991). Since these initial sightings, the number of grizzly bears visiting these sites to forage on ACMs has increased significantly. With this increase, managers are interested in protecting the ecological integrity of the moth sites and the grizzly bear population using them (USFWS 2007b; USFS 2015). This requires more information on several subjects, including grizzly bear foraging patterns at the moth aggregation sites (USFS 2015).

ACMs have an interesting life cycle and play a critical role in the ecology of the GYE grizzly bear. They migrate annually from the Great Plains in late spring to the high peaks on the eastern edge of the GYE, returning to the Great Plains at the conclusion of the summer (Burton et al. 1980; Cooley 1916). At these peaks, moths forage on the nectar in alpine flowers at night and shelter in scree fields during the day. Grizzly bears forage for ACMs in these aggregation sites, and can consume up to an estimated 40,000 moths per day (White et al. 1999). Over the course of 30 days, this equates to roughly half of a bear's annual energy budget (White 1996).

Agencies monitoring the GYE grizzly bear population have identified 31 ACM sites (Bjornlie & Haroldson 2018b), and a significant increase in use of these aggregation sites by grizzly bears in recent years (Nunlist 2020; Bjornlie & Haroldson 2018b). Based on accessibility to humans and increased grizzly bear use, Nunlist's (2020) identified two moth aggregation sites that were the highest concern for human visitor safety and bear disturbance ("North Site" and "South Site"). These peaks were the focus of our study, especially the "South Site". Vulnerability of migratory ACMs to climate change and other environmental factors is unknown. Potential annual or long-term decreases in ACM abundance due to these factors could negatively affect grizzly bears that rely on moth aggregation sites to meet their caloric need, which highlights the importance of assessing the availability of alternate food types for grizzlies that use the sites (USFS 2015). Vegetation is a predictable alternative or additional food source for grizzly bears at ACM sites, just as it is for grizzly bears ecosystem-wide. Consequently, assessing the characteristics, availability, and actual use of vegetation at ACM sites is the motivation for this study (French et al. 1994; Nunlist 2020).

Because of the importance and vulnerability of ACM sites, the Final Conservation Strategy for the GYE Grizzly Bear (USFWS, 2007) identified the need for more information on the on the association of grizzly bears and ACM sites. This was reinforced in the USFS Land

Management Plan for the Shoshone National Forest (2015), which directed the preparation of a "moth site" management plan. To address this information gap, the Forest Service initiated a series of studies, each with a different emphasis. For example, this study focuses on the food resources available to grizzly bears at an ACM aggregation site, emphasizing potential foraging on vegetation (USFS 2015).

Grizzly bears travel to moth sites to forage for ACMs (French et al. 1994). However, in keeping with the knowledge that the GYE grizzly bear is an opportunistic omnivore capable of diet shifting according to spatial and temporal variation in food availability, it is reasonable to expect that bears using the moth sites have a more complex foraging strategy. Using scat analysis, French et al. (1994) described vegetation as an important food source for grizzly bears on the South Site. Nunlist (2020) confirmed these findings with current scat analysis, but she also investigated the distribution of grizzly bears in relationship to foraging activity and landscape features at the South Site. During observations of grizzly bear foraging behavior at the South Site, high elevation meadows where grizzly bears were foraging on moths were identified, as well as five separate vegetative areas at the same elevation where grizzly bears were observed foraging extensively on vegetation. Nunlist (2020) postulated that biscuitroot (*Lomatium cous*) was the foraging focus at the vegetated areas she mapped.

Nunlist (2020) illustrated that bear activity at moth aggregation sites is not exclusively dominated by foraging for ACMs; rather, bear foraging reflects a "dual economy" in which grizzly bears consume roots and tubers in amounts that may equal or exceed consumption of ACMs. My research extended this analysis to provide clarity to grizzly bear diets and foraging patterns at the South and North Sites.

Using scat analysis, French et al. (1994) and Nunlist (2020) identified nine genera of forbs as food items grizzly bears consumed at ACM sites, including: *Trifolium* spp., *Mertensia* spp., *Myosotis* spp., *Oxytropis* spp., *Astragalus* spp., *Cerastium* spp., *Epilobium* spp., *Taraxacum* spp., and *Lomatium* spp. However, no studies have focused on the distribution of these vegetative food items on an ACM site or the spatial relationship of these food items to areas where bears forage on moths.

Thus, this project, developed by the USFS (SNF & the GYE Grizzly Bear Habitat Coordinator) and Montana State University, was created to address these remaining gaps in our understanding of grizzly bear foraging patterns on two moth aggregation sites. Our objectives were:

(1) Through scat analysis, identify the food resources grizzly bears are consuming at the North and South moth aggregation sites.

(2) Determine if the presence of biscuitroot influences whether grizzly bears dig in certain vegetative areas at the South Site.

(3) Focusing on the nine-forb genera identified in grizzly bear scat, quantify the alpha- and beta-diversity between the mountain peak and cirque-basins of the South Site. This reflects the high elevation area where grizzly bears are foraging in comparatively high density.

(4) Establish the relative abundance of the nine-forb genera identified in scat across the vegetated part of the South Site where grizzly bears forage.

Material and Methods

Site description

Our data were collected at two high-elevation study sites in the Absaroka Mountains within the Shoshone National Forest. These sites are known summer aggregation areas for ACMs and feeding areas for grizzly bears (USFS 2015; Nunlist 2020). To protect these areas from human disturbance, we refer to these sites as the generic latitudinal positions “North Site” and “South Site” (Figure 2).

The North and South sites, both about 40,000-ha, have vertical cliffs and steep talus slopes where moths are located during the day. The elevation ranges from 2,809 to 3,504-m and the tree line is at approximately 3,110-m (O’Brien & Lindzey 1994, Nunlist 2020). Vegetation is limited on mountain-side talus slopes and the peaks because of harsh environmental conditions but there are comparatively small discrete meadow areas. In addition, there are protected saddles, cirque basins with less severe topography, and adjacent plateaus that have plant communities (O’Brien & Lindzey1994). These were the focus of our vegetation surveys on the “South site”. Grizzly bear scat and hair samples were collected from both sites.

Scat collections

We opportunistically collected scats less than two weeks old within 5-m of travel routes, which is a reasonable detection distance. This occurred while traveling game and human trails and checking hair-snare stations. We also collected scats within a 23-m radius of transects where we surveyed for vegetation. To collect scats, we used plastic bags to reduce contact with fecal material. Each bag was then labeled to identify the scat and location using UTM coordinates.

Scats were collected at both the North and South Site from early July through mid-August, 2020-2021. It is common convention in dietary studies of grizzly bears, to collect more than 250 samples to ensure a representative sample (Nunlist 2020; French et al. 1994; Mealey 1975). We collected 298 scats (North Site 17; South site 281) (Figure 3 and 4) mainly on the South Site where we collected vegetation data.

Scat preservation

We observed live insects on and in most scats at the time of collection, feeding on digested and undigested contents. We removed the live insects to ensure we did not count them as food items that grizzly bears consumed. The common live insects we found in the fecal matter included maggots (Diptera) and beetles (Coleoptera).

To preserve scats, they were dried after collection on a paper plate, transferred to a paper bag, and then stored in a soil-drying room at MSU (47ºC, 11% humidity) for three days to ensure each scat was completely dry. For long-term storage before analysis, we stored samples in paper bags in our lab to keep them from partially rehydrating.

Scat analysis

Before analysis, we placed individual dried scats in 1.5-L plastic containers, large enough for them to be filled with water until the sample was completely submerged and allowed to soak for 15 to 24 hours. Each sample was soaked to help the fecal particles become more pliable. We then placed the soaked samples in a meshed strainer (sieve No. 5 mesh), and placed a fine-meshed strainer (No. 12 mesh) under the No. 5 strainer to catch any digested food items that were smaller than 2-mm. We placed the sieves under running water and stirred the sample to rinse and remove most of the fecal particles (i.e., unidentifiable digested food) away, leaving behind mostly food remnants that were not fully digested and identifiable (Figure 5).

We placed the remaining sample in a 30 x 60-cm white tray and added water to help sift through samples to find identifiable food items. Grizzly bears digest vegetation poorly (Bunnell & Hamilton 1983; Pritchard & Robbins 1990), leaving sections of plants such as leaves, stems, and seeds in the scat sufficiently large for identification (Figure 5). To identify food items to the lowest taxonomic level, we used a stereomicroscope (Leica M80, Buffalo Grove, IL) to dissect and find characteristics to help key out the plant, insect, or other food items. When we identified insects, we focused on parts of the exoskeleton that were not digested, which helped identify the lowest taxonomic level (Figure 6). We examined the structure of hairs found in scats to identify the animal consumed. Mammals such as rodents and ungulates using these peaks have unique hair structures that are readily identifiable (Hausman 1920). We first used an identification book to identify the plant parts (Harris & Harris 2001). Using multiple keys, we identified the plant to the lowest taxonomic level (Kershaw et al. 1998; Lesica et al. 2012) (Figure 6). Each item was identified and separated into insects, grasses, forbs, mammals, debris, birds, etc.

Data analysis

We recorded the percent volume of each food item identified in scat samples, totaling 100%. We recorded food items as follows: nine-forb genera previously identified as grizzly bear food items ACM aggregation sites, other graminoid species, other forbs, ACM, other insects, mammals, moss, and other vegetation and food items that could not be identified.

We calculated each food item's percent frequency by the number of times a specific item occurred in our sample group, divided by the total number of scats collected. Total percent volume was calculated of each food item in the sample group, divided by the total number of scats collected. We did not quantify rocks or debris because we believe they result from foraging on vegetation and ACMs and are not intentionally consumed.

We used the following equations to estimate each food item's overall frequency of occurrence and volume found in scats. These equations represent standard practice for estimating foods consumed by bears (Mealey 1975; Nunlist 2020).

$$F_i = \frac{\#\ of\ scats\ with\ food\ item\ i}{Total\ \#\ of\ scats} x100$$

$$V_i = \frac{\Sigma\ \%\ volume\ of\ food\ item\ i}{Total\ \#\ of\ scats} x100$$

Where F_i is the frequency of occurrence of the total number of scats, i is the identified food item found in a sample (e.g., army cutworm moth), V_i is the estimated volume percentage of the total number of scats. We estimated volume by visually considering each food item in proportion to the entire processed scat.

Food items were then ranked according to the importance value (Mealey 1980). An importance value is a measure of how dominant a food item is compared to other food items. To find the percentage of the importance value we used the following equations.

$$IV = \frac{\%\ F_i\ x\ \%\ V_i}{100}$$

$$\%\ IV = \frac{IV_i}{\Sigma\ of\ all\ IV}\ x\ 100$$

Where IV is importance value of food items. Some food items had a high frequency of occurrence but a low volume percentage. Therefore, we used the importance value equation as an indicator to establish which food items were consumed and favored more by grizzly bears. Frequency and volume results were compared with results from 2017-2018 (Nunlist 2020).

Camera and hair-snare setup

We placed hair-snare stations at both the North and South Site. In 2020, snare stations were placed at each primary trailhead 6 total (South site, n = 4; North Site, n = 2). In 2021, five additional snare stations were added (South site, n = 7; North Site, n = 4) to collect DNA data. These data were used to help estimate the number of bears that were visiting these sites as well as identify grizzly bears not previously recorded in the GYE.

At each hair snare station, to attract bears we used planks (30 x 121 x 10-cm or 12 x 60 x 10-cm) that were anchored to the ground using rebar rod. Barbed wire was attached to the planks to enhance hair collection. To attract bears without using a food reward we applied a vanilla/licorice scent. Grizzly bears visited these planks because of the odor and rubbed on the barbed wire and wood, which snagged their hair (Figure 7). A trail camera (Reconyx Hyperfire-2, Holmen, WI, Moultrie M-990i, Moultrie, GA) was placed about 1.5-m away from the plank recording the number of bears visiting the hair-snare (Figures 7, 16 and 17).

Six previously used snare stations were used in 2020 (Nunlist 2020). Five additional cameras were placed in 2021. All locations were selected to not be encountered by hunters, hikers, or cattle. We visited each plank two or more times each summer. At each visit, we collected the hairs then used a blowtorch to burn off any residual. Tweezers were used collect hairs, which were stored in coin envelopes.

Hair samples were sent to J. Fortin-Noreaus (USFW) to contribute to her research. In addition, DNA was extracted from samples at the Wildlife Genetics International lab, Nelson, British Columbia. They compared results to a comprehensive database containing for GYE grizzly bears.

DNA extraction

We collected 29 samples in 2020, 45 in 2021. Samples were purified, removing any sample inputs (e.g., soil, feces, biofilms, etc.) using the QIAGEN Dneasy Blood and Tissue kit. Clippings of at least 10 guards' hair roots were used for genotyping (Paetkau 2021).

Individual identification

Samples were passed through three phases for individual identification (e.g., first pass, cleanup, and error check). The first pass was to establish a set of 10 markers (9 microsatellites plus ZFX/ZFY for sex); any samples that were weak or difficult to read were labeled as *Xbomb*. Next, the samples were processed through the cleanup phase. This phase was to reanalyze the samples classified as *Xbomb* using 5 µL of DNA per reaction, culling any samples that had low-confidence scores in their genotypes. Finally, each sample that had complete 10-locus genotypes was checked for error.

The error-check phase established any genotyping error by surveying pairs of genotype similarities (Paetkau 2003). Checking for errors involved looking for pairs of genotypes that match at the all-but-one marker or all-but-two markers ('1MM-pairs' and '2MM-pairs'). This check prevented the identification of false individuals (Kendall et al. 2009). The samples were then compared by referencing genotypes from an electronic database from unique grizzly bear genotypes in the GYE (n = 1,338), plus comparing other regions from the Columbia Mountains (n = 676), the Northern Continental Divide Ecosystem (NCDE) (n = 1,748), and from Steve Gehman's collections from North Yellowstone (n = 31) (Paetkau 2021).

<u>Vegetation Surveys</u>

Vegetation surveys were conducted on the “South Site”, where Nunlist (2020) mapped grizzly bear foraging areas for moths and vegetation. We surveyed 21 units (i.e., vegetative plots), including the five “dig” (bears foraging on vegetation) locations mapped on the mountain peak as polygons by Nunlist (2020). For compassion eight new units were created in the adjacent cirque-basins and eight new units on the mountain peak (Figure 8). The new units were selected based on the following criteria: the elevation of the cirque-basin units ranged from 3,078 – 3,657-m and the elevation of the mountain peak units ranged from 3,658 – 3,931-m (Figure 9). We created boundaries for the units using a false color composite image in ArcGIS. To create the false color composite, we used imagery from the National Agriculture Imagery Program (NAIP) and changed the band color display as follows: Red=band 4 (NIR), Green=band 1 (red), Blue=band 2 (green). This photosynthetic display results in productive (live) vegetation depicted as red. We created units in the cirque-basins of the South Site and on both the north and south side of the mountain peak, to evaluate the difference in vegetation between the mountain peak and cirque-basin areas.

Within each unit, we used stratified random sampling. The number of locations (i.e., random points) sampled from each unit was based on the size of the unit’s area. For units greater than 40 ha we sampled 5 locations, units with an area 20 to 40 ha we sampled 4 locations, and for units less than 20 ha we sampled 1 to 3 locations (Figure 8). Within each unit, we randomly generated locations using ArcGIS. To better represent the area, random points collected throughout the unit boundary were sampled at a minimum distance of 150-m from one another. We created more random points than needed to give us more options due to the rough terrain (i.e., if the points were located on a cliff and could not be sampled, we noted this and moved to the next). To collect vegetation surveys, we used 92-m transects; at each random point we created a transect and measured the line transects with a 92-m (300-ft) field tape. Each transect was placed in the direction towards the peak or placed to stay within the border of each unit and 1-m^2 quadrats were placed along the transect at 0, 23, 46, 69, and 92-m (Figure 11). Vegetation sampling was conducted early July through mid-August; July 16-31 and August 1-9 in 2020, and July 5-31 and August 1-12 in 2021.

Percentage cover and presence/absence of forb species, including nine genera previously identified by French (1994) and Nunlist (2020): *Trifolium* spp., *Mertensia* spp., *Myosotis* spp., *Oxytropis* spp., *Astragalus* spp., *Cerastium* spp., *Epilobium* spp., *Taraxacum* spp., and *Lomatium* spp., were recorded in each quadrat. Density of biscuitroot at the non-flowering rosette stage and flowering biscuitroot were also recorded within each 1-m^2 quadrat. The density of bear craters was assessed within a 23-m radius circle at three points (0, 46, and 92 m) along each transect. To assess the density of craters, four crew members were positioned equidistant (6 m apart) along a field tape with one person pivoting at the center to cover the entire area searching and counting craters. A crater was defined by disturbed soil that showed a bowl-shaped cavity in the ground (Figure 12).

Data Analysis

To examine the biodiversity between the peak and cirque-basin areas of the South Site, vegetation samples were collected using percentage cover. Data were collected for each forb genera of interest, and other forb species. We analyzed these data using R (4.1.2) with the packages Vegan (2.5-7) and BiodiversityR (2.13-1). We created three data frames containing variables for environmental (i.e., elevation, bare ground, rock coverage), forbs (from the 9 genera of interest) and all forbs.

We compared richness (number of species) and alpha diversity (richness and evenness (relative abundance) of our nine-forbs and all forbs differences within the peak and cirque-basin sampled units. To calculate the inverse alpha diversity, we used the Simpson index (Simpson 1949) which provides a diversity measure for each vegetation type. We then ran an ANOVA (α=0.05) with a Chi-distribution test to determine if the alpha diversity of the peak differed from the cirque-basin.

$$1/D = \frac{\sum(n_i * (n_i - 1))}{(N * (N - 1))}$$

Where n_i is the number of individuals of each species, *i* is the individual species. N is the number of individual species in the community (i.e. richness).

Beta diversity is a large scale measure, which again uses richness and evenness but calculates values between different units using pairwise comparisons. We calculated the beta diversity for the nine-forb genera. The Morista-Horn index was used (Horn, 1966). We used an Adonis test to determine dissimilarities between the peak and cirque-basin units.

$$1 - MH = \frac{\sum_{i=1}(pi1 - pi2)^{2i}}{\sum_{i=1} pi_1^2 + \sum_{i=1} pi_2^2}$$

Where p_{i1} is the proportion of times an individual forb species *i* appeared in the peak areas sampled, $pi2$ is the proportion of times an individual forb species *i* appeared in the cirque-basin areas sampled. Alter this Horn index was used because of its independence from sample sizes and the number of samples collected varied due to the size of each unit.

Last, we calculated the relative dominance of the nine focal forb species that grizzly bears consumed within the peak and cirque-basin units.

To analyze the relationship between biscuitroot and bear activity using the density of craters created by grizzly bears, we used a multiple linear regression to test whether biscuitroot rosettes or flowering biscuitroot predicted high bear activity. The fitted regression model was: Y_i (crater density) = $\beta_0 - \beta_1$*(rosette density) + β_2*(flowering density).

We expected that grizzly bears were selecting specific vegetative plots to dig for biscuitroot. To test this hypothesis, we plotted the density of biscuitroot with the density of craters. Data were assessed for normality and transformed using a log transformation to improve normality and variance.

Results

Diet analysis

We analyzed 298 bear scats (North Site 17; South Site 281) (Figures 3 and 4). A list of food items found in all scats was created by frequency (%) and volume (%) (Table 1). For summary purposes, we recorded four food groups (graminoids, forbs, moths, and mammals).

The most frequently occurring food item found was forbs which were present in 75.5% of scats, while ACMs were present in 38.9% of scats and graminoids in 64.4% of scats. The most prominent food source was biscuitroot (*Lomatium* spp.), with a frequency of 65.1% (Table 1).

The food item with the highest percent volume was forbs (volume 37%), primarily biscuitroot (*Lomatium* spp.) with a volume of 29%. However, both graminoids (volume 32%) and ACMs (volume 23%) were also important in the diet of the grizzly bears at these ACMs sites

(Table 1). Mammals were consumed the least with a percentage volume of 0.8%. In addition, during our scat analysis we estimated 6,000 moths in one scat.

Scat analysis comparison- 2017-2018 vs 2020-2021

Comparing the previous food-habits study from 2017-2018 with ours in 2020-2021 indicated similar diets. Nunlist (2020) opined that when identifying food items, roots and tubers could not be confidently identified. Therefore, to allow for comparison between studies, we combined biscuitroot (*Lomatium* spp.), clover (*Trifolium* spp.), vetch (*Astragalus* spp.), and locoweed (*Oxytropis* spp.) with the roots and tuber category in both studies (Table 3). Scats collected in 2020 - 2021 contained, by volume, 23% insects, 32% graminoids, and 38% forbs. The most prominent foods were ACMs (22.9%) and roots and tubers (38%). Findings in 2017-2018 (n = 376) were similar: 20% insects, 33% graminoids, and 45.5% forbs. Similarly, ACMs (20%) and roots and tubers (45%) were the two most prominent foods (Nunlist 2020). Comparing the volume (%) from both studies, ACMs (22.9%) were consumed more by grizzly bears in 2020-2021 then 2017-2018 (20%) (Table 2).

Scat analysis comparison by importance value – 2017-2018 vs 2020-2021

Comparing the importance value calculated using both the frequency (%) and volume (%) from the food habits study completed in 2017-2018 with the food items found in 2020-2021 indicated similar diets (Table 4). The importance of ACMs and roots and tubers slightly differed between studies.

During the 2017-2018 summer collection, forbs comprised the most significant portion of the diet of grizzly bears with an importance value of 31.4% (Table 4). Graminoids and insects were also crucial, with 28.3% and 9.2% values, respectively. In the 2020-2021 collections, forbs were still the most significant portion of the grizzly bear's diet, with an importance value of 25.78%. Graminoids and insects are also crucial for grizzly bears, with 19% and 10.4%, respectively (Table 4). Roots and tubers were the principal food source during the mid-late summer of 2017-2018 and 2020-2021 at the moth aggregation sites (26.7% and 20% importance value). During the same time, ACMs (7% and 8.2%) and graminoids (28% and 19%) were consumed.

Hair-snare

We collected 18 samples in 2020, and with additional camera hair snares in 2021, we collected 45 samples. In 2020, 5 bears not previously recorded in the GYE were identified and 6 were identified in 2021. Most of the "new bears" were located on the North Site (n = 6) (Table 5). These data indicate that we collected scats from a population of foraging bears.

Vegetation

The South Site was the focus of our vegetation surveys; we quantified both alpha and beta diversity of the nine-forb genera (documented as food items grizzly bears consume) between the peak and cirque-basin areas. In addition, to establish the distribution of the nine-forb, we ranked the relative abundance within the peak and cirque-basin areas.

The alpha diversity results showed that of the nine-forb genera we recorded in the peak units did not show a significant difference in diversity of the nine-forb genera we recorded in the cirque-basin units (X^2 (1) = 18.46, p = 0.06). This indicates that the richness and evenness of forb species we recorded within the peak units were similar to the richness and evenness of forb species we recorded within the cirque-basin units.

Beta diversity compared the nine-forb genera we recorded in both the peak and cirque-basin units, the comparison results using the Horn Index showed there were more similarities (49%) within the cirque-basin units than within the peak units (42%) ($p = 0.001$, $R^2 = 0.93$). However, comparing the similarities between the peak and cirque-basin showed that they were the least similar (39%). In addition, the peak units had a higher overall percent coverage of the nine-forb genera (Figure 14), where grizzly bears were heavily foraging. These data can be used to monitor changes in diversity of the forb species grizzly bears are consuming at the South Site.

To estimate which of the nine-forb genera were dominant species within the peak cirque-basin areas. We used the rank abundance curve to visually depict the nine-forb genera richness and species evenness (Figure 13) and calculates a relative abundance found within both the peak and cirque-basin areas (Table 5). The rank abundance curve results showed that *Trifolium* spp. was dominant within both the peak and cirque-basin areas (Table 5 and Figure 13). The top-ranking forbs for the peak vegetative units were *Trifolium* spp., *Lomatium* spp., and *Myosotis* spp. (Table 5). The top-ranking forbs for the cirque-basin areas were *Trifolium* spp., *Myosotis* spp., and *Cerastium* spp. (Table 5).

These data indicate that biscuitroot is dispersed mainly within the peak area, where grizzly bears are heavily foraging for vegetation (Figure 10). In comparison, *Trifolium* spp. showed the highest-ranking relative abundance in both the peak and the cirque-basin areas. In addition, we recorded a higher percent coverage of the nine-forb genera grizzly bears consume within the peak sampling units (Figure 14).

Our fitted regression model was: Crater Density = 1.77- 0.19*(rosette density) + 0.44*(flowering density), the results showed that grizzly bears were foraging heavily (i.e., high density of craters) in areas where flowering biscuitroot was dominant (Figure 10). The overall regression was statistically significant ($R^2 = 0.20$, $p < 0.001$). Flowering biscuitroot significantly predicted grizzly bears' high crater density ($\beta = 0.44$, $p < 0.001$). However, only 20% of the variation can be explained by our liner model. In addition, where biscuitroot rosettes were dominant there was little to no foraging activity by grizzly bears (Figure 10). Biscuitroot rosettes did not significantly predict grizzly bear crater density ($\beta = -0.19$, $p = 0.10$).

Discussion

The army cutworm moth aggregation sites we studied are highly utilized by the GYE grizzly bear population during late June to mid-September (Nunlist 2020; O'Brien & Lindzey 1994). Army cutworm moths contain a high caloric density (7.91 kcal/g dry weight) (Gunther et al. 2014; White et al. 1999) and migrate in large numbers (Burton et al. 1980; Pruess 1967), where grizzly bears can consume as many as 40,000 moths per day (White et al. 1999). During our scat analysis, we estimated the number of moths found, and one scat contained approximately 6,000 ACMs. A previous food-habits study conducted in 1991 at moth aggregation sites in the GYE indicated that ACMs were consumed more by grizzly bears than any other food source (French et al. 1994).

However, in the 2017-2018 study, Nunlist (2020) showed that vegetation, especially roots and tubers, were an important food source for grizzly bears at the South Site in addition to ACMs. Our results from 2020-2021 support this finding. The grizzly bear scat analysis we conducted showed that biscuitroot (*Lomatium* spp.) was the dominant food source grizzly bears were consuming, based on the high frequency 65% and volume 29.4%. As shown in both food-habit studies, roots and tubers collectively are an important food source for grizzly bears, based on the high volume (44.8 % and 38.1%) and the importance values (26.7% and 20%), and were consumed more than ACMs (19.6% and 22.9% volume, 7% and 8.2% importance value) (Nunlist, 2020). Grizzly bears forage mostly for biscuitroot that are large in mass, at least 30% starch, and are highly digestible (Mattson 1997). Our results show that this ACM site not only provides a high caloric food source in the form of ACMs, but also a high starch food source from biscuitroot.

Meadows or vegetative areas on the mountain peak occur in a matrix of talus or boulders. They have discrete boundaries and can be mapped. A key question is whether grizzly bears choose certain meadows or vegetated areas to dig specifically for biscuitroot. Nunlist (2020) noted that grizzly bears foraged heavily at five locations on the South Site, and she conjectured that was because of the presence of biscuitroot. As we observed in the mountain peak vegetative sampling units, the growth form of biscuitroot included mature flowering plants or short statured plants growing as rosettes. Therefore, we recorded separately the density of rosettes and flowering biscuitroot. Our results support the findings of Mattson (1997) that grizzly bears foraged in areas where biscuitroot is larger (i.e., flowering biscuitroot). In addition, to Nunlist (2020) "dig" sites, we noted three more areas where grizzly bears heavily foraged (Figure 9).

Out of the nine-forb genera, both the peak and cirque-basin showed different high-ranking forb species (Table 5). Our findings from the vegetation surveys showed that biscuitroot was prominent in the mountain peak areas where grizzly bears heavily foraged (Figure 10). Clover (*Trifolium* spp.), another food source, was dominant in both the peak and cirque-basin areas. *Trifolium* spp. also has a high caloric food item (4.83 kcal/g dry weight) (Gunther et al. 2014). In addition, the beta diversity results showed that of the nine-forb genera recorded there were fewer similarities between the peak and cirque-basin sampled units. However, our alpha diversity results showed that out of the nine-forb genera we sampled within the peak were similar in diversity and species richness of the nine-forb genera we sampled within the cirque-basin sampled units.

Camera and hair snares stations provided information for the GYE grizzly bear DNA database. With additional stations in 2021, we identified 9 bears (6 new bears) whereas in 2020 we identified 7 (5 new bears). These data established that scats were collected from a population of bears. In 2017-2018, 10 new bears were identified at these aggregation sites. Including our results, 21 new bears were identified and added to the GYE database through these projects. This method is effective for identifying additional bears in the GYE to enhance population models.

Our results show that grizzly bears consumed less ACMs than vegetation compared to what French et al. (1994) found in 1991. However, our scat analysis from 2020-2021 data showed similar results to Nunlist (2020) investigation in 2017-2018 in that grizzly bear's consumed vegetation more than ACMs. These findings confirm that grizzly bears have a “dual economy” at the South Site and consume not only ACMs but vegetation, primarily roots and tubers. With the availability of two calorie rich and relatively abundant food items, the South Site provides grizzly bears with a strategic foraging location. That is, the availability of roots and tubers as an alternative food source could potentially buffer or mitigate cycles in moth abundance. We now have a better understanding of grizzly bear food habits on the South Site, a prominent ACM aggregation location. However, we don’t know if grizzly bears use similar foraging strategies at other ACM sites. If so, then the benefits of this strategy would include the significant portion of the GYE grizzly bear population that uses ACM sites annually.

Even though we have an incomplete understanding of the ecological history of ACM migrations to the east edge of the GYE and grizzly bear use of the aggregation sites, our current assessments indicate that huge numbers of ACMs are available to GYE grizzly bears annually (Clare Dittemore, personnel communication). Moreover, the number of GYE grizzly bears using ACM sites is increasing. Therefore, this very calorie rich food source is critical for maintaining the current GYE grizzly bear population. However, we don't know how vulnerable the ACM annual migration is given the environmental variables associated with agricultural practices in the areas of moth natal origin, a warming climate, and patterns of severe weather events. Therefore, developing methods to monitor annual moth migrations is important. Given what we now know about the use of roots and tubers for grizzly bears using the ACM sites, it is similarly important to monitor the availability of this food source, especially biscuitroot. Our findings related to methods for monitoring the availability of important vegetative food items at ACM sites should also be considered and employed as a monitoring program.

Increased human visitation to ACM sites is a concern for agency managers, especially at the South Site. In response, agency managers are involved in the preparation of a "moth site management plan" to address conservation of the ACM sites and the bear population that uses them. Human-bear conflicts is a real concern with increased visitor use and high densities of foraging bears. This focuses attention on the specific portions of the mountain peaks where bears are at the highest density because of localized aggregations of moths for them to forage on. Our findings show that grizzly bears also forage extensive at locations with a high density of mature biscuit root. At the South Site we found these to be discrete, mapable high elevation meadows generally juxtaposed to the areas were grizzlies forage the most intensely on moths. The meadow with the highest density of flowering biscuit root and the talus areas most favorable to moths (Nunlist 2020) were closely associated at the South Site. The biscuitroot meadows, or areas with moth aggregations in combination with biscuit root meadows, should be considered in plans to mitigate human-bear conflicts. These are the areas with the greatest potential for displacing bears.

Table 1. Diet analysis of grizzly bear scats collected at the North and South Sites in 2020-2021. Frequency (%) and Volume (%) of each diet item across all scats are listed (n = 298).

Food Item	**% Frequency**	**% Volume**
Insects	49	23.1
Euxoa auxiliaris	38.6	22.9
Formicidae	4.03	0.16
Coleoptera	3.7	<0.01
Other Insects	4.7	<0.01
Graminoids	64.4	32.0
Poaceae	50.7	1.50
Carex spp.	22.8	0.18
Juncus spp.	2.0	0.06
Other Graminoids	51.3	30.3
Forbs	75.5	36.8
Lomatium spp.	65.1	29.4
Trifolium spp.	32.2	7.30
Mertensia spp.	1.0	<0.01
Myosotis spp.	1.3	<0.01
Oxytropis or *Astragalus* spp.	3.4	0.06
Cerastium spp.	1.3	<0.01
Other Forb	9.4	0.02
Roots and Tubers	10.7	1.30
Mammalia	8.4	0.85
Rodentia	3.4	0.15
Other	5.0	0.70
Berries	0.34	0.02
Moss	3.7	0.05
Other Unidentifiable Vegetation	28.2	6.0

Table 2. Volume (%) of food items found in grizzly bear scat samples collected at moth aggregation sites in 2017-2018 and 2020-2021.

	% Volume	
	2017-2018	**2020-2021**
Food Item	**n = 376**	**n = 298**
Insects	20.3	23.1
Euxoa auxiliaris	19.6	22.9
Formicidae	0.27	0.16
Coleoptera	0.03	tr*
Orthoptera	0.36	0
Other Insects	0.04	tr*
Graminoids	33.3	32.0
Poaceae	22.3	1.50
Carex spp.	10.5	0.18
Juncus spp.	0	0.06
Other Graminoids	1.5	30.3
Forbs	45.5	38.1
Roots and Tubers	44.75	38.06
Mertensia spp.	tr*	tr*
Myosotis spp.	0.03	tr*
Cerastium spp.	tr*	tr*
Taraxacum spp.	0	tr*
Other Forb	0.73	0.02
Mammalia	0.6	0.85
Rodentia	2.3	0.15
Other	3.1	0.70
Berries	0	0.02
Moss	0	0.05

*tr: percent volume <0.01

Table 3. Importance value (%) of food items found in grizzly bear scat samples collected at moth aggregation sites in 2017-2018 and 2020-2021.

Food Item	**Importance Value % 2017-2018 n = 376**	**Importance Value % 2020-2021 n = 298**
Insects	9.20	10.43
Euxoa auxiliaris	6.94	8.16
Formicidae	0.02	0.01
Coleoptera	0	0
Orthoptera	0	0
Other Insects	0	0
Graminoids	28.30	19.02
Poaceae	11.57	0.70
Carex spp.	03.91	0.04
Juncus spp.	0	0
Other Graminoids	0.24	14.35
Forbs	31.36	25.78
Roots and Tubers	26.69	19.97
Mertensia spp.	0	0
Myosotis spp.	0	0
Cerastium spp.	0	0
Taraxacum spp.	0	0
Other Forb	0.09	0
Mammalia	0.03	0.07
Rodentia	0.05	0
Other	0.09	0.03
Berries	0	0
Moss	0	0

Table 4. New and previously identified grizzly bears that visited the North and South Sites in 2020-2021.

# Grizzly Bears	New Bears*	Previous Bears	Location	Year Collected
5	3F/1M	1F	North	2020
2	1F	1F	South	2020
2	1F/1M		North	2021
7	2F/2M	1F/2M	South	2021

*M is male bears, F is female bears

Table 5. The five top highest ranking forb species on the peak and in the cirque-basin vegetative plots.

Rank	Peak Forb Species	Relative Abundance	Cirque-basin Forb Species	Relative Abundance
1	*Trifolium* spp.	526	*Trifolium* spp.	347
2	*Lomatium* spp.	244	*Myosotis* spp.	151
3	*Myosotis* spp.	122	*Cerastium* spp.	86
4	*Astragalus* spp.	115	*Mertensia* spp.	72
5	*Cerastium* spp.	92	*Epilobium* spp.	29

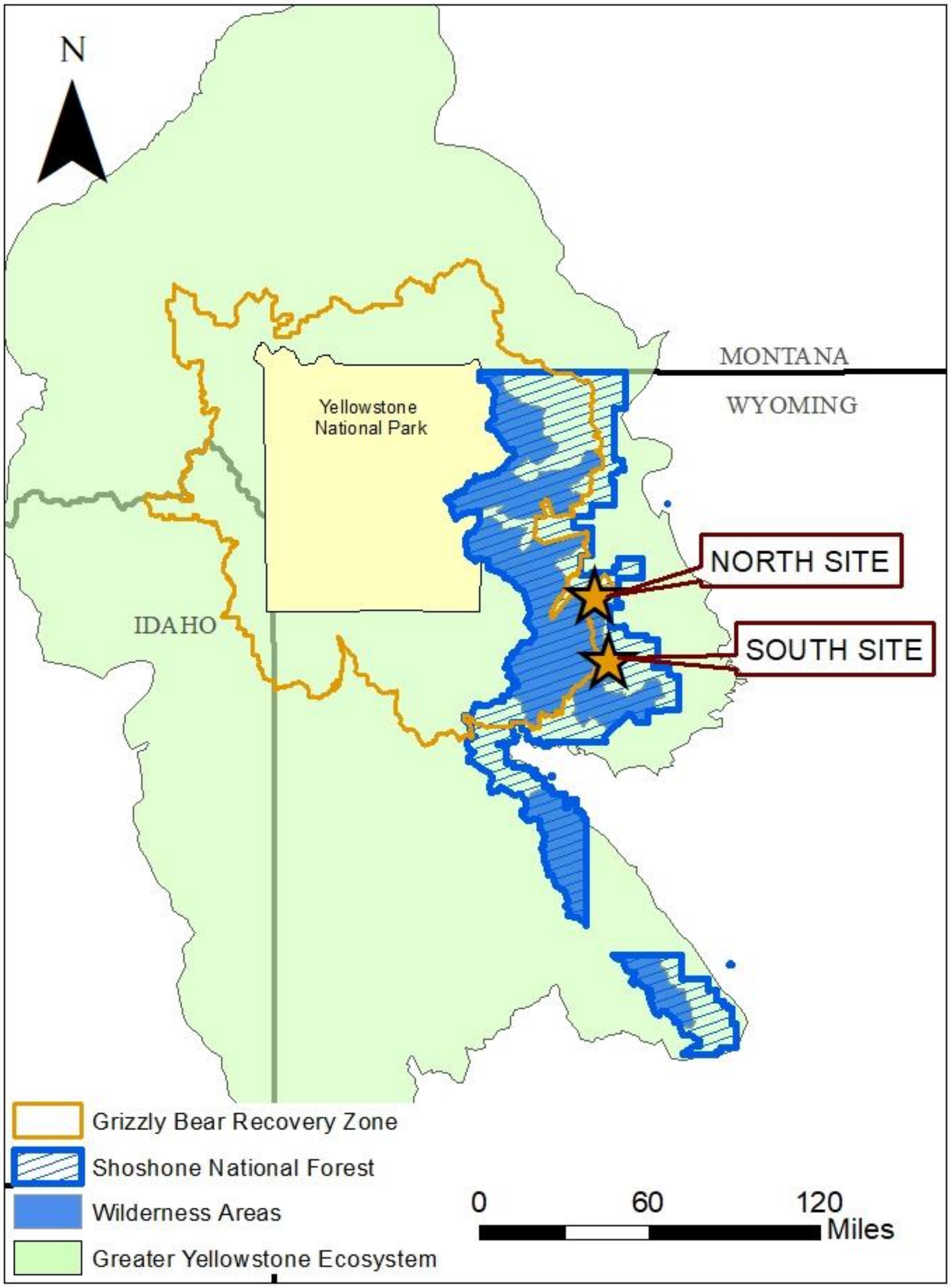

Figure 2. Study areas (North and South Sites) within the Absaroka Mountain Range in the Shoshone National Forest in the Greater Yellowstone Ecosystem, Wyoming.

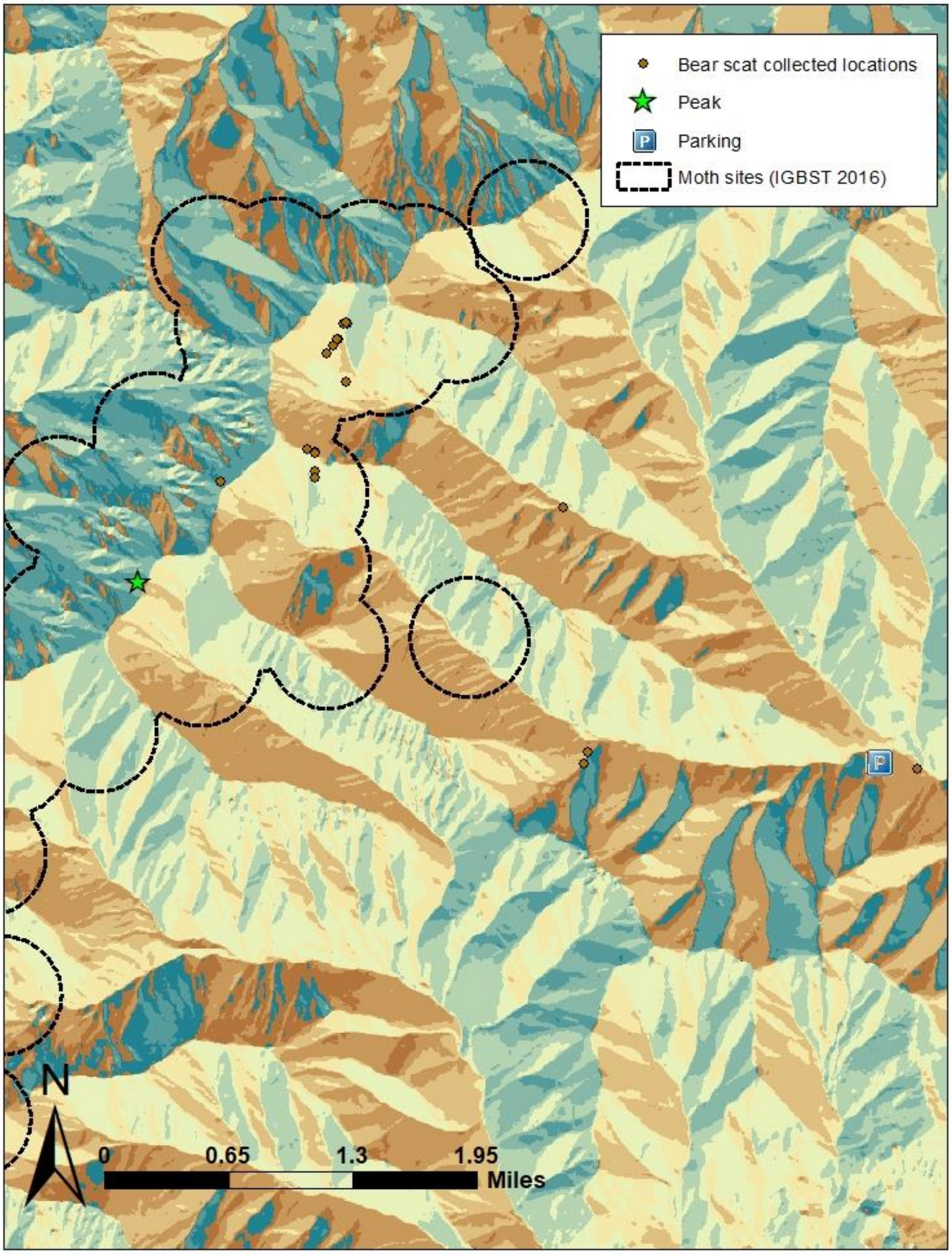

Figure 3. Opportunistically collected bear scat locations at the North sits in 2020-2021.

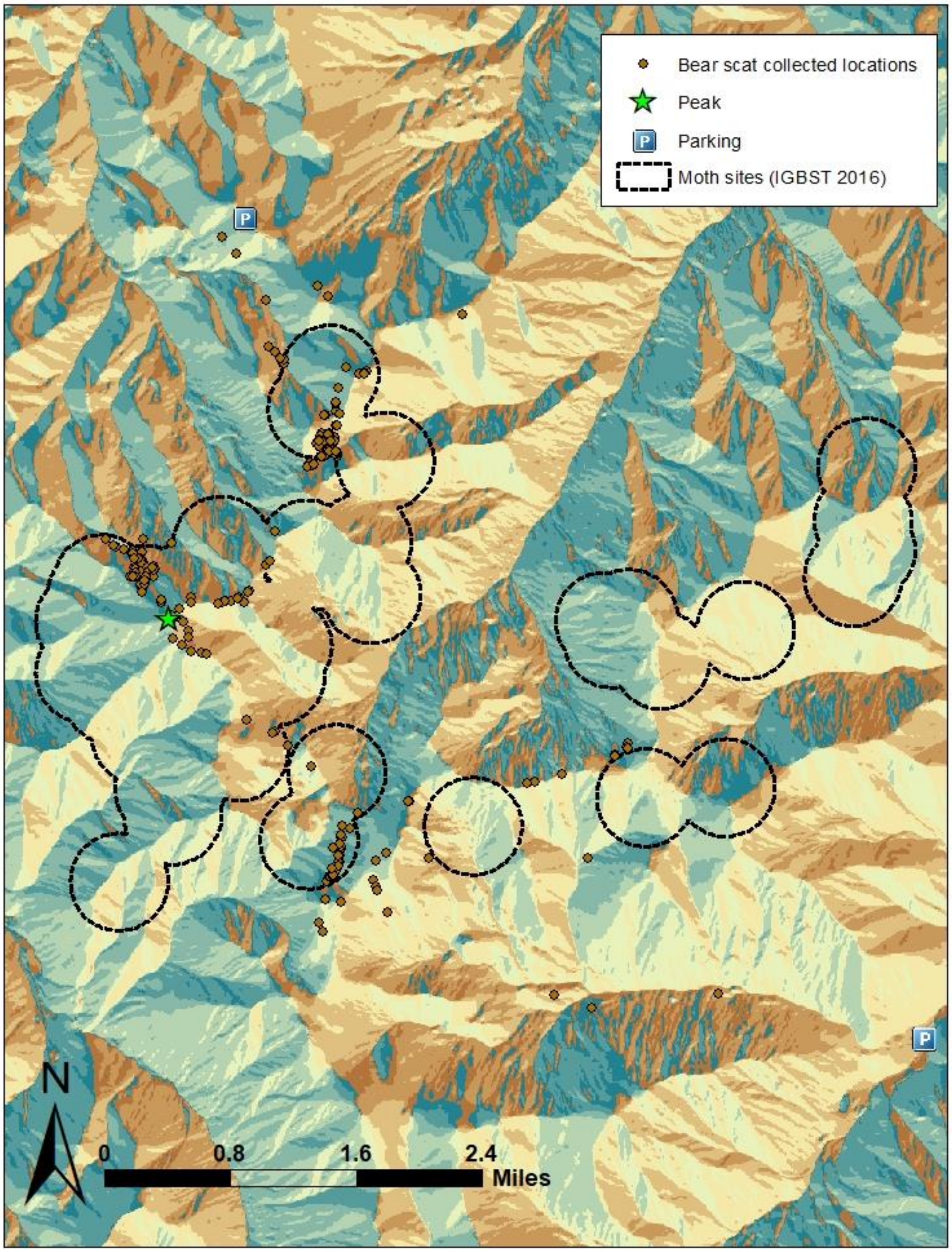

Figure 4. Opportunistically collected bear scat locations at the South Site in 2020-2021.

Figure 5. Processing scat samples for analysis: soaking scat sample for 24 hours in container (top left), scat samples rinsed removing digested food particles where partially digested food items remain (bottom left), and sifting through sample to find identifiable food items (right).

Figure 6. Identified partially digested food items found in samples: army cutworm moth (*Euxoa auxiliaris*) (left), ant (*Formica* sp.) (top right), and biscuitroot (*Lomatium* spp.) (bottom right).

Figure 7. Camera and hair-snare setup. Trail camera setup secured to a boulder (left), and hair-snare plank secured to the ground with rebar (right).

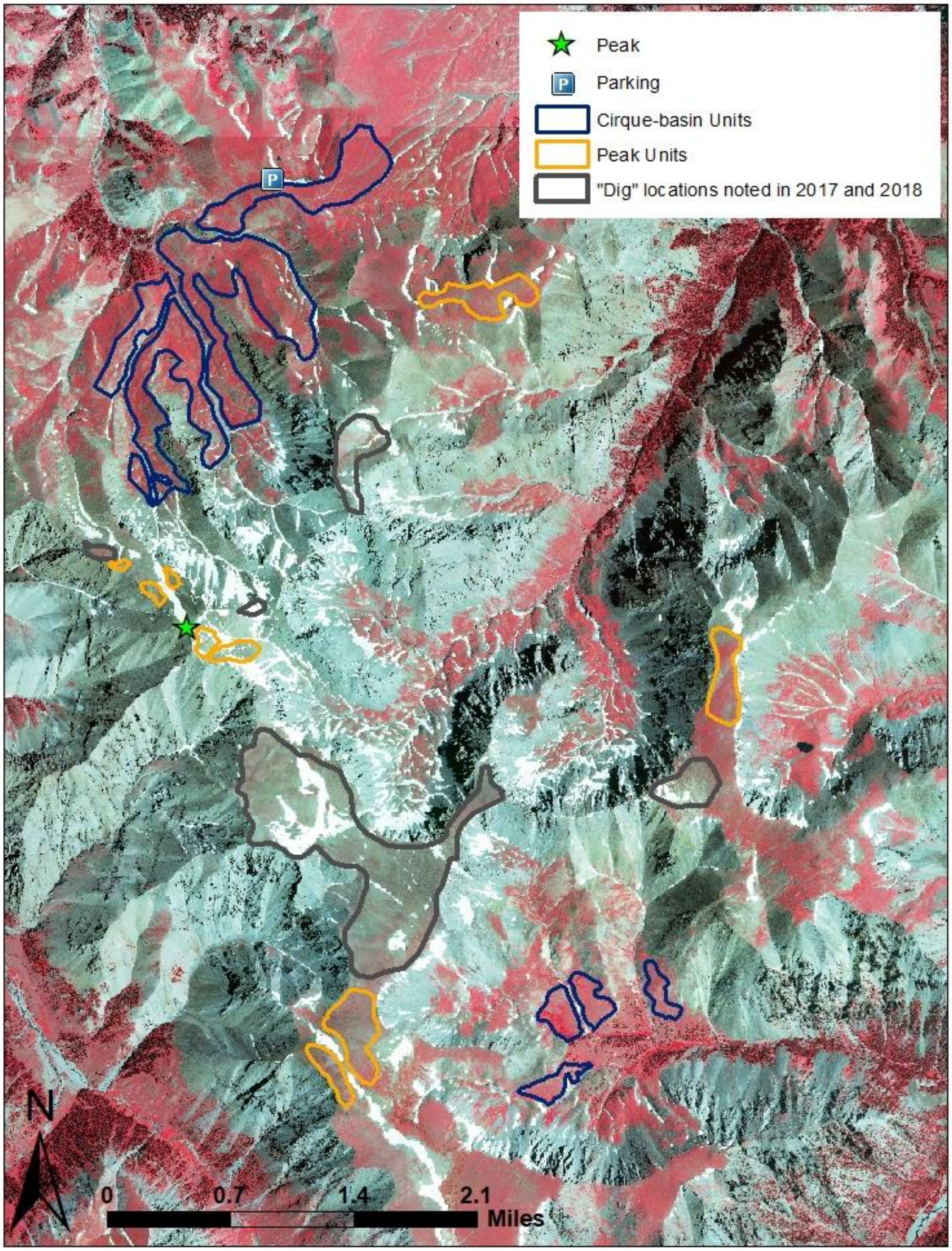

Figure 8. Peak (n = 13) and cirque-basin (n = 8) units surveyed for vegetation at the South Site.

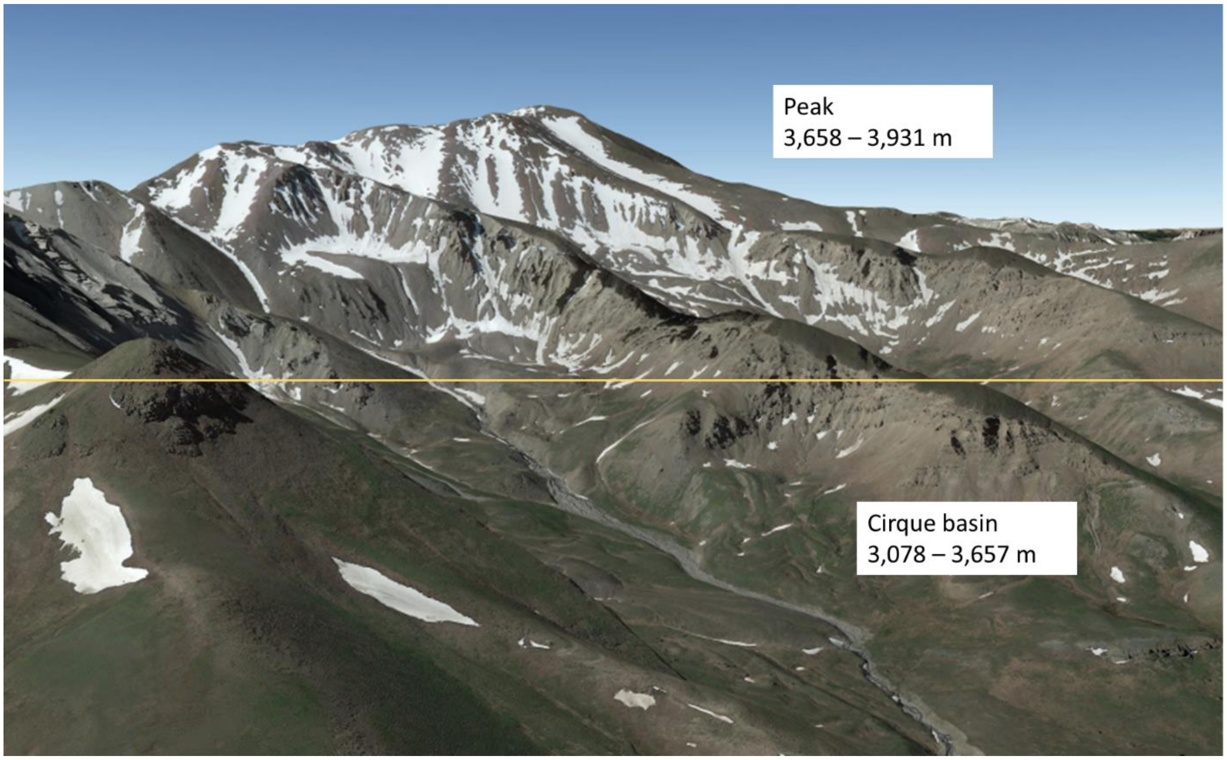

Figure 9: Sites where sampling units were created to complete vegetation surveys on the South Site.

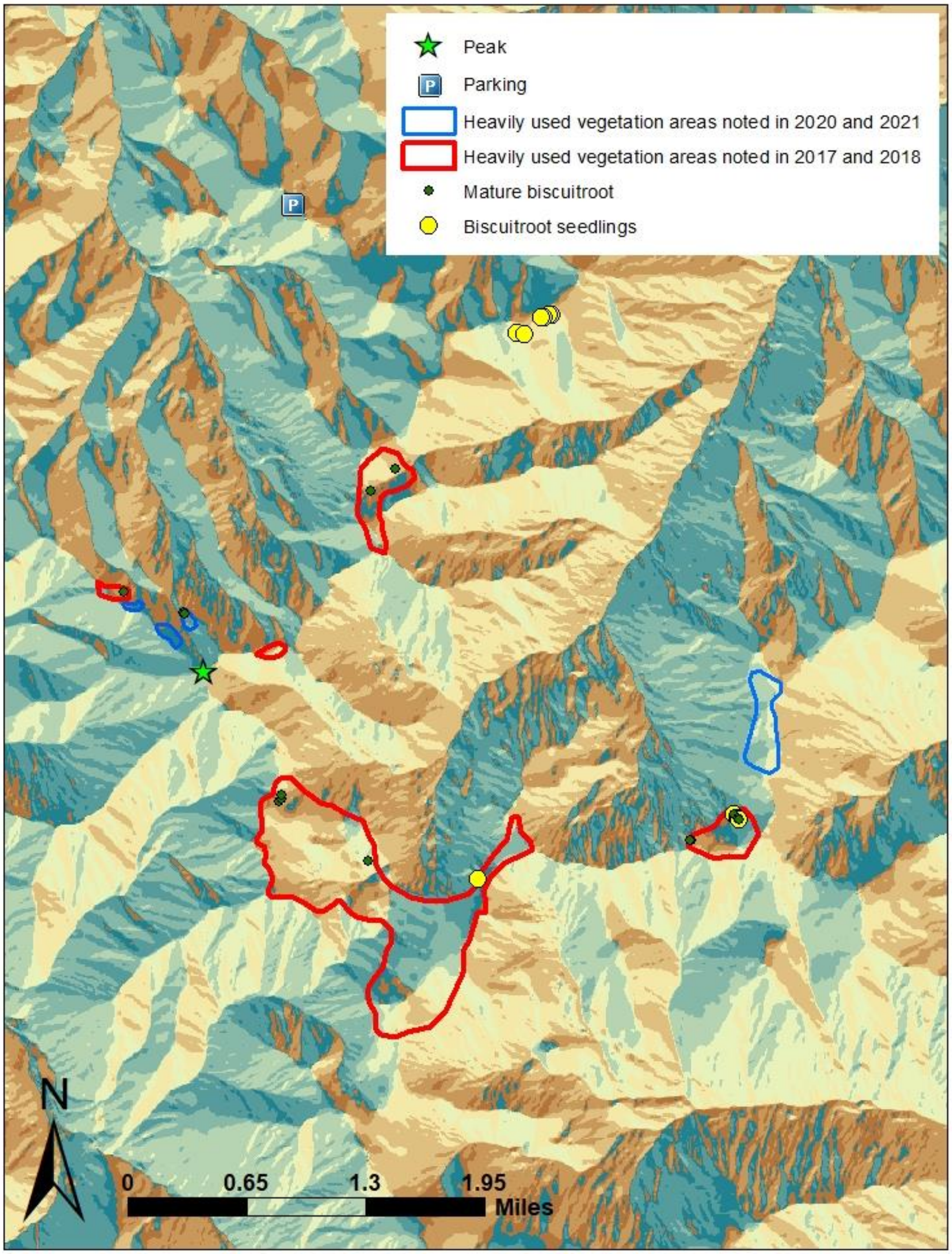

Figure 10. Units where grizzly bears were found heavily foraging (i.e., high density of craters) and where both a high density of rosette and flowering biscuitroot were located on the South Site.

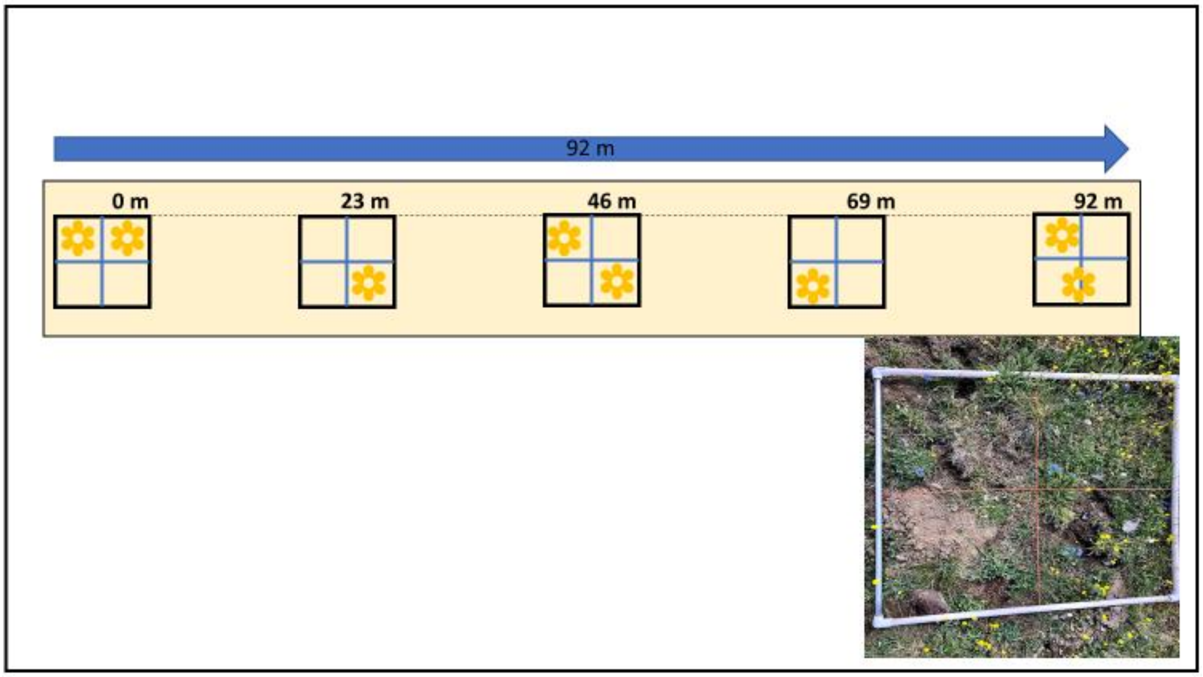

Figure 11. Example of a 92-m transect showing five, 1 m^2 quadrats placed equidistantly along the transect.

Figure 12. Example of an area with craters (i.e., disturbed ground with bowl-shaped cavities) created by grizzly bears digging for roots and tubers.

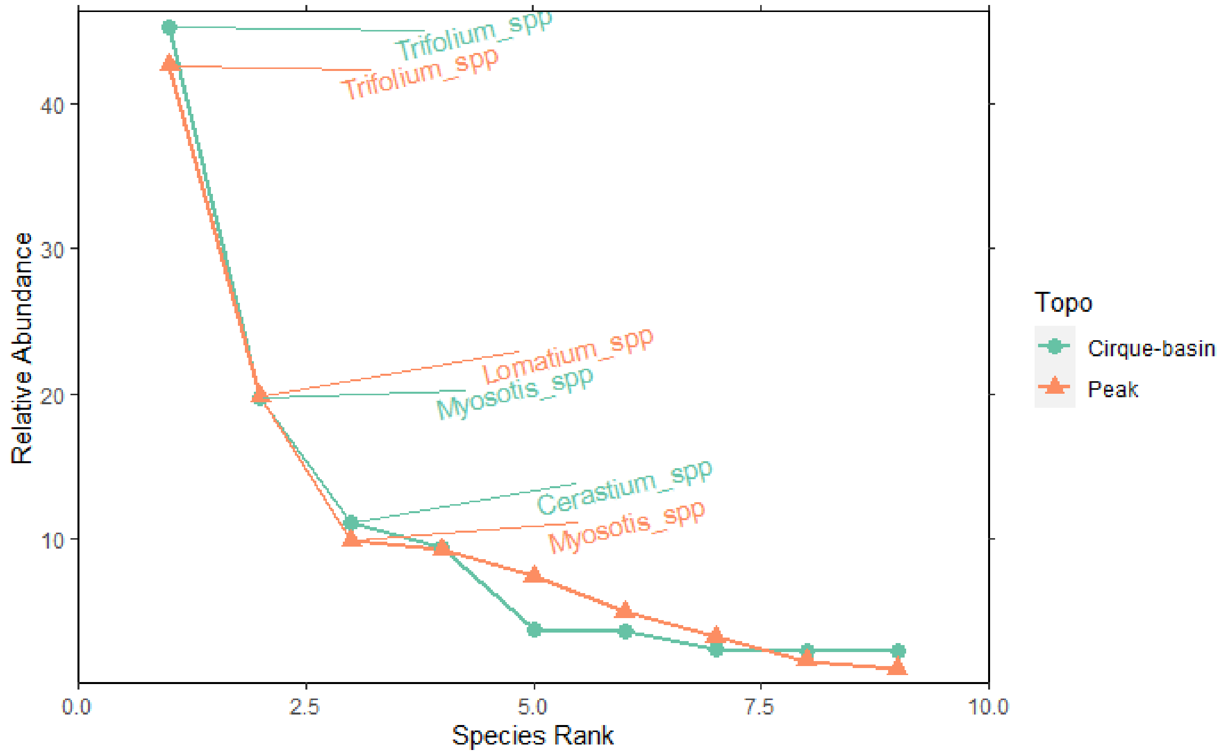

Figure 13. Rank abundance curves for forb species of interest, showing the three dominant genera for both the peak and cirque-basin units on the South Site.

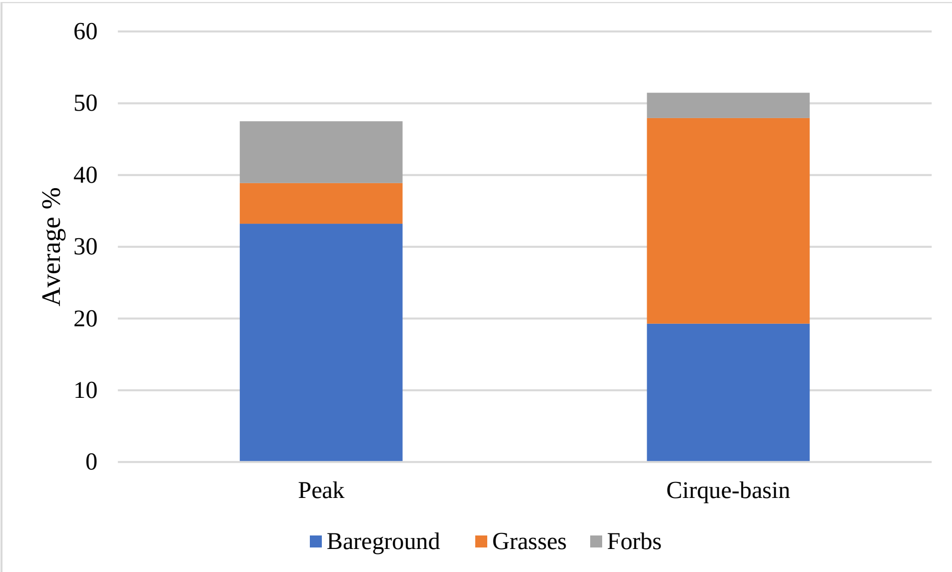

Figure 14. Average percent coverage of the nine-forbs genera, grasses, and bareground within the peak and cirque-basin sampling units.

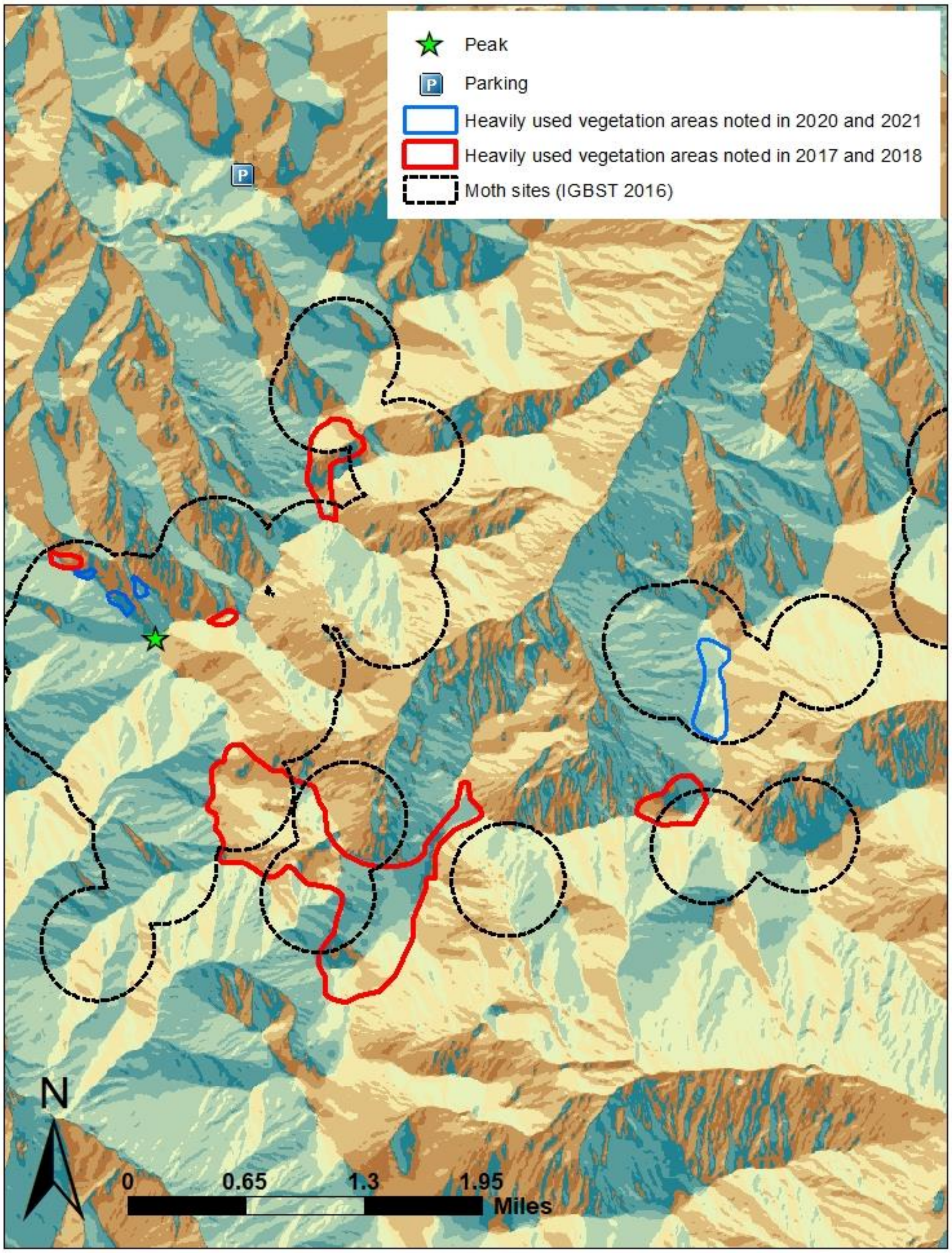

Figure 15. Vegetation areas that were heavily foraged by grizzly bears noted in 2017 – 2018 (Nunlist, 2020) and 2020 – 2021.

Figure 16. Camera trap photograph of a family group consisting of a female with two cubs of the current year, 2 August, 2020.

Figure 17. Camera trap photograph of two cubs of the current year at a hair-snare plank, 2 August, 2020.

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CHAPTER THREE

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Conclusion

We investigated the availability and use of grizzly bear food resources at key ACM aggregation sites in the Absaroka Mountain Range, Wyoming. Specifically, we addressed if grizzly bears utilize vegetation to augment a diet of ACM at a prominent aggregation site.

The SNF is developing a “moth site” management plan focusing on the conservation of ACM sites and the bears that travel to them for foraging. This project considers several important factors related to the management plan. Given increased human use on public lands and ACM sites specifically, management agencies are concerned about their vulnerability to human activities. In these open, high elevation environments, bears are easily displaced by humans and the potential for surprise encounters is high with such significant bear densities. Landscape level changes in food availability and associated foraging patterns of GYE grizzly bears is an additional component of a dynamic situation that involves the ACM sites.

Agency managers currently have no mechanism to assess variability in the annual migration of ACM from the Midwest to the eastern edge of the GYE. However, it is possible that grizzly bears that use the ACM sites would experience a food loss if the number of migratory ACM varied among years or declined over time. These are trends that may develop with a warming climate and patterns of severe weather conditions. Regardless, the grizzly bear population that uses the 31 ACM sites annually is more resilient if multiple foraging opportunities are available, which we wanted to assess.

Based on an analysis of potential human disturbance at 31 ACM sites, two were identified as study locations to provide supportive information for a management plan (Nunlist 2020). Ease of human access was determined by proximity of roads and trails to each ACM site and, in combination with topographic constraints, was used to prioritize sites for study (Nunlist 2020). The two selected are indicated as “North” and “South” sites for anonymity.

Previous investigations at these sites using scat analysis and observations of foraging bears revealed that vegetation is an important food item for grizzly bears at moth aggregation sites, in addition to ACMs (French et al. 1994; Nunlist 2020). French et al. (1994) conducted a food-habits study at moth aggregation sites in the GYE in 1991. Their results showed that ACMs were the prominent food source for grizzly bears on these peaks, but vegetation was also utilized. In addition, the recently completed food-habits study for these two aggregation sites (Nunlist 2020) revealed that, by frequency and volume, forbs dominated the diet of grizzly bears, especially roots and tubers (Nunlist 2020). ACM ranked second.

Nunlist (2020) observed grizzly bears digging in high elevation meadows at the South Site and mapped five locations where foraging effort was concentrated. These were near locations where grizzly bears focused foraging efforts for ACM. With this observation, Nunlist (2020) postulated that the bears were digging for biscuitroot, prompting this study. In addition, French et al. (1994) and Nunlist (2020) identified 9 genera of forbs found in scats retrieved from these moth sites.

By combining the results of our 2020-2021 investigation with the findings of Nunlist (2020) 2017-2018, we confirmed that grizzly bears at the South Site are consuming vegetation and ACM, in that order, as indicated by percent volume and frequency in scats. The vegetative material is predominantly roots and tubers, but the dominant species is biscuitroot. This describes a “dual economy” on the South Site involving two calorie rich food items available for bears foraging there.

Nunlist (2020) mapped five discrete meadows near the summit on the South site that consistently had high densities of bears foraging on vegetation. These were a focus of our investigations. In these meadows we recorded the density of flowering (mature) biscuit root and craters created by grizzly bears digging for this root. The density of the craters was positively related to the density of flowering biscuitroot in these meadows. This indicates that grizzly bears are drawn to these meadows because of the high density of flowering biscuit root.

We assessed the vegetative composition in the areas available to foraging grizzly bears at the South Site (about 40,000 ha), focusing on the nine genera of plants identified through scat analysis (French et al. 1994; Nunlist 2020). We divided this higher portion of the peak into two sampling areas by elevation for comparison: the cirque basins (3,078-3,657-m) and mountain peak (3,658-3,931-m). We characterized the plant communities in 8 and 13 study units, respectively. The relative abundance of these nine-forb genera varied between the mountain peak and cirque basin sampling units but were more available in the mountain peak sampling area. Clover, with a large root structure, was the dominant species for both the mountain peak and cirque basin sampling areas, but biscuitroot was only present in the mountain peak area.

Management Recommendations

We confirmed what French et al. (1994) and Nunlist (2020) reported. Vegetation is an important part of the diet of grizzly bears on the South site. In addition, we verified that roots and tubers are currently more prominent in their diet than ACM, especially biscuitroot. However, we don’t know if this foraging pattern applies to other ACM sites in the Absaroka Range. We recommend trying to assess if the reliance by GYE grizzly bears on roots and tubers is found at other ACM sites.

Important changes have occurred in the past 25 years in the availability of traditional food resources for the GYE grizzly bear. In response, we have observed that this population is remarkably capable of diet shifting and has increased in spite of these changes. One component of this shift in foraging patterns includes an increased use by GYE grizzly bears of ACM sites. ACMs are now a critical part of the diet of this population. On the South site, as we demonstrated, this is combined with a reliance on roots and tubers. In concept, a population that relies heavily on only one food item, is more vulnerable, especially if that item is subject to fluctuations. Consequently, it is favorable that grizzly bears have two significant food resources to utilize at the South ACM site. However, we don’t know how grizzly bears balance or prioritize use between these two food types. For example, if moths are not as abundant in a given year, do grizzly bears make up the difference with roots and tubers or vice versa? We may not be able to determine this synergism, but we can respond to the documented importance of ACM sites by developing methods to monitor the abundance of ACM and roots and tubers over time. The vegetation monitoring methods we developed here could serve as a template for tracking changes in the availability of roots and tubers for grizzly bears at the South Site. Discerning patterns in ACM and root and tuber availability could help managers assess and anticipate the productivity of the South Site and other ACM sites for foraging grizzly bears, which is associated with GYE grizzly bear population status.

Nunlist (2020) mapped areas where grizzly bears consistently gathered in higher numbers on the South Site. In these locations she observed them foraging on moths in talus slopes and on vegetation in high meadows. We have confirmed that the bears were digging for roots and tubers (especially biscuitroot) in the meadows. The talus slopes and meadows where the bears focus foraging are relatively close together near the summit of the peak at about 3600-m. This defined area is where the bears are most vulnerable to displacement by humans and where surprise encounters are likely to occur. As the SNF addresses bear conservation and human safety concerns on the South site in a management plan. The map of foraging areas by Nunlist (2020), combined with the findings of this project, gives the SNF a starting point for considering spatial and temporal restrictions on human travel. It also provides a focused area for monitoring seasonal and annual variation in bear use.

At the South Site, we identified that grizzly bears are foraging extensively in areas with a higher density of flowering (mature) biscuitroot. That demonstrates the importance of these plants and the locations where they grow. However, there isn't much known about the ecology of *Lomatium cous* at high elevations. Therefore, we recommend continued biscuitroot monitoring at the South Site, which can be accomplished by efforts to monitor changes in cover and growth. We also recommend monitoring annual snow accumulation patterns in relationship to locations with biscuitroot, especially as it relates to the near monocultures we found of mature flowering biscuit root versus smaller non-flowering biscuitroot in rosette form. Possibly the meadows with almost exclusively biscuitroot in rosette form may be snowbound longer. In addition, as discussed, locations with flowering biscuit root are extensively excavated by grizzly bears. They are prone to erosion and “overharvesting” by repeated excavating by bears. The percent of bare ground is high. This could also be monitored to assess long-term trends.

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