UNIVERSITÉ DE SHERBROOKE

Relationship Between Environmental Characteristics and the Distribution of Grizzly Bears (*Ursus arctos*), Kluane National Park (Yukon)

by

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Abstract

In Kluane National Park (Yukon), the grizzly bear (*Ursus arctos)* is at the top of the nordic food chain and an excellent indicator of the ecological integrity of this ecosystem. A study on its habitat was realized, taking into account the survival of this specie as well as human safety in the Park. This study shows the direct relation between the biophysical characteristics of the environment and the distribution of bear sightings in the Slims river valley. This relation is presented by a bear presence probability map. It varies through the summer season, due to the changes in the bear's diet. The most critical period is late summer. The most valued environments are deciduous shrubs (spring), alpine meadows (early summer), gravel and alluvial deposits (late summer) and open spruce forest (fall). Almost 60 % of the sightings occur in these four preferred habitats. Also, sightings are more frequent at elevations between 720 and 940 m and between 1 380 and 1 600 m, on slopes that varies between 0 and 15 % and on east and north-east aspects. Field data collected are bear food biomass, vegetation cover, geomorphological landforms and bear sightings by hikers during 10 years. The use of a Geographic Information System enables the possibility of realizing a useful and integrated management of the environment, and mostly the threatened grizzly bear.

Résumé

Relation entre les caractéristiques du milieu naturel et la répartition du grizzli (*Ursus arctos*) au Parc national Kluane (Yukon).

Au Parc national Kluane (Yukon), le grizzli (*Ursus arctos)* se retrouve à la tête de la chaîne alimentaire nordique et il est un bon indicateur de l'intégrité écologique de cet écosystème. C'est dans une optique de survie de l'espèce et de sécurité envers les humains qu'une étude sur son habitat est réalisée. Dans cette étude, on démontre qu'il existe une relation directe entre les caractéristiques biophysiques du milieu et la répartition des observations d'ours dans la vallée de la rivière Slims. Cette relation est présentée au moyen d'une carte de probabilité de présence d'ours. Cette relation varie au cours de la période estivale, en fonction des habitudes alimentaires changeantes des ours. La saison la plus critique est la fin de l'été. Les milieux naturels les plus prisés sont le milieu arbustif feuillu (printemps), la prairie alpine (début d'été), la zone de végétation éparse sur dépôts alluviaux (fin d'été) et la forêt ouverte d'épinettes (automne). Près de 60 % des observations se font dans ces quatre classes d'habitats préférentiels. De plus, les observations d'ours sont plus fréquentes à des altitudes variant entre 720 et 940 m et entre 1 380 et 1 600 m, sur des pentes entre 0 et 15 % et orientées vers l'est et le nord-est. Les données recueillies sur le terrain sont la biomasse présente en terme d'abondance de nourriture d'ours, le type de couvert végétal, les types de formations meubles et les observations d'ours par les visiteurs sur 10 ans. En combinant ces données dans un système d'information géographique, il est possible de réaliser une gestion intégrée plus efficace du territoire et surtout de l'espèce vulnérable qu'est le grizzli.

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1. Introduction

1.1. Issue

Kluane National Park (Figure 1) is one of the few remaining refuges for the grizzly bear (*Ursus arctos)*. At the top of the Nordic food chain, the grizzly bear is a good indicator of the ecological integrity of the ecosystem in which it lives. From a sustainable development perspective, it is important to ensure the survival of each of the components that comprise this unique ecosystem. To this end, designated protected wildlife areas can make a significant contribution to the development of a strategy for ensuring ecosystem biodiversity (Merrill *et al.,* 1995). Indeed, biodiversity is one of the most important indicators of ecological integrity (Parks Canada, 1998). Since the grizzly bear is an indicator species of the region, it is essential to gain a better understanding of this species and its habitat.

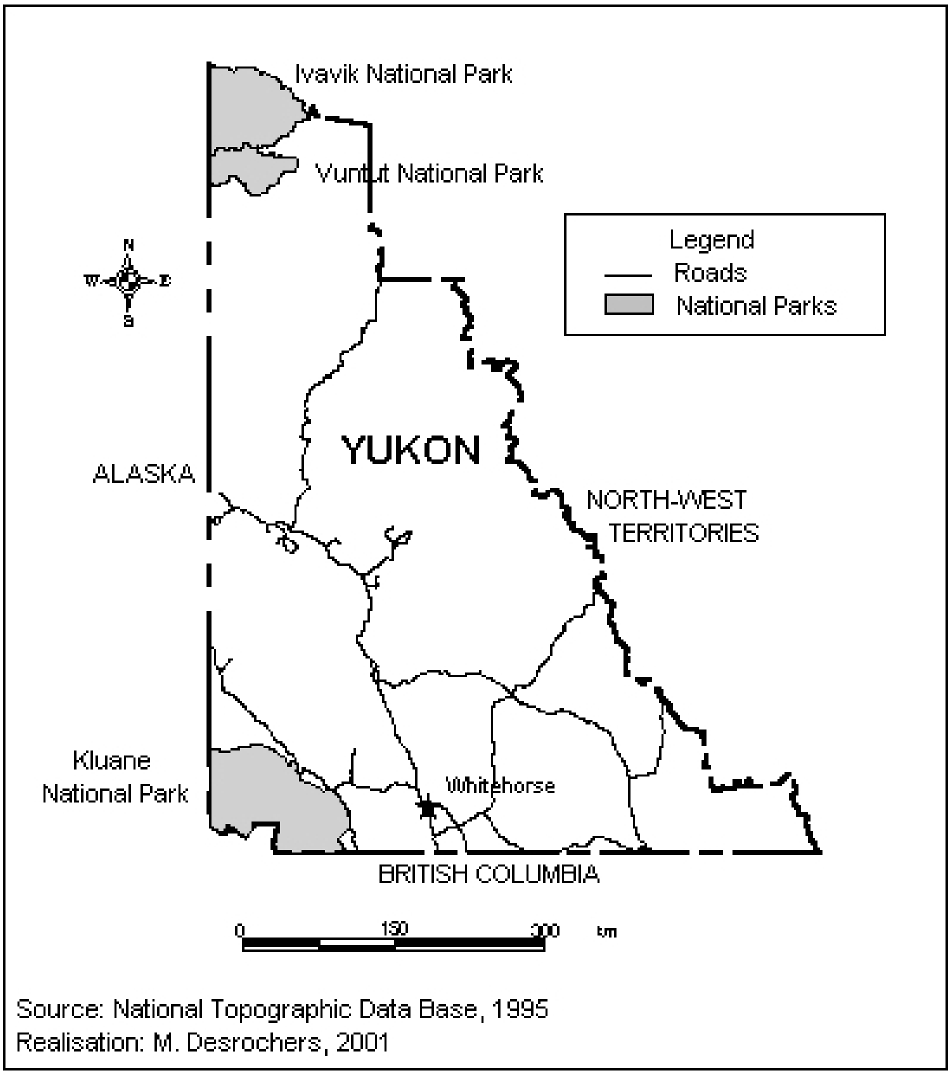


Figure 1 - Location of Kluane National Park

The aim of Canada's national parks system is to preserve the country's natural diversity for the enjoyment of current and future generations (Canadian Heritage, 1998). It is imperative to take into account the impact of human activities on the environment, while ensuring visitor safety. The presence of bears in a park requires effective management methods in order to avoid bear-human encounters and be able to respond appropriately if necessary. Through a better knowledge of the environment, the species' behaviour, human reactions in conflict situations and the history of conflicts, managers can hope to gain a comprehensive understanding of the situation. The rationale of a study dealing with human-bear interactions lies in the need to ensure the survival of the species and the safety of national park visitors.

The grizzly bear has been a threatened species in the United States (excluding Alaska) since 1975 and is designated vulnerable in Canada (Singer, 1978). In fact, the grizzly bear currently occupies less than half of its former range (Agee et al., 1989). It is estimated that there are between 52 000 and 63 000 grizzly bears in North America (Peek et al., 1987). In the Yukon, more specifically in Kluane National Park, the very large grizzly bear population is still intact and remains relatively undisturbed by human activities. However, the body of knowledge concerning this species is minimal. With an estimated population of more than 400 individuals living in the park (McCann, 1997b), proper management of the species is a priority in the park's management plan (Environment Canada, 1990). To this end, a specific grizzly bear management plan was instituted in the early 1990s and includes funding for research (Environment Canada, 1992). An important question concerns the grizzly bear's habitat and interaction with Park visitors. Geographic data will thus help us gain a better understanding of the variables that influence the distribution of the grizzly bear in areas visited by humans.

Although most grizzly bears tend to flee when they detect the presence of humans (Herrero, 1985), several factors may explain their behavioural response to the presence of humans: the history and nature of interactions at a specific site, access to "human" food, the size and characteristics of the animal population, as well as the importance of natural habitats and the availability of natural food sources (Mattson, 1990). Since the rate of grizzly bear mortality caused by the presence of humans is directly linked to the number of human—grizzly bear encounters (Mattson and Herrero, 1996), it is important to properly understand their interrelationship.

Our objective is to demonstrate a direct relationship between the biophysical characteristics of the grizzly bear's environment, the abundance of bear food (mainly plant) in the study sector, as well as the frequency of grizzly bear sightings by visitors within the park. Although these sightings may be imprecise and sometimes incorrect, their large number helps compensate for their shortcomings. Provided that the limitations of the information obtained by visitors are taken into account, such a database can be beneficial. In this regard, previous studies have shown that, despite certain limitations, sighting data constitute a useful source of information that is of great value for threatened wildlife species (Agee *et al.*, 1989; Stoms *et al.*, 1993).

If we know the grizzly bear's preferred habitats and foods, as well as the factors that repel it, it is easier to identify the specific areas where bears and humans share the same territory. This is borne out if we accept the hypothesis that the grizzly bear's presence in a location constitutes an indicator of habitat quality (Pereira and Itami, 1991). Given the complexity of the phenomenon studied, a multifactorial approach, combined with a Geographic Information System (GIS), is preferred. In fact, studies by Clark *et al.* (1993) have shown that the multifactorial approach is essential for modelling and identifying preferred black bear (*U. americanus*) habitats, which would not have been identified using a single layer of information. Indeed, mapping a phenomenon as dynamic as potential human—grizzly bear interactions requires a multidisciplinary approach, since a wide variety of knowledge is indispensable to the development and application of any GIS (Aronoff, 1993). In addition, remote sensing has proven to be a valuable and useful tool for quantitatively describing, mapping and assessing grizzly bear habitat using an ecosystem approach (Craighead *et al*., 1985).

1.2. Scientific hypothesis

The rationale for studying grizzly bear habitat and behaviour is to ensure the survival of this species, while also ensuring visitor safety. The aim of this study is, therefore, to verify the following hypothesis: there is a relationship between the biophysical characteristics of the environment and grizzly bear distribution.

1.3. Objectives

Starting from the above-stated hypothesis, a general objective and a specific objective have been put forward.

The main objective is to integrate, using a multifactorial approach, the biophysical components of the environment and of preferred grizzly bear habitat, along with grizzly bear sightings by visitors, into a GIS in order to generate maps of the probability of the presence of bears.

The specific objective, which supports the main objective, is directly related to the grizzly bear's feeding habits. Since these habits vary from season to season, it is important to determine and illustrate cartographically the probability of the presence of bears as a function of the seasonal availability of plant foods, which in turn is related to the grizzly bears' changing diet.

2. Location and description of the study site

Kluane National Park is located in southwestern Yukon Territory (60ºN, 138ºW). A UNESCO world heritage site, the park was established in 1972. It covers an area of 22 013 km^2 and is representative of the Northern Coast Mountains Natural Region. The Park encompasses the country's highest peak, Mount Logan, at an elevation of 5 959 m, the world's largest icefields outside polar areas (more than 4 000 glaciers) and the largest biodiversity north of the 60th parallel (224 species of vertebrate animals and 814 species of vascular plants). With its neighbours Wrangell-St. Elias and Glacier Bay national parks (Alaska), as well as Tatshenshini-Alsek Provincial Park (British Columbia), Kluane National Park is part of the world's largest international protected area, covering more than 98 000 km^2 (Figure 2).

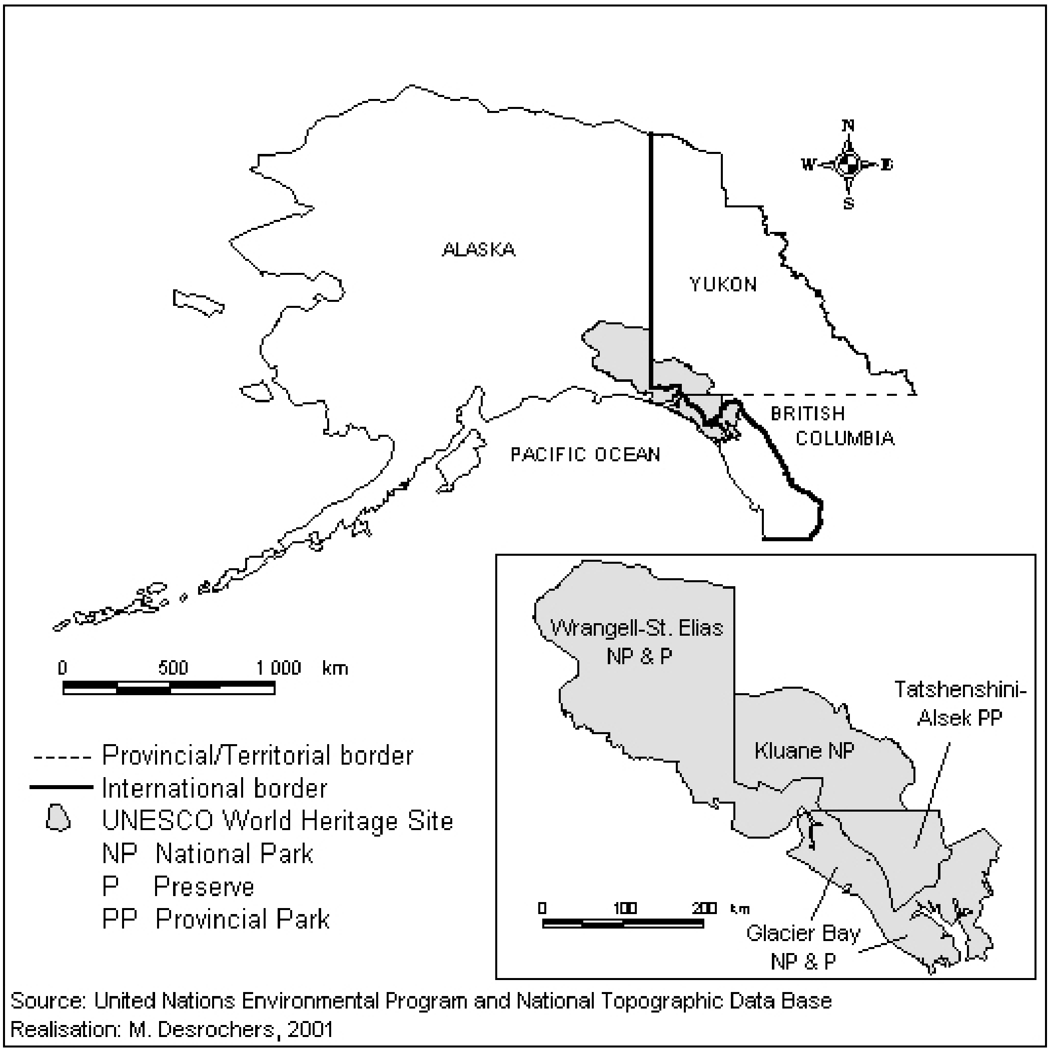


Figure 2 - Location of the UNESCO world heritage site

More specifically, the territory included in this study is comprised within the Slims River Valley, in the northern section of the park covered with vegetation (Figure 3).

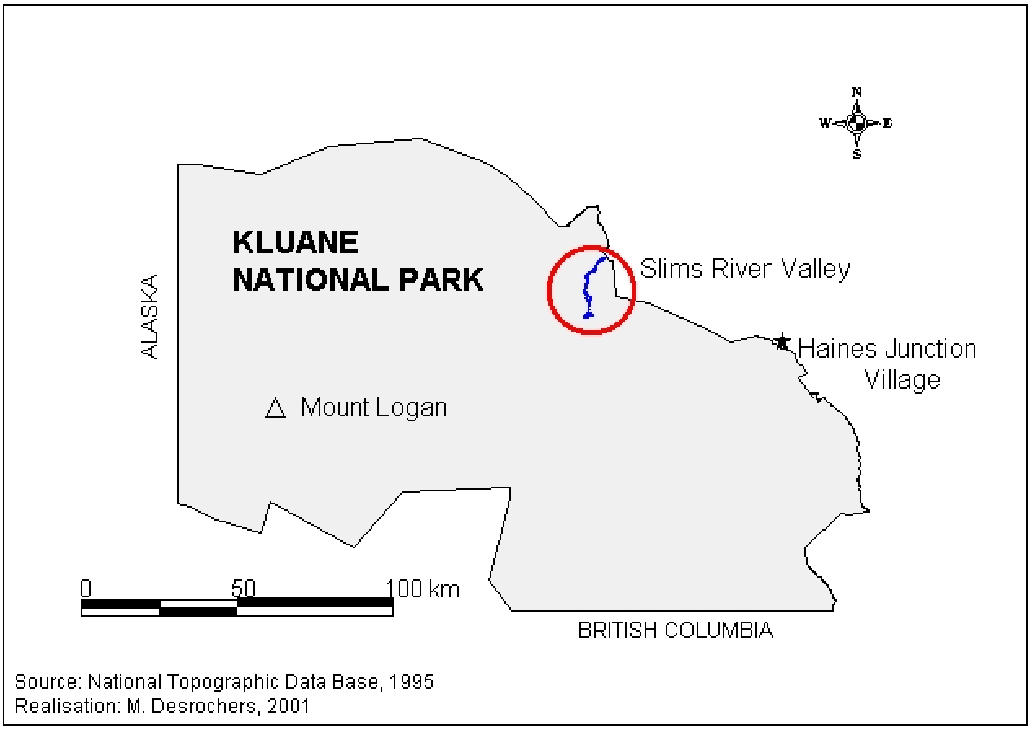


Figure 3 – Location of the Slims River Valley

2.1. Geology

The geological structure of the area surrounding Kluane National Park is very complex. Seismic activity is intense and the numerous fault complexes are the result of intense geological processes. The study area comprises two physiographic regions: the St. Elias Mountains (geosyncline) and the Yukon Plateau (anticline), which are separated by the Shakwak Trench, a broad graben 8 to 16 km wide. Nearly 80 per cent of the park is located within the St. Elias Mountains region (Figure 4). With their complex geological history, the rocks are heavily folded and faulted (Rampton, 1981).

www.parkscanada.ca

Figure 4 – St. Elias Mountain Range with Mount Logan in the background

The frontal range of the St. Elias Mountains is composed of the Kluane Range, which borders the Shakwak Trench and reaches its highest point at an elevation of approximately 2 700 m. This area is characterized mainly by deep V-shaped valleys separated by many large tributaries (Slims, Duke, Donjek, White rivers, etc.). Northwest of the Kluane Range is the Duke Depression, composed mainly of valleys and plateaus with a maximum elevation of 1 600 m. Finally, the icefields of the St. Elias Mountains comprise the remainder of the territory of Kluane National Park. This region has numerous valley glaciers, icefields more than 2 000 m thick and high peaks (between 3 000 m and 6 000 m), including the highest peaks in Canada. The site is characterized by heavy tectonic activity, with many small earthquakes daily, related to the movement of the Pacific plate under the North American plate. This tectonic activity is responsible for the metamorphosis of the Devonian sediments to marble, slate and schist.

2.2. Landforms

In Kluane National Park, evidence of active geomorphological processes can be seen everywhere. The mountains are high, rugged and steeply scarped, glaciers and icefields cover more than half the territory, the soil is thin and poorly developed, periglacial processes are very active, the flow of the streams is highly variable and the vegetation is sparse and fragile (Gray, 1985).

Glacial processes have sculpted the entire landscape of the park. Since the Upper Tertiary, the region has been glaciated at least four times (Denton and Stuiver, 1967). This is attested by the icefields, as well as the resulting valley glaciers, which are several kilometres wide, several tens of kilometres long and up to a kilometre thick (Figure 5). There are also many alpine glaciers, glacial cirques and rock glaciers, which have a direct impact on the landscape as agents of erosion, transport and sedimentation.

Figure 5 – Aerial view of the Kaskawulsh valley glacier

The last glaciation of the Pleistocene, called Kluane (ended around 12 000 BP), contributed to the deposition of surface till (Gray, 1985). Alluvial gravels, sand dunes and loess deposits constitute the other surficial materials of the sector. Since the park is located in the discontinuous permafrost area, permafrost is frequent (Muller, 1967; Gray, 1985).

A number of dynamic forms are visible within Kluane National Park: scree slopes, talus cones, landslides, alluvial cones, various types of moraines, etc. The surficial deposits are variable: glaciofluvial, lacustrine and aeolian (dunes and loess).

2.3. Hydrography

Kluane National Park drains into four different basins. The one of interest to us is the Yukon River basin, into which the Slims River flows. The Slims River watershed occupies an area of 2 456 km², 55 per cent of which is covered by the Kaskawulsh glacier. Meltwater from this glacier accounts for 70 to 90 per cent of the flow of the Slims River (Sawada and Johnson, 2000). The Slims River empties into Kluane Lake 22 km further, then into the Kluane River, before reaching the Yukon River. The Yukon River joins the Mackenzie Delta, 2 250 km downriver, very close to the Bering Sea. The remainder of the glacier meltwater flows into the Kaskawulsh River, which drains into the Alsek River basin, which in turn empties into the Pacific Ocean, only 250 km downstream (Bostock, 1969) (Figure 6).

The Slims River Valley is typical of a glacial valley (Figure 7). Its channel is of the anastomosed type and often covered with very fine aeolian deposits. This silt is easily transported and resedimented downstream, which contributes to the sediment input of the river delta at its mouth with Kluane Lake. Its regime is of the glacial type, resulting in a wide variation in flow depending on the season and the time of day. Barnett (1974) has even calculated a flow variation of 35 to 40 per cent in less than ten hours for the Slims River.

Several tributaries, with high-energy gradients, flow into the Slims River, forming immense alluvial cones that are still very active. Most of the glaciofluvial floodplain is covered with fine deposits (sands and silts) (Gray, 1985). Downstream, the river flows into Kluane Lake, forming a delta of approximately 11 km² (Gray, 1985). Bostock (1952) has estimated that the delta grows by 50 m to 70 m per year.

Modified from Krebs *et al.* (2000)

Figure 6 – Colour composites of the study site, Landsat TM image

Figure 7 – General aerial view of the Slims River Valley looking upstream

2.4. Climate

The main factor influencing the climate of the southwest Yukon region is the barrier effect of the coastal mountain range, which blocks the moisture and warm air from the Pacific Ocean. The climate is considered dry continental and even semi-arid in certain valleys, including the Slims River Valley. The mean annual temperature in Haines Junction is –3.7 C. During July and August, the mean daily temperature ranges from 15°C to 20°C, while it is below the freezing point from October to April (Gray, 1985). There are 20 to 30 frost-free days on average during the summer (Gray, 1985). Mean annual precipitation is around 280 mm, nearly half of which falls as snow (Douglas, 1974; Gray, 1985). However, the icefields within the park can receive up to 20 m of snow a year (UNESCO, 1994). Latitude remains another important factor. Located geographically at 60°N, Kluane National Park receives approximately 19 hours of sunlight a day during the summer, and less than 6 hours in winter.

2.5. Flora

Only 18 per cent of the area of Kluane National Park lies outside the icefields (Gray, 1985). In general, the vegetation is divided into three elevation strata: montane, subalpine and alpine zones. Most of the valleys and foothills (elevation of between 760 m and 1 000 m) are covered by an open montane forest of white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*). There are also communities of shrubs and grasses, associated with marshes, peat bogs and ecotones, due to the many disturbances associated with fire and geomorphological processes (especially fluvial). Slow-growing or stunted shrubs (up to 3 m high), such as willow (*Salix* spp.), dwarf birch (*Betula glandulosa*) and alder (*Alnus* spp.), as well as isolated specimens of *Picea glauca* grow in the transition zone (elevation of between 900 m and 1 400 m). The treeline is located between the elevations of 1 050 m and 1 200 m, depending on the micro-climates. Above the elevation of 1 400 m lies the alpine tundra, which is divided into two sub-sections. The lower part is characterized by a mosaic of krummholz and shrubs less than 1 m high, dominated by *Salix* spp. and *Betula* spp., while the upper part is covered with dwarfed vascular plants characteristic of the alpine tundra (Douglas, 1974).

The forest dominated by Picea glauca represents the climax of this region. In terms of flora, 814 taxa of vascular plants have been inventoried within or close to the park boundaries (Douglas, 1980). A number of these species are endemic to the park (Caswell, 2000). There are also several rare plants, such as *Aster yukonensis*, *Artemisia fuscala* and *Oxytropis viscida* (UNESCO, 1994). The vegetation that covers the glaciofluvial floodplain of the Slims River Valley, especially its delta, has been identified as one of the park's most unique and interesting botanical phenomena (Douglas, 1980). A number of halophytes are found here, forming eight distinct communities (Gray, 1985). Their presence is closely related to the sector's unique pedological and geomorphological components, essentially silty loess.

2.6. Wildlife

Kluane National Park has abundant wildlife. There is a very large population of Dall sheep (*Ovis dalli*), the largest and most abundant mammal in the park, more than 400 grizzly bears (*Ursus arctos*) and about 100 black bears (*U. americanus*). There are also large numbers of mountain goats (*Oreamnos americanus*), the largest subspecies of moose in North America (*Alces alces*), a few caribou (*Rangifer tarandus*) and other mammals: wolf (*Canis lupus*), wolverine (*Gulo gulo*), muskrat (*Ondatra zibethicus*), mink (*Mustela vison*), marmot (*Marmota monax*), red fox (*Vulpes vulpes*), lynx (*Lynx canadensis*), porcupine (*Erethizon* dorsatum), otter (*Lutra canadensis*), coyote (*Canis latrans*), beaver (*Castor canadensis*), snowshoe hare (*Lepus americanus*) and arctic ground squirrel (*Spermophilus parryii*). Of the some 150 species of birds observed in the park, 118 breed there. Mountain bluebirds (*Sialia currucoides*), falcons (*Falco peregrinus*), bald eagles (*Haliaeetus leucocephalus*), golden eagles (*Aquila chrysaetos*) and trumpeter swans (*Cygnus buccinator*), a vulnerable species (Mosquin *et al.*, 1995), are commonly sighted.

2.7. Visitors

Visitation at Kluane National Park exceeds 70 000 visitor-days annually (Jackson, 1998). The Sheep Mountain sector (which encompasses the Slims River Valley and its surrounding area) receives on average nearly 2 000 one-day hikers a year and around 600 registered hikers who head off into the backcountry for a minimum of two days.

2.8. Slims River Valley

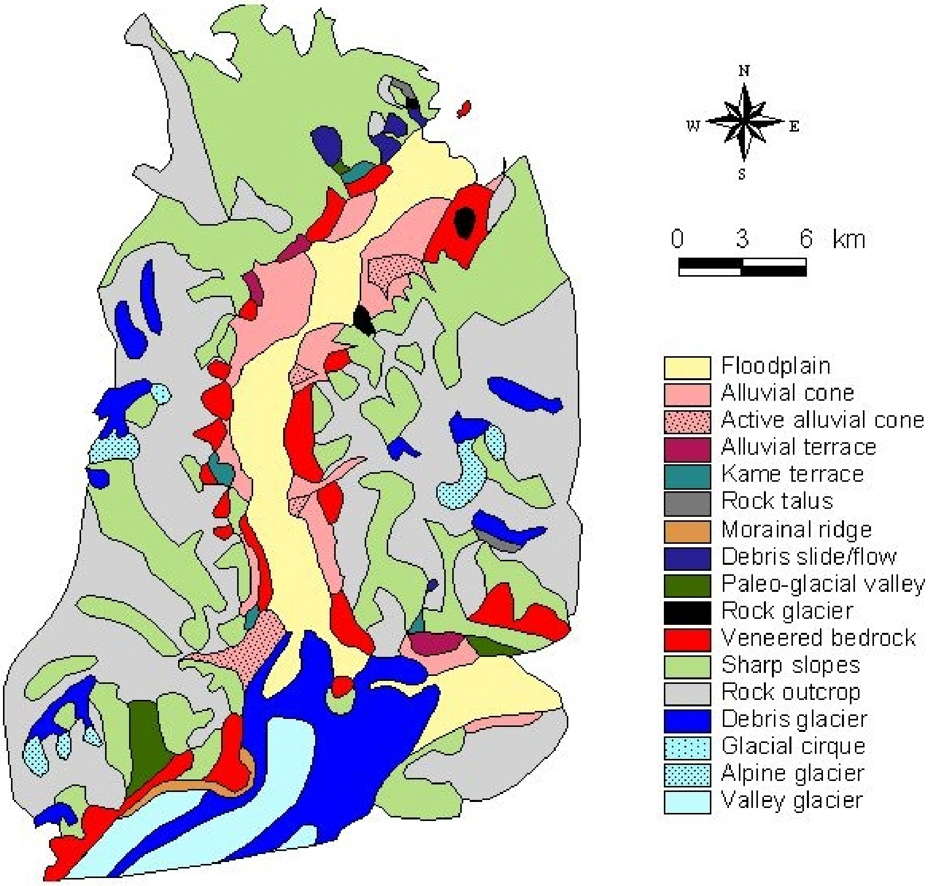
Within Kluane National Park, data collection was carried out in the Slims River Valley (60°50'N, 138°40'W), i.e. an area of 498 km² (Figure 6). This territory is included in the 18 per cent of the park that is covered by vegetation. This valley is crossed by the Slims River, which is fed by the Kaskawulsh glacier (Figures 8 and 9). This is the park's most popular site and the one most visited by hikers because of the spectacular view of the Kaskawulsh glacier that dominates it. Hikers can opt to hike either the east or west side. There are unmarked routes on both sides of the valley. However, the west slope is much more travelled by hikers since it leads to the lookout at Observation Mountain (2 114 m), which provides a view overlooking the Kaskawulsh glacier (Figure 6). The glacial valley extends nearly 22 km before joining the frontal moraine. Hikers spend on average four days here in order to complete the entire route.

The frequency of grizzly bear sightings is very high given the valley's landforms. Surrounded by large mountainous massifs, the corridor accessible to animal species and hikers is fairly narrow and restricted. It should be noted that almost all bear sightings in the Slim's River Valley are of grizzly bears, since Kluane black bears are found mainly in the southeastern part of the park.

Figure 8 – Aerial view of the Slims River Valley looking upstream

Figure 9 – Aerial view of the Slims River Valley looking downstream

The landforms of the sector are particularly diversified, as shown in Figure 10 (modified from Gray, 1985; Muller, 1958, 1967; Rampton, 1981). The Slims River floodplain is bordered by numerous alluvial cones and steep slopes scattered with glacially scoured rocks. Many rock outcrops are visible from each side of the valley. In addition, silty loess from the glacier promotes growth of distinctive vegetation, especially on the delta.



Modified from Gray (1985); Muller (1958, 1967); Rampton (1981)

Figure 10 - Geomorphology of the Slims River Valley

The study of this valley is interesting and relevant for our purposes. It receives one-third of all the hikers in the entire park who venture into the backcountry for a minimum of two days (Figure 11). Between 1988 and 1998, nearly 35 per cent of all bear sightings in the park were made in this valley (Desrochers, 1998). This valley is therefore heavily used and its management is a priority (Environment Canada, 1990). Moreover, the studies clearly indicate that increased use of the Slims River Valley by visitors will have a rapid negative impact on grizzly bear survival within the park, within a period of as little as 5 to 10 years from now (Hegmann, 1995).

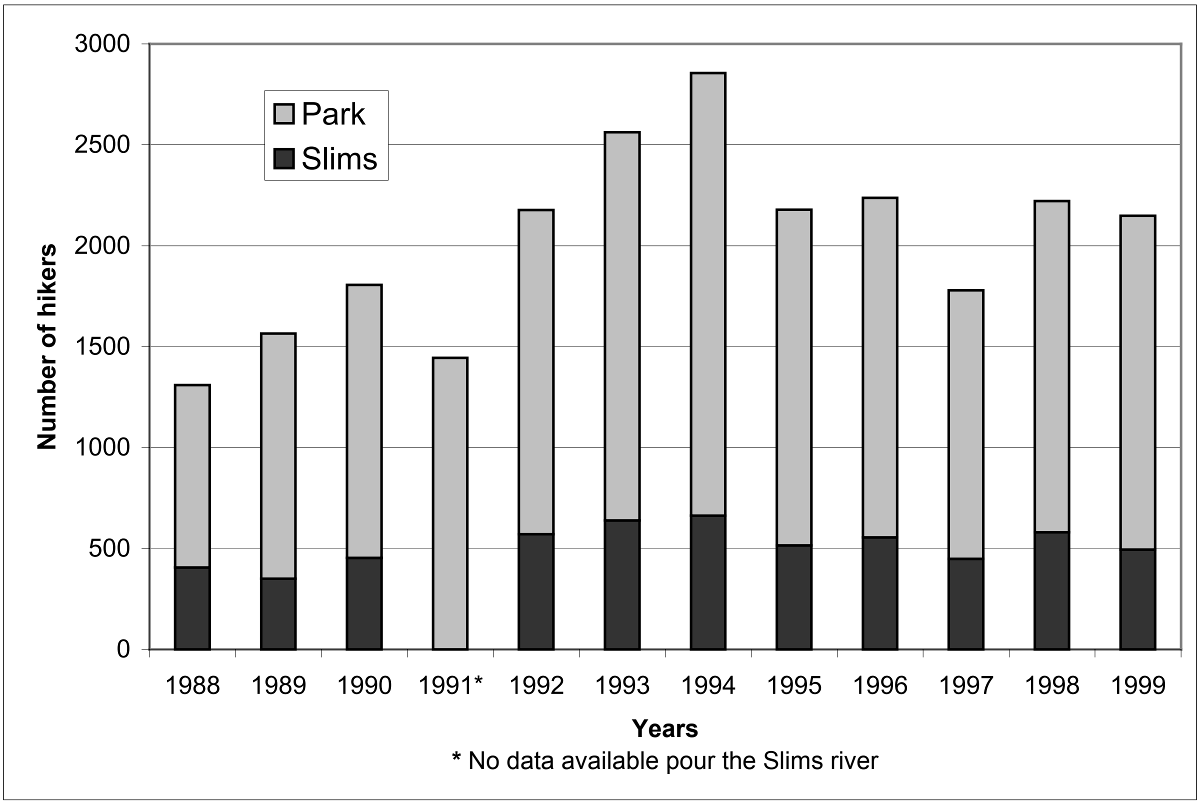


Figure 11 – Number of registered hikers visiting the backcountry in the Slims River Valley and total number for Kluane National Park (1988-1999)

3. Methodology

The methodology aims to identify the biophysical characteristics of the environment favoured by the grizzly bear and to validate these characteristics using grizzly bear sightings by visitors. By combining these two elements, it will be possible to produce a map of the grizzly's preferred seasonal habitat in the study sector, which can be interpreted as a map of the probability of bear presence. This requires several steps: a review of previous studies, compilation of the bear sightings database, identification of the biophysical characteristics of the environment, data acquisition, identification of the grizzly bear's diet, identification of preferred grizzly bear habitats, and production and validation of the maps of the probability of grizzly bear presence (Figure 12).

3.1. Review of previous studies

Grizzly bear studies are more common in the large Rockies ecosystem (Canadian and American) given the strong demographic pressure on the species habitat. In the Yukon, with a population of more than 6 000 grizzly bears versus a total human population of 30 000, conditions are very favourable to grizzly bears. A number of researchers have studied grizzly bear habitat, but few studies have been carried out in the Yukon. Pearson (1975) conducted a comprehensive study of grizzly bears of Kluane National Park between 1964 and 1969, which is still used as a reference today. His research provided data on the behaviour and feeding habits specific to the Kluane grizzly bears, which were found to have adapted to the specific biophysical conditions of the environment.

The work carried out under the *Kluane Grizzly Bear Research Program* (1992-1997) provided data on the number of individuals present in the park, the size of their territory, their diet (from fecal analyses), behaviour, genetics, etc. (McCann, 1994, 1996, 1997a, 1997b). These findings constitute our main reference in terms of specific and current knowledge about the Kluane grizzly bear.

3.2. Compilation of the bear sightings database

Kluane National Park has maintained a database of bear sightings since 1987. This is an effective way of recording all bear sightings in the park by visitors, employees and researchers. A sample of the bear observation form is provided in Appendix 1. The information collected includes the location, the sector of the park, the number of hikers in the group, the sighting date and time, the bear's response (if it was aware of the presence of humans), the bear's activity at the time of the sighting, the details of the confrontation (if applicable) and the individuals involved. These data are then compiled in a spreadsheet (Access® or Excel®) by year. All sightings made by hikers while on the Slims East or Slims West route (on either side of the valley) between 1988 and 1998 were included. Sightings made by car, airplane, helicopter or any other vehicle were removed from the database in order to restrict the analysis to the hikers' environment.

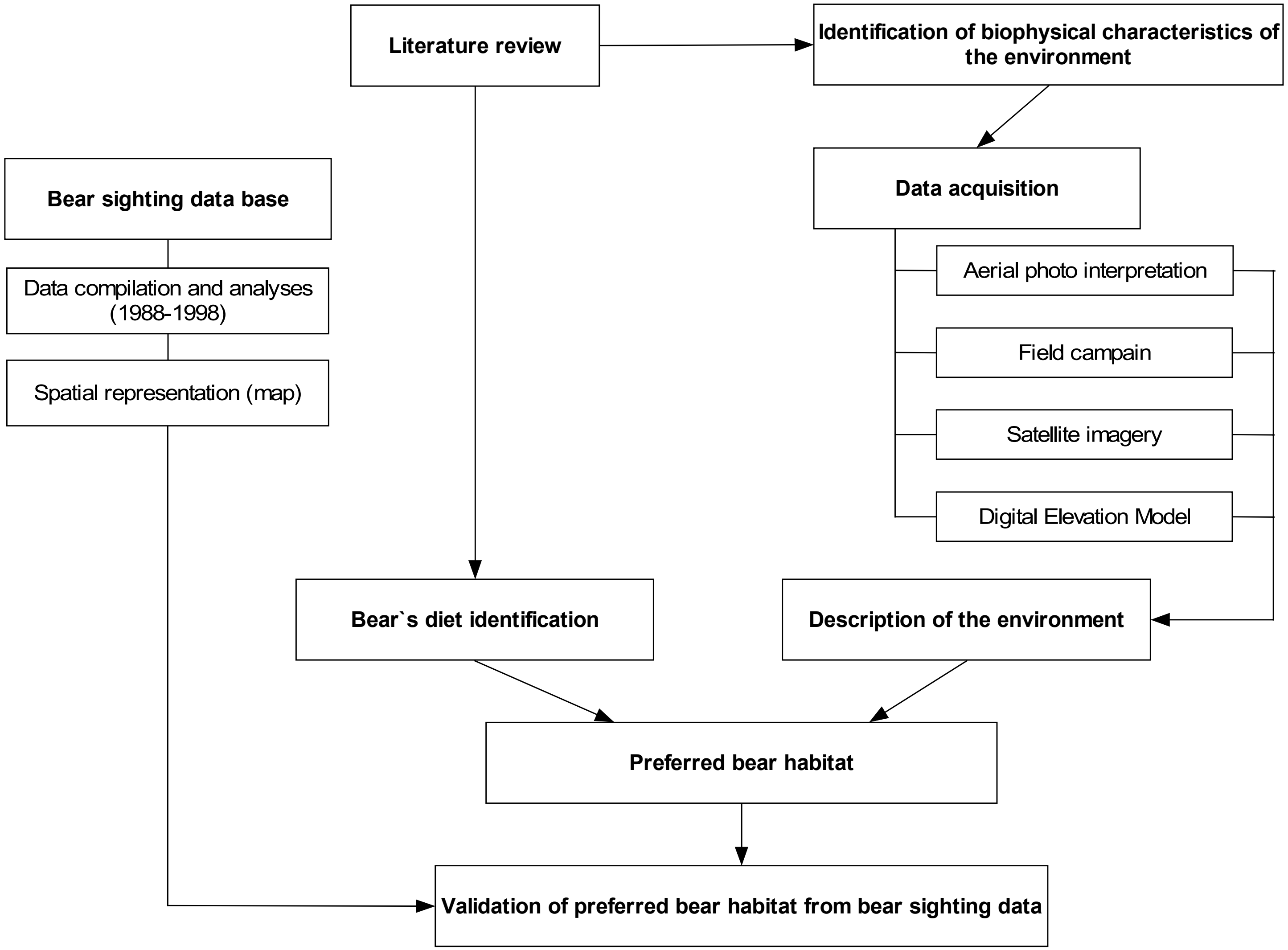


Figure 12 – Methodology chart

The location is given in UTM coordinates from topographic maps. The assigned coordinates are rounded based on the 1 km² UTM grid, in order to reduce positioning uncertainty. Inconsistent UTM coordinates (less than 1 per cent), i.e. bear sightings on the Kaskawulsh glacier (inaccessible to both humans and bears) were deleted. Like other studies based on sightings of animal species, it must be assumed that the habitat conditions remain relatively constant for the period of time covered by the sighting data (Agee *et al.*, 1989; Stoms *et al.*, 1993). In this case, very few changes had occurred in the study site over the 10 years (1988-1998), given the slow evolution of this Nordic ecosystem. There were also no fires or major human or natural disturbances during the period concerned.

3.3. Identification of the biophysical characteristics of the environment

A review of previous studies reveals certain important factors relating to the grizzly bear's habitat. Mace and Waller (1996) identified habitats where bears are more likely to be found, such as rock grasslands, shrublands, forest, avalanche chutes and slabrock. The importance of the landforms and vegetation is therefore noted. In this regard, Servheen (1983) and Waller and Mace (1997) were able to identify a territory use pattern that is directly linked to vegetation, which in turn is directly related to the animal's diet. Indeed, diet is the most decisive factor influencing the grizzly bear's spatial movements (McLaughlin, 1981; Servheen, 1983; Mace and Waller, 1996; Hamilton, 1987; Nadeau, 1987; Kansa and Riddell, 1993; Clark *et al*., 1994; Wellwood and MacHutchon, 1999; Mano, 1994; Nomura and Higashi, 2000). The search for food is therefore the main activity during the summer season (Wellwood and MacHutchon, 1999). Indeed, the availability of food appears to be the most decisive factor for the survival of the grizzly bear population in the North (Curatolo and Moore, 1975; Reynolds, 1979, 1980; Quimby, 1974; Quimby and Snarski, 1974; Larsen and Markel, 1989).

The grizzly bear is an opportunistic omnivore (Hamer, 1985). However, in Kluane, it behaves more like an herbivore, since more than 80 per cent of its diet consists of vegetation (Pearson, 1975). However, unlike herbivores, grizzly bears do not have a digestive system that enables them to extract the maximum amount of energy and nutrients from the plants. In order to store enough energy to survive 5 to 8 months of inactivity (McCann, 1996), they must therefore consume a very large quantity of plants (Wellwood and MacHutchon, 1999). It is estimated that when late summer arrives and the berries are ripe, grizzly bears can gain up to 450 g a day until they enter their dens to hibernate for the winter (Pearson, 1975).

It is therefore necessary to identify the food available, hence the plant biomass present, based on the feeding habits specific to the grizzly bears of Kluane National Park. A number of studies provide precise information on grizzly bears' diet (Pearson, 1975; McCann, 1994, 1997a, 1997b; Lindberg, 1995; McCormick, 1999). Eight predominant plant species in the grizzly bears' diet were identified as indicative of an excellent habitat for the park's grizzly bears. In addition, 20 other important species found in the area were included, in order to cover the grizzly bear's entire diet.

It should be pointed out that the grizzly bear's diet changes during the season, as a function of the growth of certain plants or berries for example. Certain favourite species can therefore be grouped together by season (Hamer and Herrero, 1983; Herrero, 1985; Mattson *et al.*, 1991). In addition, the preferred areas vary depending on the season (McCormick, 1999).

In the spring, grizzly bears are found at lower elevations, where the first plants appear (the Poaceae family for example), and where young prey (moose, Dall sheep, etc.) can be found. During the summer, they tend to move up to higher elevations in search of certain specific plant species (*Hedysarum* spp., *Equisetum* spp., etc.), until the first berries ripen. At this point, they then seek the places where berries are abundant (*Vaccinium* spp., *Shepherdia* spp., *Arctostaphylos* spp., etc.). When the first snows appear at higher elevations, grizzly bears tend to move back down to lower elevations and locations where the most nutritious plants are found, as winter approaches (Pearson, 1975; Servheen, 1983; McCann, 1997b). However, it would be tedious to include the climate variable in the analysis given its very great variability at this latitude. Nevertheless, it is important to point out its impact on the biophysical environment. In fact, some studies have demonstrated that in years of low berry productivity, grizzly bears may not survive the following winter (Pearson, 1975; Welwood and MacHutchon, 1999).

It will be recalled that most studies on grizzly bears were carried out in the Rocky Mountains. It is therefore essential to study the grizzly bear's habitat in the Yukon, more specifically in the Slims River Valley. To this end and given the relationship between the vegetation and certain environmental characteristics, two other biophysical characteristics were selected as being significant:

- Topography (elevation, slopes and aspect);
- Landforms and surficial materials.

3.4. Data acquisition

Data acquisition took place in the summer of 2000, in the Slims River Valley (Figure 13). The techniques and methods used are described in the following four subsections: photo-interpretation, field work (vegetation and landforms), classification of the satellite image and digital elevation model (DEM).

3.4.1. Photo-interpretation

Three triplets of black and white aerial photographs dating from 1977 cover the Slims Valley at a scale of 1:50 000, as well as a black-and-white triplet dating from 1956 at a scale of 1:78 000. The aerial photographs were used before, during and after the field work. The photo-interpretation made it possible to clearly delineate homogeneous areas of vegetation and to locate the geomorphological attributes of the landscape.

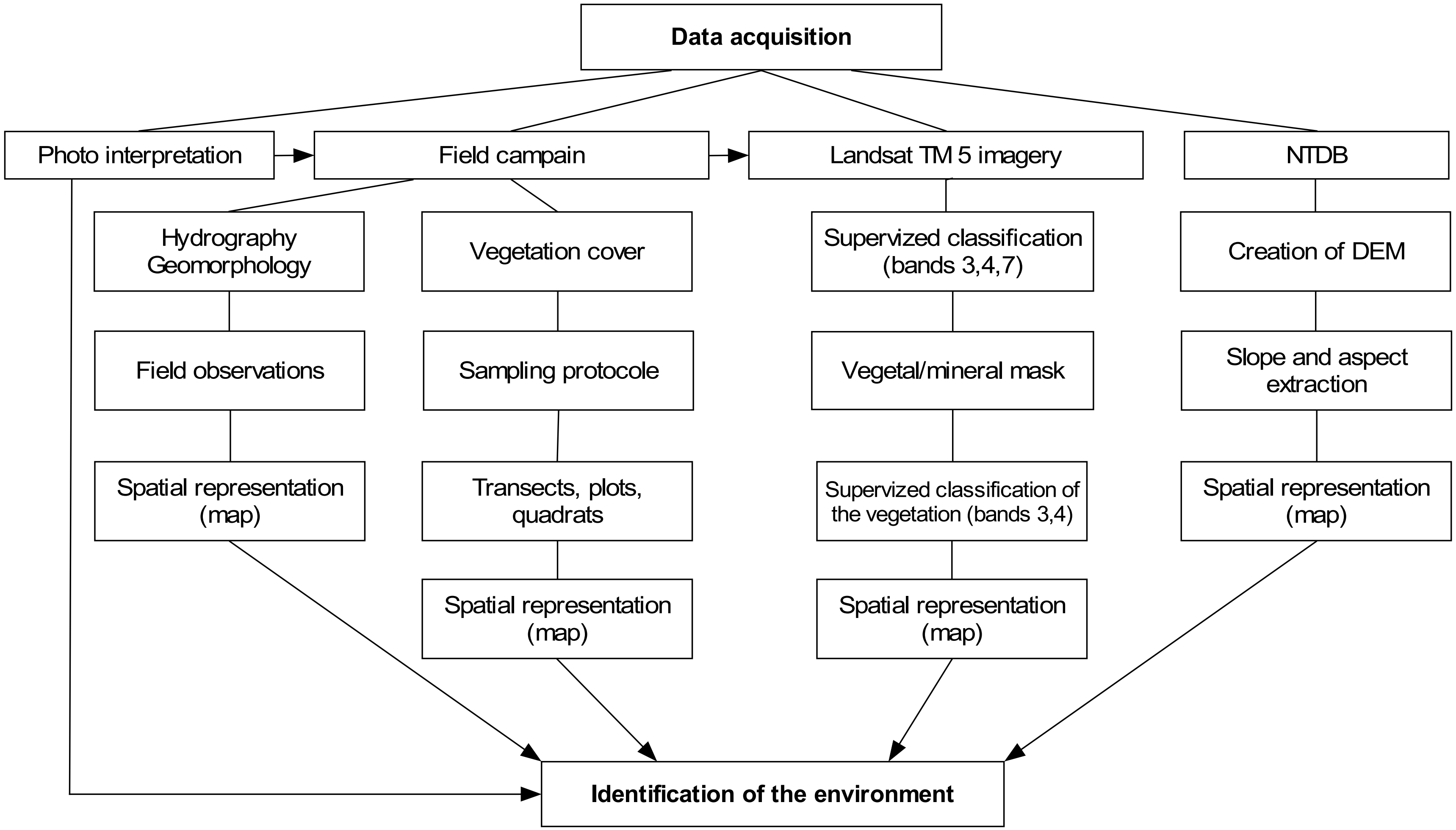


Figure 13 – Data acquistion chart

3.4.2. Field work

The objectives of the field work were to sample the vegetation present, the biomass of plants used as food by bears, as well as the plant associations present in order to carry out the supervised classification of the satellite image (Figure 14). It has been demonstrated that when studying bear habitat, it is more relevant to attempt to identify the main types of vegetation than to conduct an inventory by species (Manley *et al.*, 1992). Observations on the landforms and surficial materials of the sector under study were also noted.

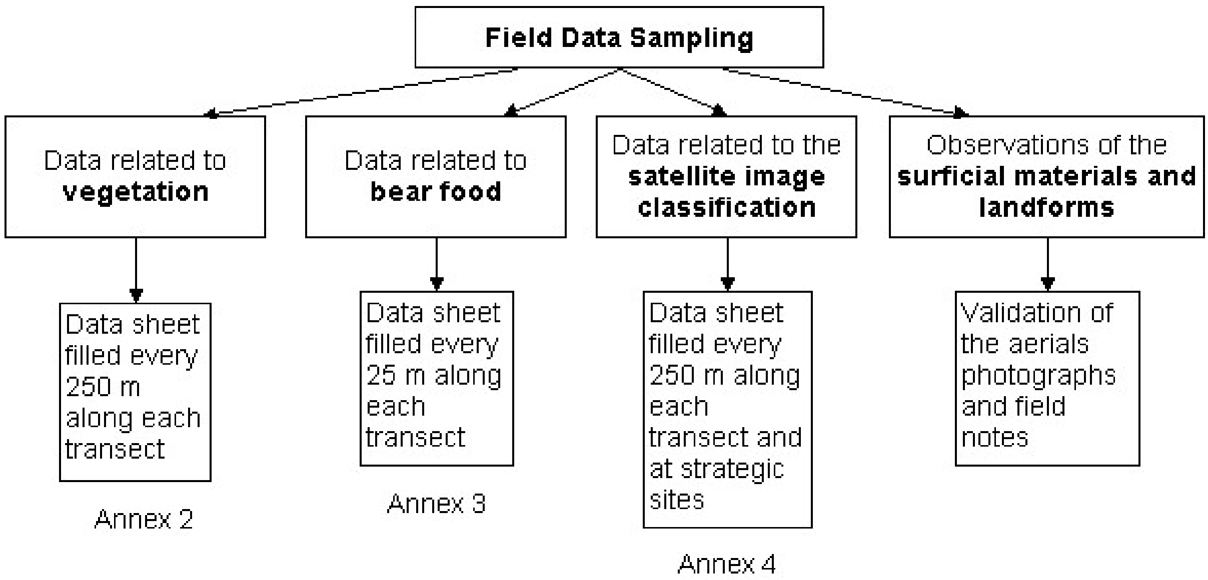


Figure 14 – Field data collection methodology

A) Vegetation

Vegetation sampling was carried out along 13 transects, in the homogeneous areas previously identified by photo-interpretation, starting near the river and moving up the slopes, until a major obstacle was encountered or to the edge of the vegetation. The transects were laid out parallel to each other, approximately 5 km apart. The length of the transects varied from 55 m to 1725 m. Several studies have demonstrated the effectiveness of the transect method for assessing potential grizzly bear habitat (Hamer and Herrero, 1983; McCrory *et al.*, 1986; Herrero *et al.*, 1986; McCrory and Mallam, 1991; Lindberg, 1995).

Complete inventories of the vegetation in circular 7.5 m-radius sample plots along the transect were conducted at 250 metre-intervals (predetermined by an azimuth), until an obstacle (topographic or other) prevented us from continuing. All tree, shrub and moss species were identified and a percentage cover assigned to them. For each site, the following data were noted: date, site code (identified by valley and transect), geographic coordinates and elevation (from a global positioning system), observer's name, site number (linked to the database for the satellite image), landforms, deposits, slope, aspect, sketch of the site, classification given in terms of vegetation, transect number, distance on this transect, number of photographs taken, percentage cover of the bedrock, surficial materials, water and/or snow on the surface, percentage of woody debris on the ground, signs of the presence of bears and wildlife in general, soil compaction index, percentage cover of each plant species selected as important to the grizzly bear's diet, height class of the plant and development stage (flowering, fruit or other).

At the same locations, a data sheet was completed on the forest composition over an 11-m radius from the center point. The following data were recorded: site number, percentage of tree cover for each stratum, understorey density for hardwoods and conifers in the four directions, as well as the species, size, diameter at breast height (DBH) and status class of each tree present in the sample plot.

For dead wood, two 25 m-long transects were completed in two directions (N, S, E, and/or W) and each dead tree more than 4 cm in diameter was noted, as well as its diameter.

In addition, all along the transect, systematically every 25 m, a biomass survey of bear food present on the ground was completed (Figure 15). In a 1-m^2 quadrat, all the predetermined species (Table 1) on the list were identified and noted.

For each species, the percentage of cover, the height class of the plant, the number of flowers and/or berries, the mass of the flowers and/or berries and the development stage were recorded. In addition, all along the transect, the vegetation transitions, or ecotones, were noted in addition to the exact location (geographic coordinates and elevation), the name of each class involved and the type of transition.

For the collection of data relating to the satellite image classification, another data sheet was completed at each site (of 250 m) and at certain strategic and/or representative locations (i.e. within a homogeneous area of vegetation called a polygon, at more than 100 m from each boundary). It should be noted that the homogeneous areas were pre-selected from the photo-interpretation, various documents relating to the park's vegetation cover and maps.

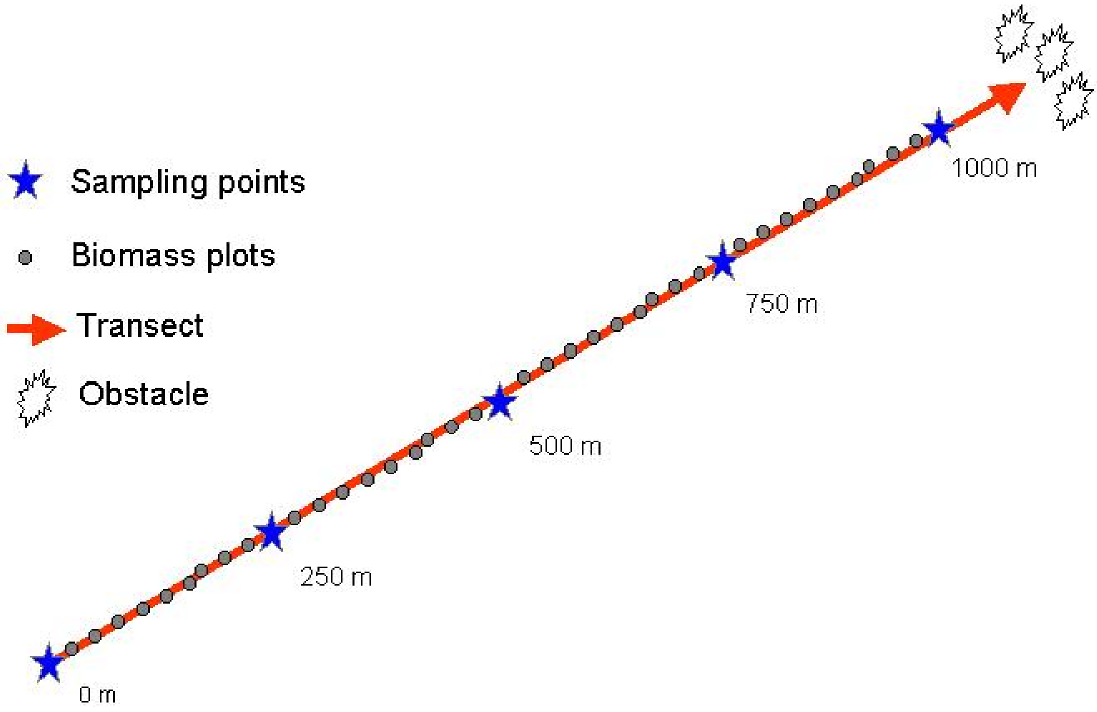


Figure 15 – Example of vegetation sampling along a slope

B) Surficial materials and landforms

The information on the landforms and surficial materials comes from several sources: field observations, aerial photographs, oblique photographs taken on the ground and from aircraft in the summer of 2000, previous studies (Gray, 1985) as well as maps and reports of the Geological Survey of Canada (Muller, 1958, 1967; Rampton, 1981). Two complete maps (landforms and surficial materials) covering the study site were produced by digitization using the MapInfo 5.5® computer program.

3.4.3. Classification of the satellite image

Four Landsat 5 TM images, taken on September 6 and 8, 1996, cover the park. These images were first orthorectified by a private firm. The Slims Valley is covered by orbit 60, image 18. Ground resolution is 25 m. Bands 1 to 5 and 7 are available. The software used for the classification was PCI 6.0®, since it was the one available to the park as well as at CARTEL. The use of TM images is recognized as a tool for efficiently mapping large wildlife habitats (Lyon, 1983). The satellite image was first limited to the study sector. Several band combinations were then tested in order to more clearly identify the landscape characteristics. With a maximum likelihood classification for bands 3, 4 and 7, a mask was created, including the pixels associated with the vegetation environment solely and excluding the mineral environment and the glaciated areas (Giugni *et al.*, 1998).

Table 1 – List of species selected for the sampling of bear food

No	Plant species	Common name	Part eaten
1	*Arctostaphylos uva-ursi*	Bearberry, kinnikinick	Berries
2	*Elaegnus communtata*	Silverberry	Berries
3	*Empetrum nigrum*	Black crowberry	Berries
4	*Shepherdia canadensis*	Soapberry	Berries
5	*Equisetum arvense*	Horsetail	Foliage
6	*Hedysarum alpinum*	Alpine sweet-vetch, liquorice-root	Roots
7	*Oxytropis campestris*	Field locoweed	Flowers
8	*Astragalus* spp.	Milk-vetch	Foliage, roots
9	*Carex* spp.	Sedges	Foliage
10	Poaceae	Grasses	Foliage
11	*Salix* spp.	Willow	Catkins
12	*Heracleum lanatum*	Cow-parsnip	Foliage, flowers
13	*Epilobium angustifolium*	Fireweed	Foliage, flowers
14	*Arctostaphylos rubra*	Red bearberry	Berries
15	*Vaccinium caespitosum*	Dwarf blueberry, dwarf bilberry	Berries
16	*Vaccinium vitis-idaea*	Mountain cranberry	Berries
17	*Vaccinium uliginosum*	Bog blueberry, bog bilberry	Berries
18	*Viburrnum edule*	Low bush-cranberry	Berries
19	*Ribes* spp.	Currant, gooseberry	Berries
20	*Epilobium latifolium*	Broad-leaved willow herb, river-beauty	Foliage, flowers
21	*Eriophorum* spp.	Cotton-grass	Foliage
22	*Rosa acicularis*	Prickly rose	Fruits
23	*Salix arctica*	Arctic willow	Catkins
24	*Salix reticulata*	Net-veined willow	Catkins

The maximum likelihood classification for the vegetation was carried out on this mask with bands 3 and 4, from the training sites surveyed during the fieldwork. The effects of the atmosphere and of the relief were disregarded, given the use of a single image and the project objective. The vegetation classes selected were those used by the managers of Kluane National Park in their own vegetation classification project for the entire Park (Appendix 4).

3.4.4. Creation of a digital elevation model

The digital elevation model (DEM) was created from a digital topographic database (DTDB) dating from 1995 and using the computer program ArcView 3.2®. The Slims River Valley is covered by three digital files (115B15, 115B16 and 115G02), which include all the topographic, hydrographic, land use and infrastructure data, etc. The DEM was obtained from the interpolation of the contours of the DTDB at 1:50 000, followed by spherical kriging with 12 contiguous areas. It was then converted to matrix format, with a resolution of 25 m^2. The biggest advantage of the DEM is that it makes it possible to quickly extract the topographic variables of elevation, slope and aspect for the entire study sector. This was done with *Spatial Analyst* for ArcView 3.2®.

3.5. Identification of the grizzly bear's diet

From previous studies in the park (Pearson, 1975; McCann, 1994, 1997a, 1997b), it was possible to determine the specific diet of the Kluane grizzly bears. The identification of the plant species eaten and their importance in the grizzly bear's diet by season (or seasonal biomass - BS) were determined on the basis of fecal analyses carried out as part of the *Kluane Grizzly Bear Research Project* (the collection and analysis methods are described in McCann (1997a)), discussions with Park biologists (McLaughlin, 2000) and previous studies (McLaughlin, 1981; Wellwood and MacHutchon, 1999). Biomass algorithms for the seasonal availability of food were adapted from McCormick (1999, p. 5). The values are associated according to a relative scale whereby 1 = 0.2 (low) and 5 = 1.0 (high) in terms of the importance of the plant species in the grizzly bear's diet by season.

The seasonal biomass was calculated for each species significantly present in the Slims River Valley. The seasons used were the same as those recommended by the *Kluane Grizzly Bear Research Project*, namely spring (May 1 to June 14), early summer (June 15 to July 14), late summer (July 15 to August 31) and fall (September 1 to October 14). After that, grizzly bears head to their dens to hibernate.

The percentage cover of each species was compiled and the mean calculated for each environment. Relative abundance (RA) was estimated from the quantity of food available in one environment relative to all the other environments. The mean abundance of each species in each environment was standardized. To this end, all the means were divided by the maximum abundance value of the environment for each plant species, which gives a RA value of between 0 and 1 for each plant species important in the grizzly bear's diet.

The environment biomass (EB) is an estimate of the quantity of food available in each environment as well as the importance of this plant species in the grizzly bear's diet. The EBs were calculated for the spring, early summer, late summer and fall, by adding the products of the multiplication of the BS values by their respective RAs, for each environment, using the following equation:

$$EB_{jk} = \sum_{i=1} (SB_{ik} * RA_{ij})$$

where SB = Seasonal biomass
RA = relative abundance
i = plant species important in the grizzly bear's diet (n = 12)
j = habitat types (n = 7)
k = dietary seasons (n = 4)

The EBs are ranked from 1 to 8 for each season. The no vegetation environment is considered to contain no food and its value is therefore zero.

3.6. Identification of the environment

The matrix layer representing the types of vegetation obtained by classification of the satellite image from surveys in the field was associated with the matrix layer of surficial materials (modified from Gray, 1985; Muller, 1958, 1967; Rampton, 1981) using the *Tabulate areas* function in ArcView 3.2®. The geomorphological characteristics are thus associated with each type of vegetation. The same procedure is performed to identify the characteristics of elevation, slope and aspect of these slopes.

3.7. Identification of preferred habitats

Once the environment biomass (EB) was calculated, the rank of each environment was identified for each season. A relative numerical value (between 1 and 8) representing preferred habitats could thus be assigned to the various environments. A map was produced for each season. This map is intended as a reclassification of the image of the environment according to a Boolean method, using ArcView 3.2® (with the EB values obtained).

Finally, the same procedure was performed in order to combine all the ranking values for all the seasons combined. Thus, a map of the sum of the EB values of all the environments was produced, for the entire summer season.

3.8. Validation of preferred habitats using grizzly bear sightings

It is an interesting exercise to superimpose the data on environments, topographic features and preferred bear habitats for each season onto the data on grizzly bear sightings by visitors. Performing a cross tabulation (*Tabulate areas* in ArcView 3.2®)) yields the total number of grizzly bear sightings by class, for each season. A chi-square test is then applied to the values, in order to determine whether the observed frequencies are different from the expected frequencies, all based on the area of each class (environments, topographic features and preferred habitats). This step is also carried out for the entire summer season, while the preferred habitat classes are matched with the total number of grizzly bear sightings.

4. Results

4.1. Vegetation classes

Maximum likelihood classification of the vegetation, with bands 3 and 4 (on the vegetation mask) yielded a success rate (or Kappa coefficient) of 86 per cent. The vegetation classes and their area are described in Table 2, the photographs of these environments are presented in Figure 16, while the classified image is presented in Figure 17. In Table 2, note that nearly 57 per cent of the image is not covered with vegetation. The top three classes by area are gravel and/or alluvial deposits with 13.3 per cent, open spruce forest with 9.8 per cent and deciduous shrubs with 9.2 per cent of the territory under study.

4.2. Biomass of importance in the grizzly bear's diet

During the sampling of vegetation in general and more specifically of the plant species of significance in the grizzly bear's diet, 69 species were inventoried on 26 transects, 141 sampling sites and 731 quadrats (1 m²) (Appendix 5).

Of the 20 species selected as important in the grizzly bear's diet, 12 proved to be significantly present in the Slims River Valley, i.e. their presence was not due to random association ($\alpha = 0.05$) (Figure 18 and Table 3).

The most abundant species was A*rctostaphylos uva-ursi*, a berry much sought after by grizzly bears, followed by the Poaceae family (previously called Gramineae) and *Carex* spp. (Figure 19).

Table 2 – Distribution of the vegetation classes of the classified Landsat TM image.

Vegetation class	Description	Surface of the image km²	%
NV	No vegetation	281.5	56.5
GA	Gravel and/or alluvial deposits	66.3	13.3
MA	Marsh	8.5	1.7
G	Grassland	9.0	1.8
DS	Deciduous shrubs	45.8	9.2
OSF	Open spruce forest	48.9	9.8
AM	Alpine meadows	24.5	4.9
AB	Alpine barrens	13.5	2.7
Total		498.0	100.0

Gravel and/or alluvial deposits

Deciduous shrubs

Marsh

Open spruce forest

Grassland

Alpine meadows

Alpine barrens

Figure 16 – Vegetation classes

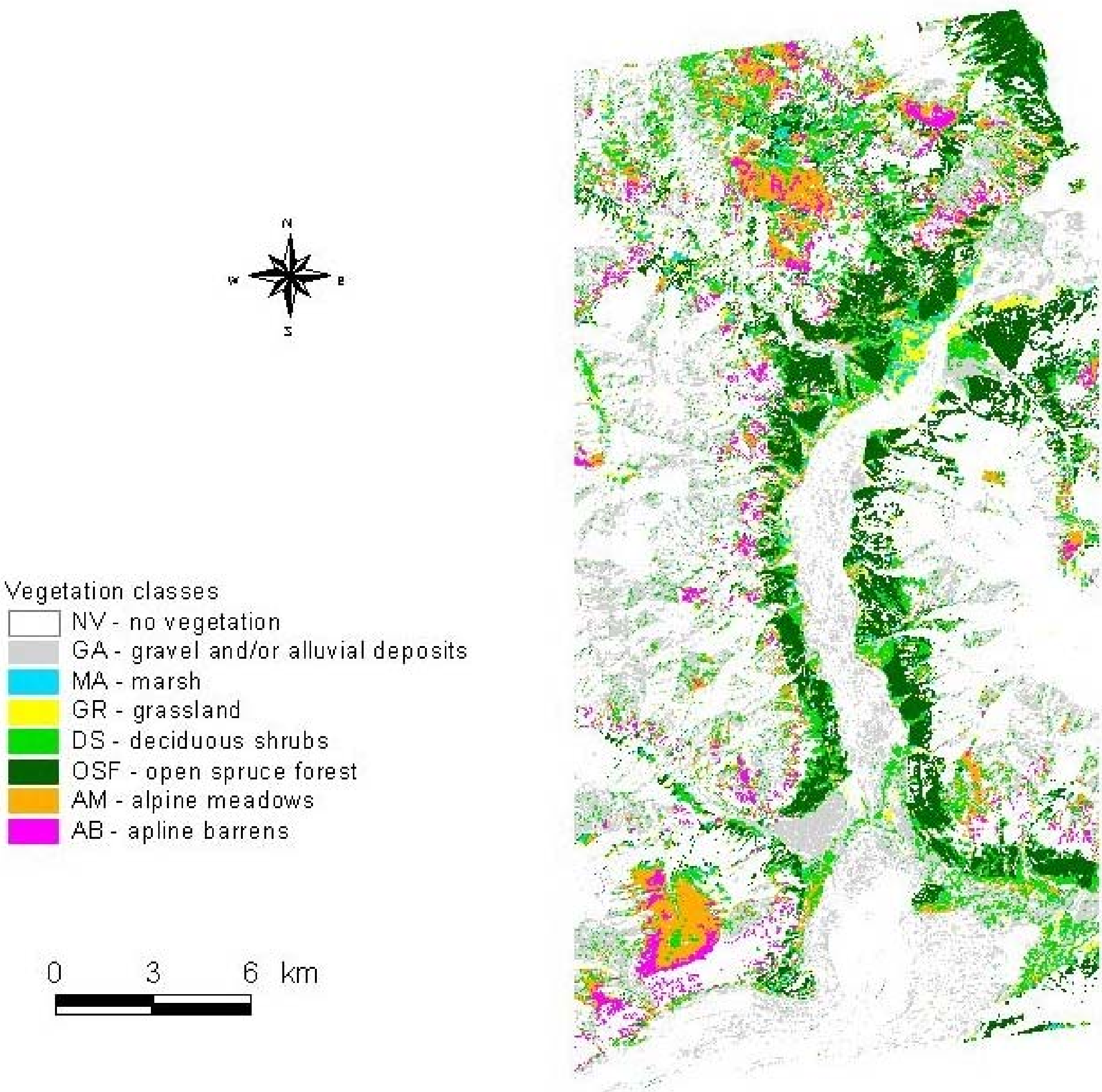


Figure 17 – Maximum likelihood classification of the vegetation

Arctostaphylos uva-ursi

Carex spp.

Arctostaphylos rubra *

Shepherdia canadensis

Salix spp.

Rosa acicularis

Oxytropis campestris

Salix arctica *

Astragalus spp. *

Salix reticulata *

Epilobium latifolium

Poaceae family

*Photos taken from MacKinnon *et al.* (1999)

Figure 18 – Plants significantly present in the Slims River Valley

Table 3 – Plant species important in the grizzly bear's diet and significantly present in the Slims River Valley

Code	Plant species	Common name	Part eaten
ARUU	*Arctostaphylos uva-ursi*	Bearberry, kinnikinick	Berries
SHCA	*Shepherdia canadensis*	Soapberry	Berries
OXCA	*Oxytropis campestris*	Field locoweed	Flowers, foliage
ASTR	*Astragalus* spp.	Milk-vetch	Foliage, roots
CARE	*Carex* spp.	Sedges	Foliage
POAC	Poaceae	Grasses	Foliage
SALI	*Salix* spp.	Willow	Catkins
ARRU	*Arctostaphylos rubra*	Red bearberry	Berries
EPLA	*Epilobium latifolium*	Broad-leaved willow herb, river-beauty	Foliage, Flowers
ROAC	*Rosa acicularis*	Prickly rose	Fruits
SAAR	*Salix arctica*	Arctic willow	Catkins
SARE	*Salix reticulata*	Net-veined willow	Catkins

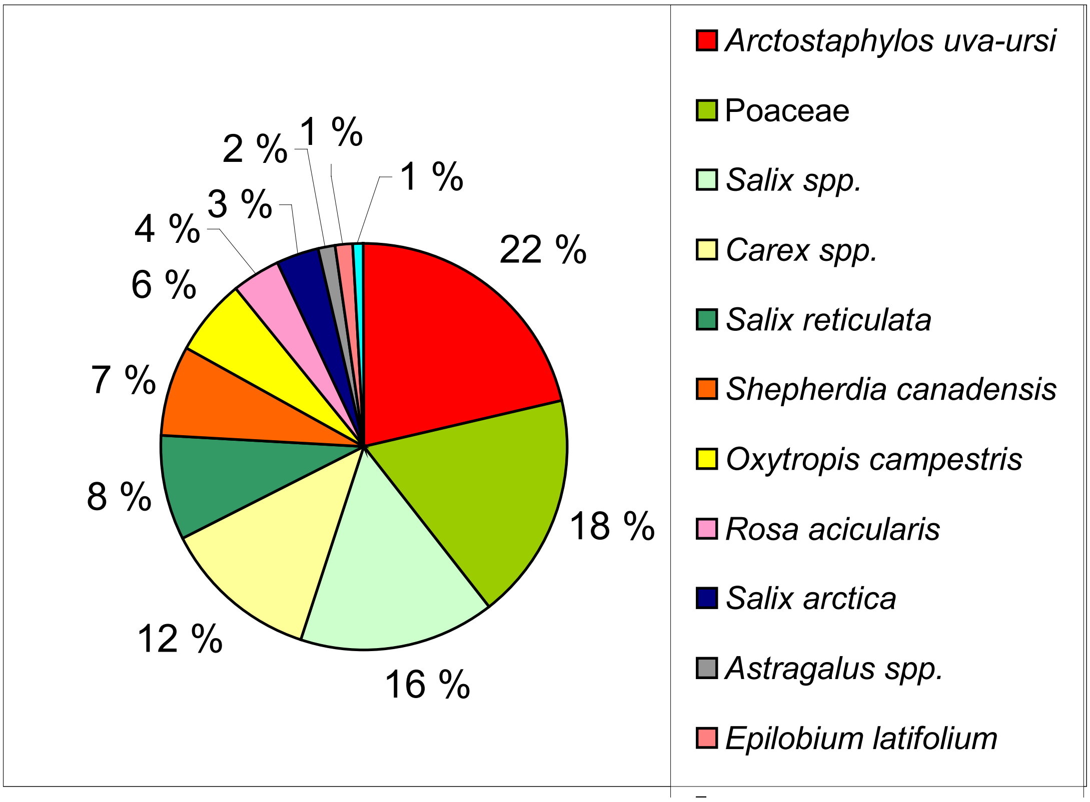


Figure 19 – Relative importance of the plant species significantly present in the Slims River Valley

With these species now identified, the next step is to try to determine the main vegetation environments in which they are found (Figure 20). Note that more than half the species (56 per cent) are found in two environments: open spruce forest and alpine meadows. These two environments are therefore the most critical in terms of bear food abundance. This finding becomes important for the management of the environments significant to the grizzly bear's survival, as well as proper management of visitor access.

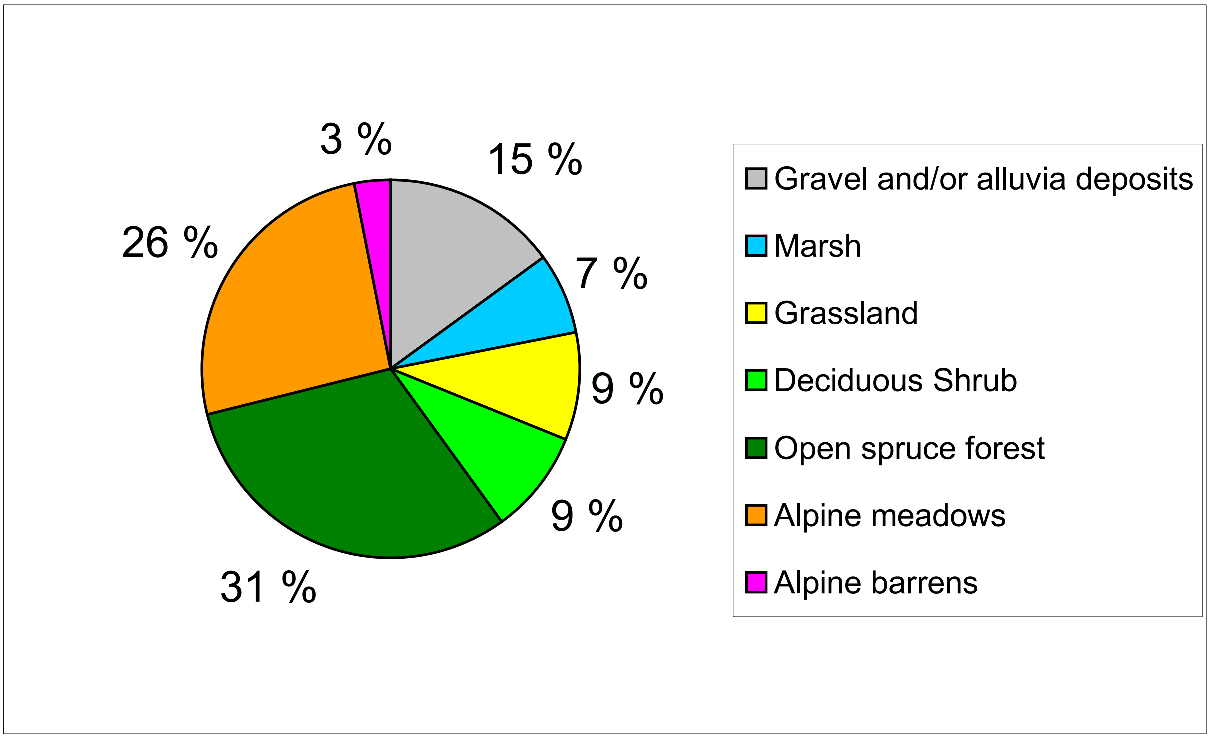


Figure 20 – Distribution of the plant species significantly present by vegetation classes from the satellite images

With these species now identified and located, it is important to assign them a nutritional value, in terms of seasonal biomass (Table 4). The species with the highest seasonal biomass values (by adding up all the seasons) are *Arctostaphylos uva-ursi*, *Shepherdia canadensis*, *Oxytropis campestris* and the Poaceae family. These are key species in the grizzly bear's diet in Kluane National Park.

Now that we know the seasonal biomass value of each species, the next step is to examine the relative abundance of each species for each of the seven environments sampled (Table 5). The relative abundance values range from 0.000 to 1.000. The shaded values indicate high relative abundance values.

Table 4 – Seasonal biomass value, reflecting the importance of the plant species in the grizzly bear's diet, per season. Values range from 0.2 (low) to 1.0 (high).

Plant species	Code	Spring	Early summer	Late summer	Fall
Arctostaphylos uva-ursi	ARUU	0.6	0.2	0.6	0.6
Shepherdia canadensis	SHCA	0.2	0.4	1.0	0.8
Oxytropis campestris	OXCA	0.6	1.0	0.6	0.2
Astragalus spp.	ASTR	0.6	0.6	0.4	0.2
Carex spp.	CARE	0.4	0.4	0.4	0.4
Poaceae	POAC	0.8	0.6	0.6	0.4
Salix spp.	SALI	0.8	0.6	0.4	0.4
Arctostaphylos rubra	ARRU	0.4	0.2	0.6	0.6
Epilobium latifolium	EPLA	0.2	0.4	0.6	0.6
Rosa acicularis	ROAC	0.2	0.4	0.6	0.6
Salix arctica	SAAR	0.4	0.6	0.6	0.4
Salix reticulata	SARE	0.4	0.6	0.6	0.4

Table 5 – Relative abundance of plant species per environment

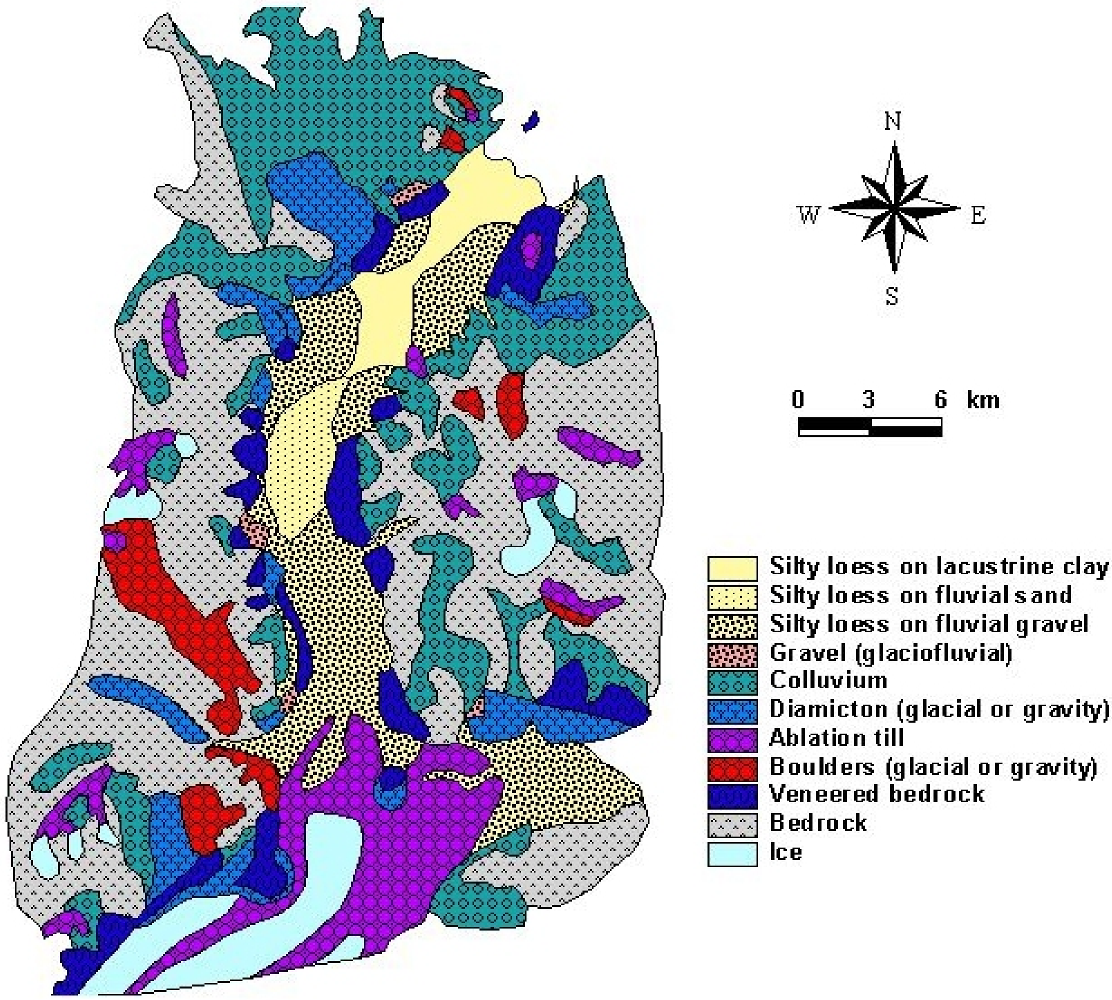
Plant	Environments						
Species	GA	MA	GR	DS	OSF	AM	AB
ARUU	0.656	0.000	0.510	1.000	0.694	0.000	0.000
SHCA	1.000	0.000	0.465	0.741	0.852	0.000	0.035
OXCA	1.000	0.000	0.000	0.564	0.000	0.000	0.000
ASTR	0.000	0.000	0.305	0.000	1.000	0.110	0.916
CARE	0.393	0.000	1.000	0.000	0.532	0.608	0.641
POAC	0.400	0.847	0.404	0.204	0.496	1.000	0.349
SALI	0.230	0.118	0.278	1.000	0.398	0.192	0.010
ARRU	0.000	0.332	0.000	1.000	0.000	0.000	0.000
EPLA	0.932	0.000	0.000	0.000	0.000	1.000	0.839
ROAC	0.000	0.000	0.861	0.066	1.000	0.000	0.000
SAAR	0.000	0.000	0.000	0.000	0.000	1.000	0.588
SARE	0.000	0.000	0.000	0.000	0.000	1.000	0.637

See table 4 for the plant species codes.
GA Gravel and/or alluvial deposits, MA marsh, GR grassland, DS deciduous shrubs, OSP open spruce forest, AM alpine meadows, AB alpine barrens.

4.3. Surficial materials and landforms

The environment has been profoundly shaped by glacial activity, given the proximity of the Kaskawulsh glacier of the Slims River Valley. The surrounding relief is composed primarily of steep slopes overlain by rather unstable surficial deposits. Fluvial action continues to be significant, given the daily variability in the flow of the main rivers and streams, due to the hydrological regime, which is governed by glaciers upstream.

In terms of significant geomorphological variables that influence the quality of the preferred habitat, it was decided to take only the surficial materials (Figure 21) into consideration, since they are directly related to the type of vegetation that covers them. It will be recalled that vegetation remains the most decisive factor with respect to grizzly bear habitat. In terms of surficial materials, the study site is composed mainly of bedrock (bare rock) covered by colluvium (Table 6).



Modified from Gray (1985); Muller (1958, 1967); Rampton (1981)

Figure 21 –Surficial materials of the Slims River Valley

Table 6 – Area and percentage of land cover by each class of surficial materials

Surficial materials	Area of the image Km²	%
Silty loess on lacustrine clay	13.9	2.8
Silty loess on fluvial sand	8.9	1.8
Silty loess on fluvial gravel	58.7	11.8
Gravel (glaciofluvial)	2.0	0.4
Colluvium	105.5	21.2
Diamicton (glacial or gravity)	30.8	6.2
Ablation till	45.2	9.1
Boulders (glacial or gravity)	19.4	3.9
Veneered bedrock	29.3	5.9
Bedrock	155.4	31.2
Ice	28.9	5.8
Total	498.0	100.0

4.4. Topographic features

The most striking feature of the Slims River Valley is the high-energy relief, the sides of the valley being steeply sloped (Figures 22 and 23).

It can be seen that the relief is highly rugged, with slopes of 19 per cent on average and many steep slopes. The elevation varies between 724 m and 2 686 m, with an average of 1 354 m.

4.5. Grizzly bear sightings by visitors

The Slims River Valley is the major attraction of Kluane National Park. More than a third (34.7 per cent) of the sightings in Kluane National Park occur in this valley (Figure 24). In the 10 years during which grizzly bear sightings by visitors were compiled, 1 004 were within the study area. On average, a group of hikers sees 1.6 bears per sighting (or completed form), for a total of 1 613 bears seen over a 10-year period. Taking into consideration the fact that the summer season has 167 days, it can be said that approximately one bear a day has been observed in the Slims River Valley in the past 10 years. The sightings are more frequent in late summer, when there are obviously more visitors in the park. In fact, there is a relationship between the number of visitors in the Slims River Valley and the number of grizzly bear sightings ($r^2 = 0.48$, $P < 0.038$, $\alpha = 0.05$) (Figure 25).

As Desrochers (1998) demonstrated, the spatial distribution of the sightings is clustered; the sightings are not distributed randomly. The two figures show the spatio-temporal distribution of the sightings between 1988 and 1998. The first presents the dispersion of the points (Figure 26), while the second takes into consideration the sum of the sightings, by 500-m2 pixel (Figure 27).

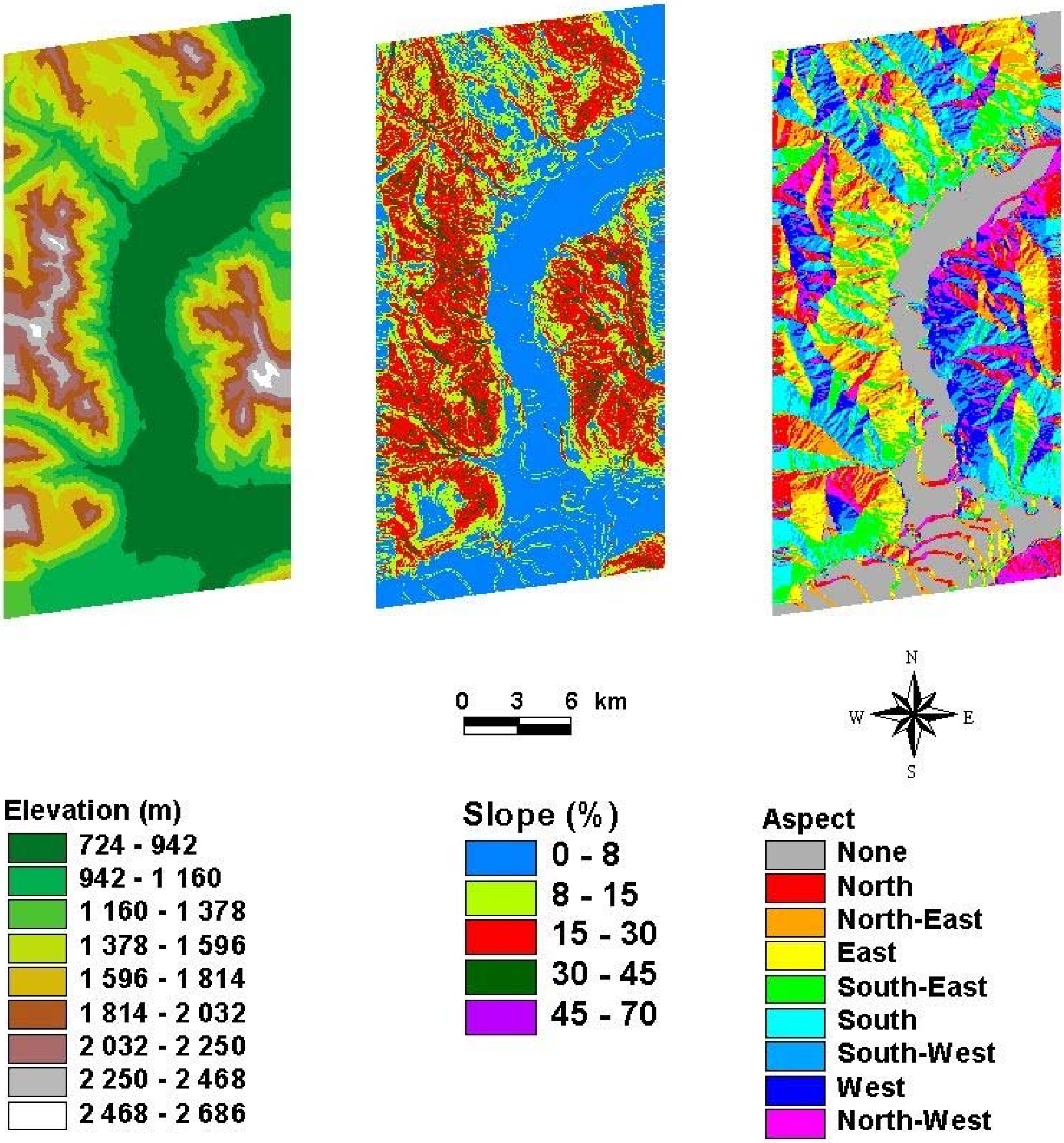
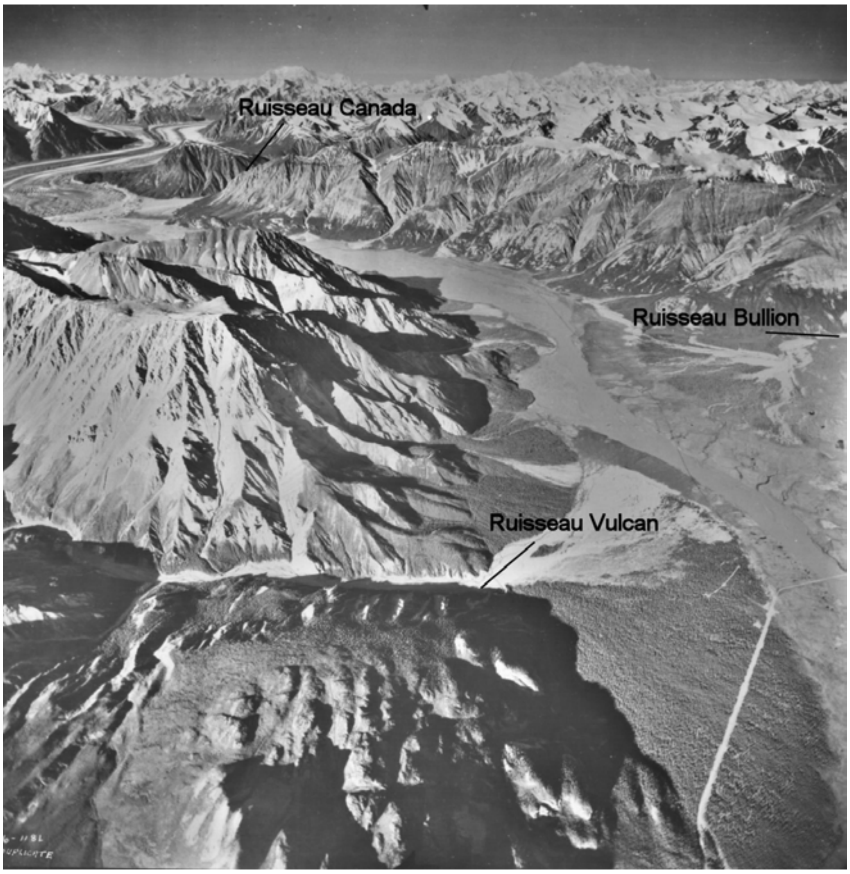


Figure 22 - Elevation, slope and aspect of the study area



Oblique photograph T6 – 118L

Figure 23 - Slims River Valley aerial photograph

4.6. Environment

The environment of the Slims River Valley is divided into seven classes, each of which has specific characteristics (Table 7). It was agreed to use the same terminology as the vegetation classes, since vegetation remains the most important factor in the analysis.

4.7. Preferred habitats

Each environment is combined with the environment biomass value, for each season. The scale ranges from 1 (low) to 8 (high). The no vegetation environment is considered to contain no available food and its value is therefore zero (Table 8).

Note that the open spruce forest environment represents the most favoured habitat, since it ranks first for the fall and second for the spring and late summer. It will be recalled that this environment covers an area of nearly 10 per cent of the image and 23 per cent of the area that is covered with vegetation.

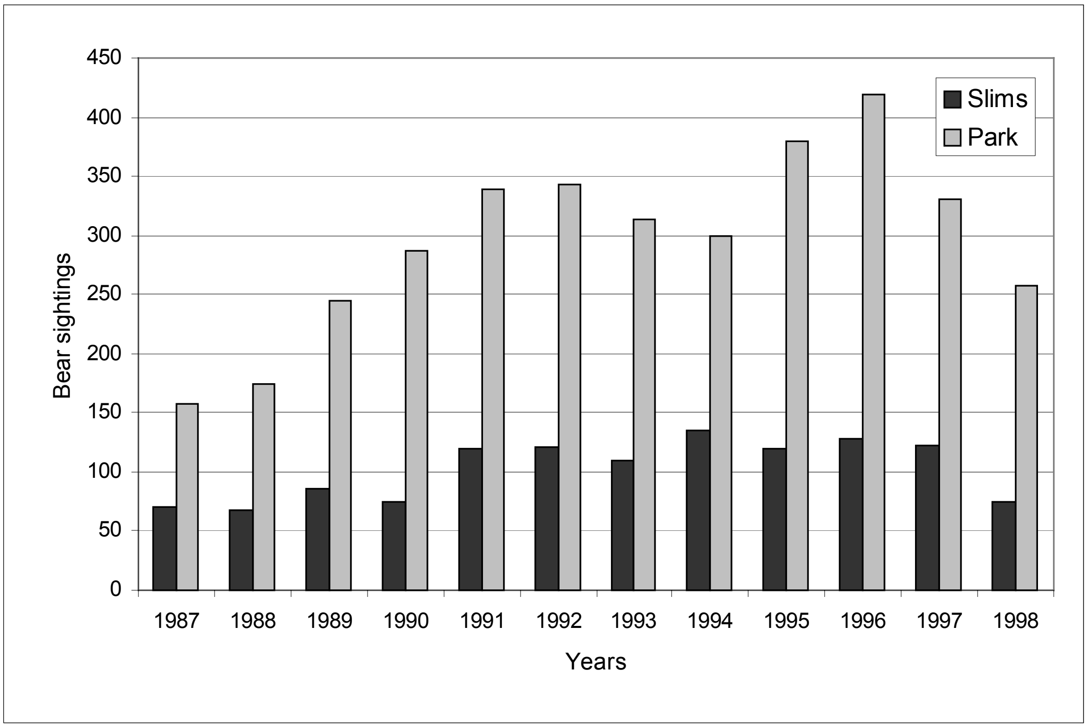


Figure 24 – Number of grizzly bear sightings by visitors in the Slims River Valley and for Kluane National Park as a whole (1987-1998)

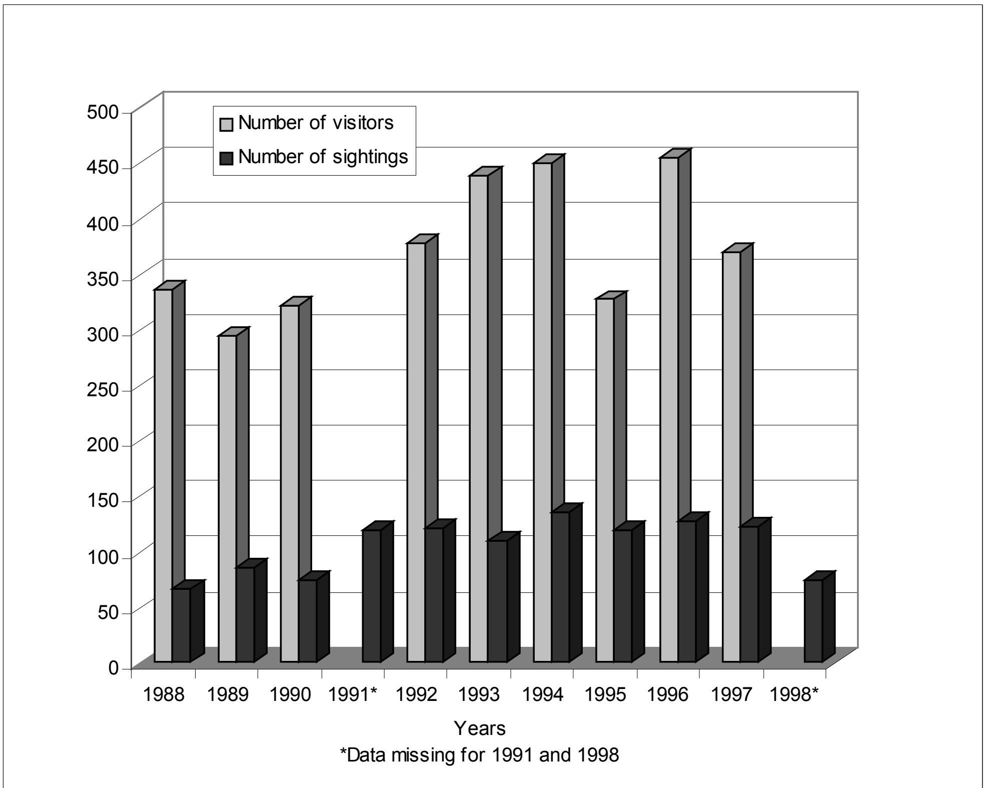


Figure 25 – Number of visitors and grizzly bear sightings in the Slims River Valley (1988-1998)

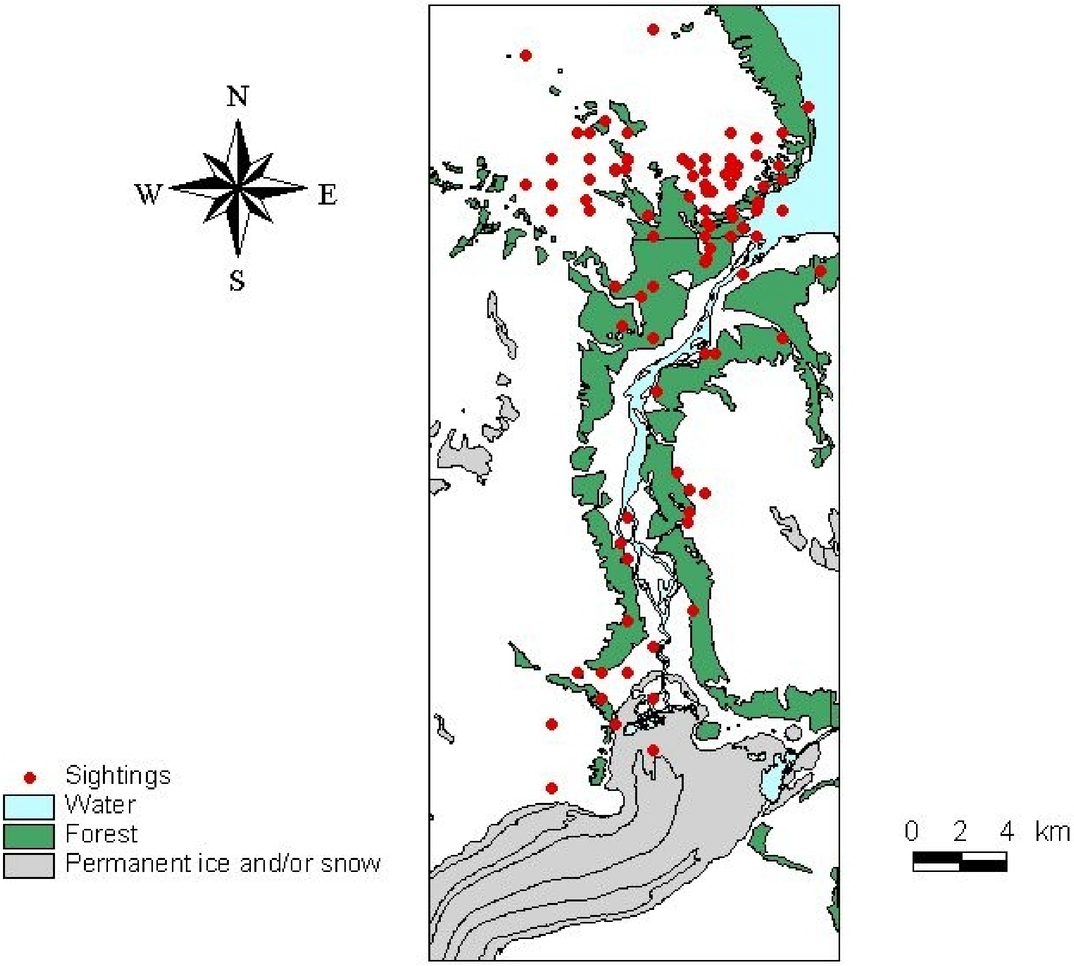


Figure 26 - Distribution of grizzly bear sightings (1988-1998)

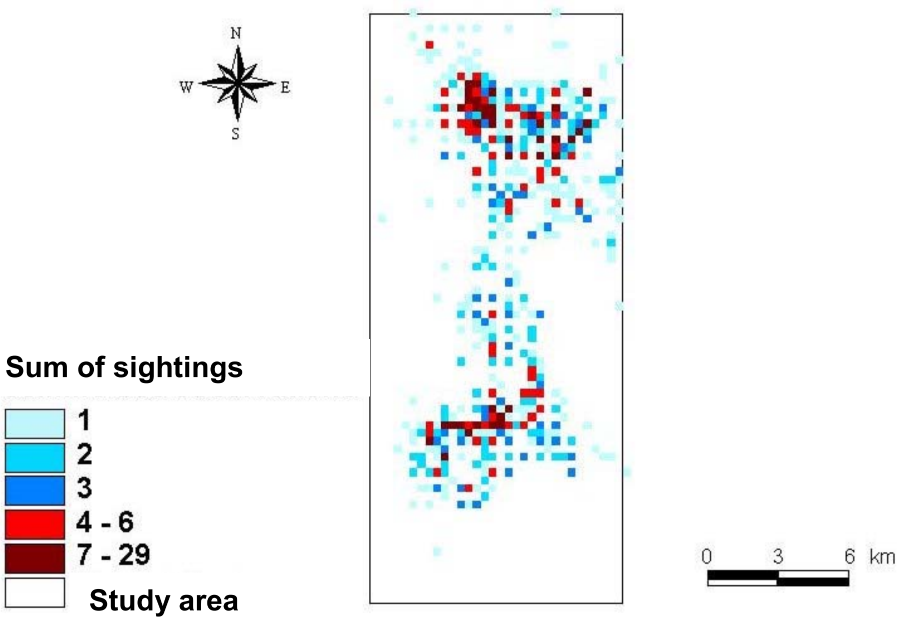


Figure 27 – Sum of grizzly bear sightings per 500 m² pixel (1988-1998)

Table 7 – Description of the dominant characteristics of the environment

Code	Environment	Description
NV	No vegetation	Dominated by bedrock or gravel and/or alluvial deposits, elevation mostly between 720 and 940 m, on slopes that vary between 0 and 30%. Absence or very little presence of vegetation.
GA	Gravel and/or alluvial deposits	Dominated by fluvial gravel deposits and bedrock, often situated on alluvial fans, elevation between 720 and 940 m, on gentle slopes (0 to 8%) or steep slopes (15 to 30%). Scattered vegetation, mostly shrubs and herbaceous, *i.e. Dryas drummondii*, *Epilobium latifolium* and *Sheperdia canadensis*.
MA	Marsh	Variable wetlands (depending on the year), covered by fluvial deposits, at low elevation (720 to 940 m), on gentle slopes (0 to 8%), often associated with glaciofluvial floodplains. Vegetation characterized mostly by moss, *Carex* spp., *Eriophorum* spp., *Equisetum* spp., *Juncus* spp. and Poaceae.
GR	Grassland	Small areas covered by variable deposits, at elevation between (720 and 1370 m), mostly on gentle slopes (0 to 8 %). Dense herbaceous vegetation, among which *Artemisia* spp. and Poaceae.
DS	Deciduous shrubs	Covered by fluvial gravel, mostly on passive alluvial fans, at low elevations (720 to 1370 m), mainly on gentle to moderate slopes (0 to 15%). Vegetation composed of shrubs (1 to 3 m) like *Salix* spp., *Alnus* spp., *Populus tremuloides*, *P. balsamifera* and *Betula glandulosa.*
OSF	Open Spruce Forest	Found on diamicton and fluvial gravel, at low elevations (720 to 940 m), on gentle to moderate slopes (0 to 15%). The individuals of *Picea glauca* are scattered through the stands, with an average DBH of 12 cm and average height of 7,5 m. The under-story is covered by species of *Lupinus* spp., *Sheperdia canadensis* and *Arctostaphylos uva-ursi*.
AM	Alpine meadows	Alpine environment characterized by different glacial deposits (till, diamicton, etc.), at high elevations (1 370 to 2 250 m), on variable slopes (0 to 30%). Herbaceous vegetation mainly composed of Poaceae, *Carex* spp., *Aster* spp., *Saxifraga* spp., *Anemone* spp., *Salix reticulata* and numerous species of lichens.
AB	Alpine barrens	Alpine environment covered by ice-fragmented rocks, at high elevations (1 370 to 2 250 m), on moderate to steep slopes (15 to 30%). Some plant species are found between the rocks, such as *Saxifraga* spp., *Silene acaulis* and numerous species of lichens.

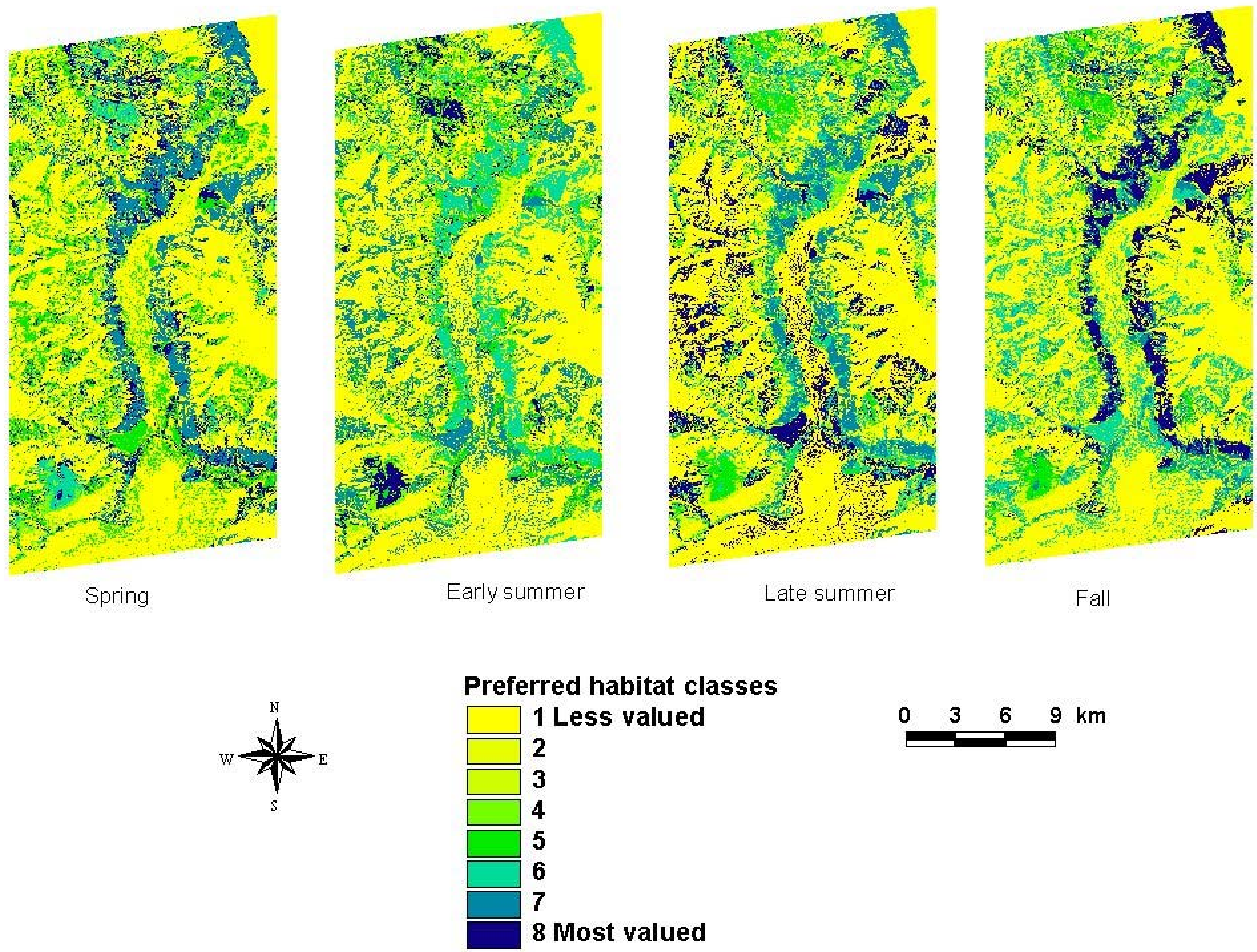


Figure 28 – Preferred habitat classes according to the seasons

Table 8 – Preferred grizzly bear habitat, by environment and abundance of food important in its diet, for each season

Environment	Spring		Early summer		Late summer		Fall	
	EB	rank	EB	rank	EB	Rank	EB	rank
AB	1.753	4	2.105	4	2.111	3	1.604	3
AM	2.262	6	2.624	8	2.764	5	2.142	5
DS	2.463	8	2.001	5	2.842	6	2.427	7
GA	2.041	5	2.439	7	3.042	8	2.362	6
GR	1.700	3	1.625	3	2.163	4	1.928	4
MA	0.698	2	0.608	2	0.542	2	0.519	2
NV	0.000	1	0.000	1	0.000	1	0.000	1
OSF	2.315	7	2.229	6	2.938	7	2.468	8

AB = Alpine barrens AM = Alpine meadows DS = Deciduous shrubs GA = Gravel and/or alluvial deposits
GR = Grassland MA = Marsh NV = No vegetation OSF = Open spruce forest
EB = Environment biomass. Values in grey represent most favoured bear habitat.

The second most preferred environments are the gravel and/or alluvial deposits and deciduous shrub environments. The former covers 13 per cent of the image (or 31 per cent of the environment that is covered with vegetation). It represents the preferred environment in summer, but also ranks second in early summer and third in the fall.

Although the deciduous shrub environment covers only 9.2 per cent of the territory under study (or 21 per cent of the territory that is covered with vegetation), it remains a preferred environment, especially in the spring. Finally, the importance of the alpine environment may be noted. In fact, alpine meadows rank fourth in terms of the grizzly bear's preferred habitat, all seasons combined. This class covers 5 per cent of the image (for 11 per cent of the environment that is covered with vegetation).

These four classes represent the most-favoured bear environments, generally for the summer season.

The ranking of each environment in terms of preferred habitats is presented for each season in Figure 28. What stands out immediately is the clear difference among the four seasons.

The location of the preferred sites (shown in blue on the maps) differs from season to season. Table 9 presents the area covered by each rank, for each season. Note that for all the seasons, 56.4 per cent of the territory is classified as low in terms of preferred grizzly bear habitat. Late summer, followed by fall, are the seasons during which the most-preferred grizzly bear habitats (ranks 7 and 8) cover the largest areas.

Table 9 – Area of each rank of preferred habitat for each season

Rank	Spring		Early summer		Late summer		Fall	
	km²	%	km²	%	km²	%	km²	%
1	281.0	56.4	281.0	56.4	281.0	56.4	281.0	56.4
2	8.2	1.7	8.2	1.7	8.2	1.7	8.2	1.7
3	9.0	1.8	9.0	1.8	13.8	2.8	13.8	2.8
4	13.8	2.8	13.8	2.8	24.4	4.9	24.4	4.9
5	66.3	13.3	46.1	9.2	9.0	1.8	9.0	1.8
6	24.4	4.9	49.2	9.9	46.1	9.2	66.3	13.3
7	49.2	9.9	66.3	13.3	49.2	9.9	46.1	9.2
8	46.1	9.2	24.4	4.9	66.3	13.3	49.2	9.9
Total	498.0	100.0	498.0	100.0	498.0	100.0	498.0	100.0

In order to produce meaningful inter-seasonal comparisons, we simply need to add up the environment biomass values for each season and compare them (Table 10).

Table 10 – Comparison between the sum of environment biomass (EB) for each season

	Spring	Early summer	Late summer	Fall
∑ EB	13.238	13.641	16.400	13.450

Thus, the season with the highest preferred habitat value is late summer, followed by early summer. The fall and the spring have lower values and represent times of the tourism season when the probability of sighting a bear is lower.

If environments ranked from one to four can be considered less preferred habitats and environments ranked from five to eight represent most preferred habitats, and the values for the four seasons are totalled, this results in values ranging from 4 to 32 (but 28 is the maximum value in this case). Figure 29 presents the sum of the environment biomass ranks, all seasons combined.

With respect to the area covered by the two classes of less preferred and most preferred habitat, we note that nearly a third of the territory can be considered unsuitable as bear habitat. It should be noted that most of this territory is inaccessible to both bears and humans (Table 11).

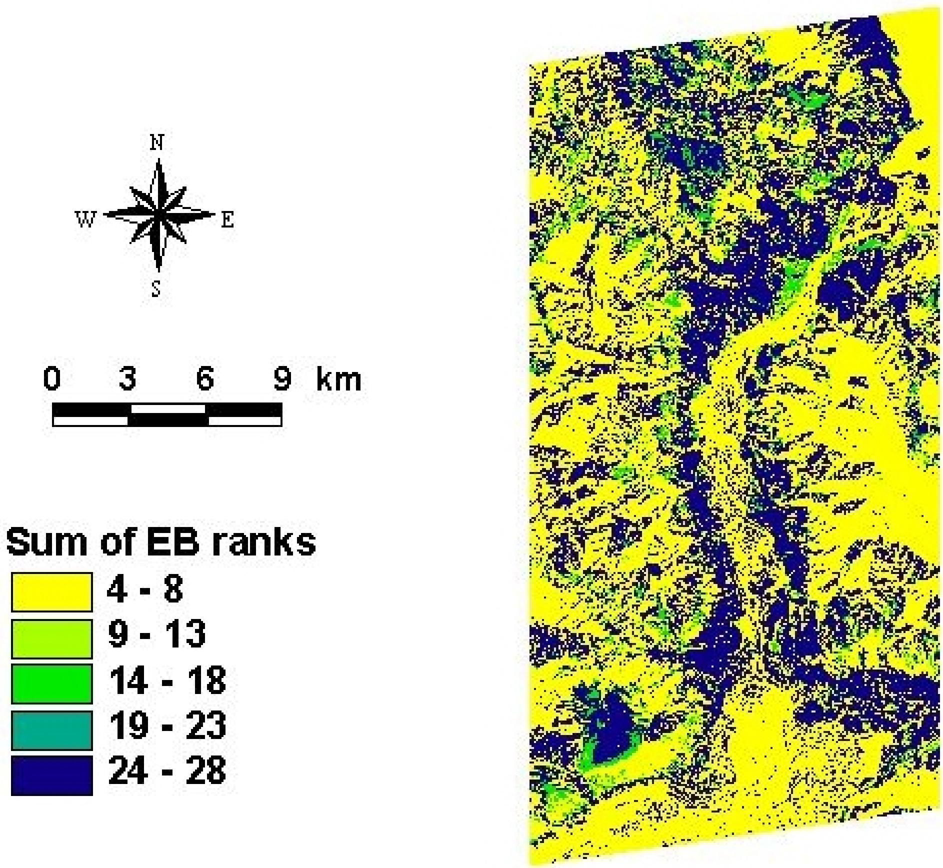


Figure 29 - Sum of environment biomass (EB), all seasons combined

Table 11 –Less preferred and most preferred habitat, all seasons combined

Classes (ranks)	Description	Area of the image	
		km²	%
4 to 16	Less preferred habitat	312	63
17 to 28	Most preferred habitat	186	37

4.8. Validation of preferred habitats using grizzly bear sightings

4.8.1. Grizzly bear sightings and environments

Before comparing grizzly bear sightings and preferred habitats, we should take a step back and first compare the environments to these sightings. The number of grizzly bear sightings, for all the summer seasons between 1988 and 1998, was compared to the expected frequencies established statistically by a chi-square test which relates the number of sightings that would normally be expected, based on a comparison of the area of each environment (Table 12).

Table 12 – Grizzly bear sightings by environment

Env.	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
NV	56.5	343	568	-225	89.1
GA	13.3	125	134	-9	0.6
MA	1.7	29	17	12	8.5
GR	1.8	22	18	4	0.9
DS	9.2	139	92	47	24.0
OSF	9.8	194	99	95	91.2
AM	4.9	131	49	82	137.2
AB	2.7	21	27	-6	1.3
Total	100.0	1 004	1 004	0	352.8

Value of x^2 = 352.8, df = 7, P < 0.000 000, α = 0.05

Env. = Environment

NV = No vegetation GA = Gravel and/or alluvial deposits MA = Marsh GR = Grassland

DS = Deciduous shrubs OSF = Open spruce forest AM = Alpine meadows AB = Alpine barrens

The value of x^2 = 352.8 is clearly higher than the expected frequency (in this case = 14.1 with a df of 7), which confirms that there is a strong relationship between the variables. Therefore, the distribution of grizzly bear sightings among the various environments differs significantly from the frequencies that would be expected based on the proportion of area of each environment class. In addition, based on sighting data, the environments most used by bears appear to be open spruce forest, alpine meadows and deciduous shrubs, while the least used environment is the no vegetation environment. This finding is quite plausible, since this environment is of less interest to bears, except as a corridor for accessing more suitable environments.

4.8.2. Grizzly bear sightings and topographic features

We will now compare grizzly bear sightings as a function of the sector's topographic features. The value of x^2 = 290.9, which compares sightings with elevation, is clearly higher than the expected frequency (in this case = 15.5 with a df of 8), which confirms that the sightings are not distributed proportionately to area when compared to elevation (Table 13). In addition, the 724 m to 942 m and 1 378 m to 1 596 m classes appear to be over-represented in terms of number of bear sightings, while the 942 m to 1 160 m classes and the classes higher than 1 814 m are under-represented. This accurately reflects the locations where grizzly bears prefer to roam, i.e. at middle elevations, where the gravel and/or alluvial deposits, deciduous shrub and open spruce forest environments are mainly found, as well as at elevations between 1 300 m and 1 600 m, where alpine meadows are found.

When grizzly bear sightings are matched with the percentage of the slope, a value of x^2 = 168.3 is obtained, which is clearly higher than the expected frequency (in this case = 9.5 with a df of 4). Grizzly bear sightings are therefore distributed non-proportionately to the area of each slope class (Table 14).

Table 13 – Grizzly bear sightings by elevation

Elevation (m)	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
724 to 942	28.8	468	289	179	110.6
942 to 1 160	14.6	90	147	-57	21.8
1 160 to 1 378	12.1	105	122	-17	2.2
1 378 to 1 596	12.7	180	128	52	21.6
1 596 to 1 814	13.2	130	132	-2	0.1
1 814 to 2 032	9.1	30	91	-61	41.2
2 032 to 2 250	6.4	1	64	-63	62.3
2 250 to 2 468	2.8	0	28	-28	28.1
2 468 to 2 686	0.3	0	3	-3	3.0
Total	100.0	1 004	1 004	0	290.9

Value of x^2 = 290.9, df = 8, P < 0.000 000, α = 0.05

Table 14 – Grizzly bear sightings by slope

Slope %	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
0 to 8	39.3	543	396	147	54.6
8 to 15	25.2	299	253	46	8.4
15 to 30	30.4	143	305	-162	86.1
30 to 45	5.0	19	50	-31	19.2
45 to 70	0.04	0	0	0	0
Total	100.0	1 004	1 004	0	168.3

Value of x^2 = 168.3, df = 4, P < 0.000 000, α = 0.05

Based on these results, it may be assumed that grizzly bear sightings occur much more frequently on slopes between 0 per cent and 15 per cent, while the proportion of grizzly bear sightings on steep slopes (15 per cent to 45 per cent) is lower. Note that no sightings were made on slopes of more than 45 per cent. This seems quite logical, since the grizzly bear is a mammal that chooses the easiest path to get from one place to another.

We will now compare grizzly bear sightings with aspect of the slopes (Table 15). The value of x^2 = 62.3 obtained is considerably higher than the expected frequency (in this case = 15.5 with a df of 8). This clearly indicates that grizzly bear sightings are not distributed proportionately according to the area of each aspect class. Based on the results, it may be assumed that the east and northeast slopes are over-represented relative to the others, while the north slopes are under-represented.

Figures 30, 31 and 32 illustrate the percentage distribution of sightings according to the three topographic criteria. Although all three factors are significant, the most decisive factor is elevation, followed by slopes and, finally, their aspect. This indicates that elevation appears to be more important to bears as a factor in habitat choice than slope or aspect. This is highly probable since the phenology of the plants is directly related to elevation and since the presence of food (therefore of specific plants) is the most important criterion in the selection of preferred habitat.

Table 15 – Grizzly bear sightings by aspect

Classes	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	(O-E)² / E
None	26.2	257	263	-6	0.1
N	12.0	84	121	-37	11.3
NE	10.4	152	105	47	21.0
E	9.4	138	94	44	20.6
SE	9.9	89	99	-10	1.0
S	9.4	75	94	-19	3.8
SW	8.7	93	88	5	0.3
W	6.3	53	63	-10	1.6
NW	7.7	63	77	-14	2.6
Total	100.0	1 004	1 004	0	62.3

Value of x^2 62.3, df = 8, P < 0.000 000, α = 0.05

4.8.3. Grizzly bear sightings and preferred habitats

When the distribution of grizzly bear sightings by visitors is cross-tabulated with the preferred habitats, it is apparent that the sightings are not distributed evenly among the various preferred habitats, when all seasons are combined (Table 16). Figure 33 clearly shows that, apart from class number 1 (which, it will be recalled, includes the no vegetation class that covers nearly 57 per cent of the image), far more sightings are noted in the preferred habitat classes. This therefore confirms that the selection of our variables accurately represents the preferred habitats of grizzly bears in the study sector.

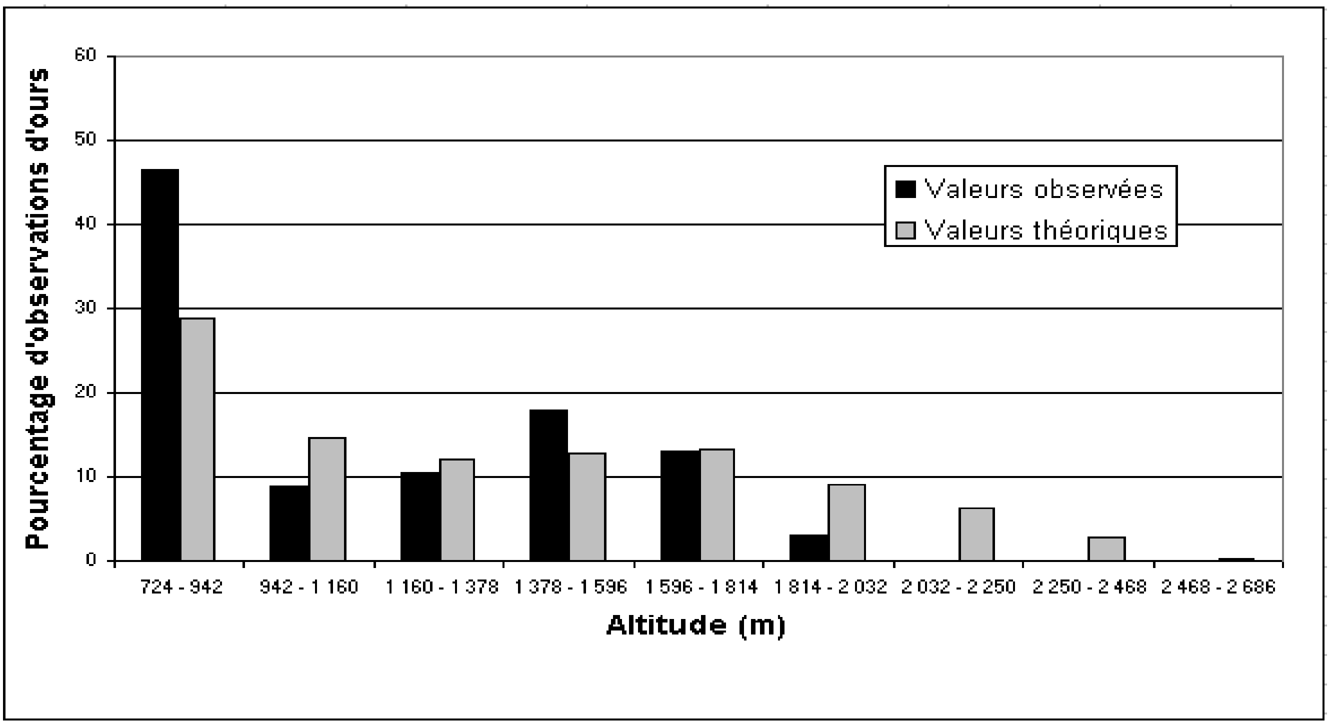


Figure 30 – Percentage of grizzly bear sightings by elevation

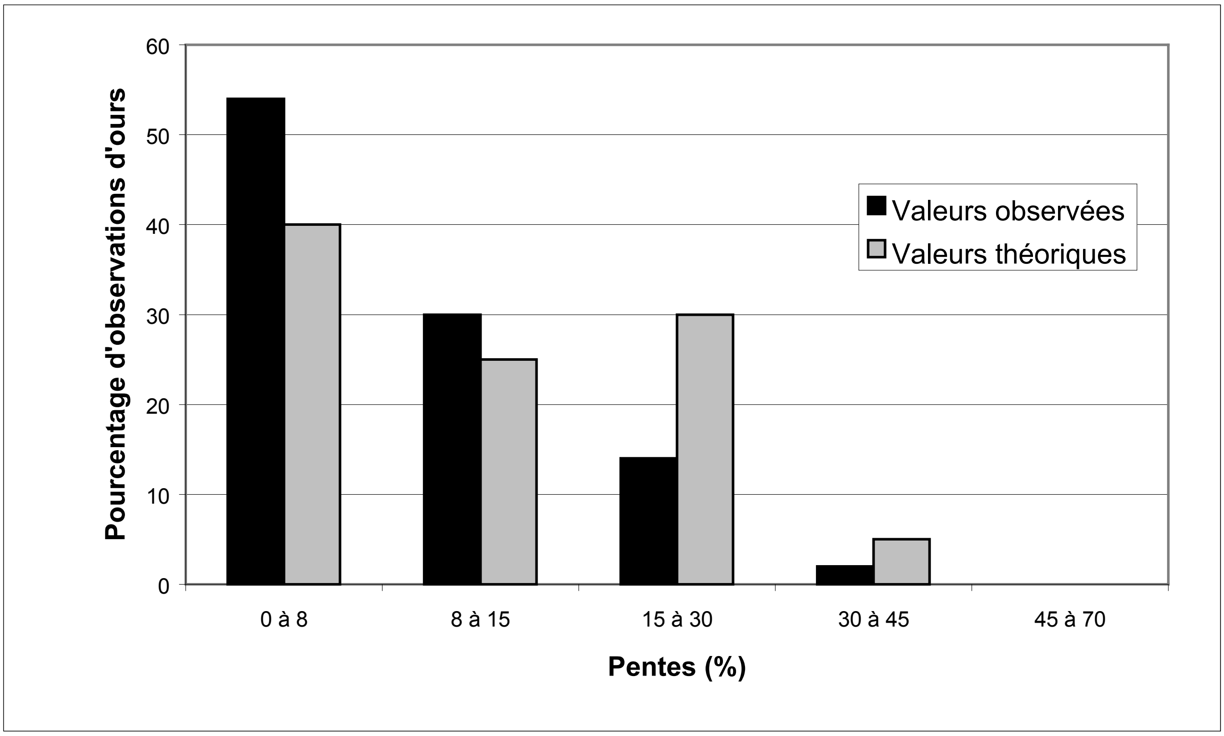


Figure 31 – Percentage of grizzly bear sightings by slope

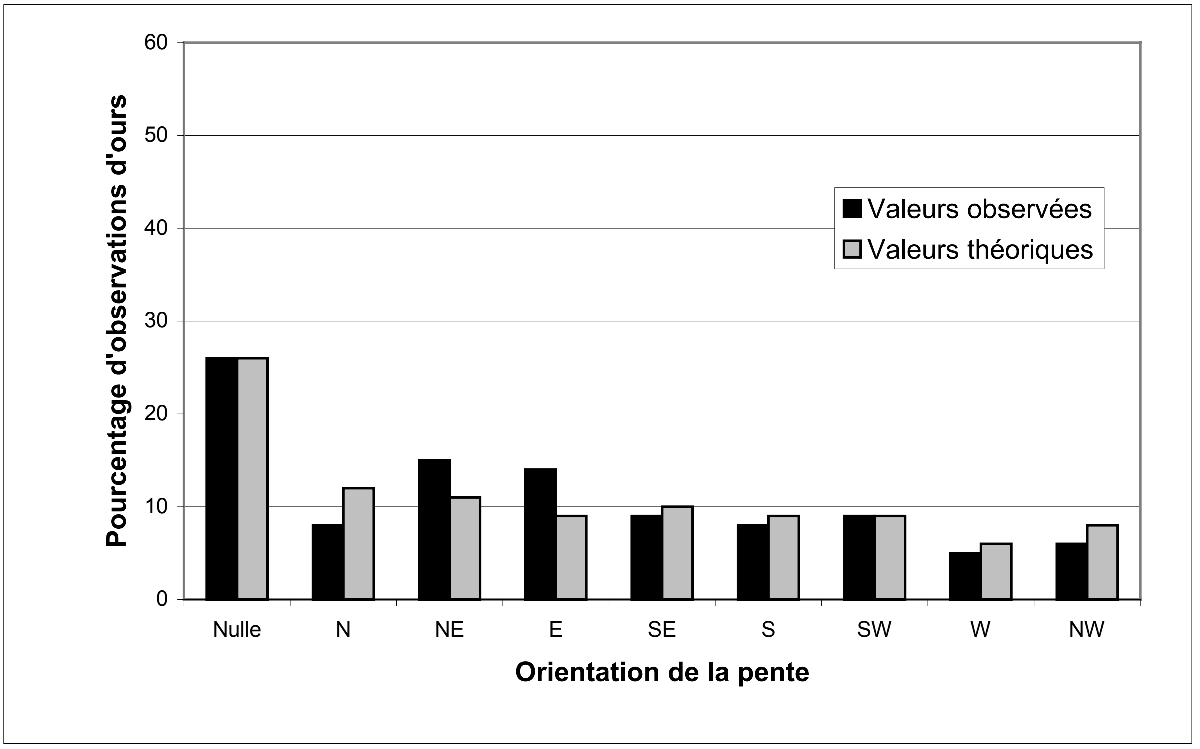


Figure 32 – Percentage of grizzly bear sightings by aspect

Table 16 – Number of grizzly bear sightings by preferred habitat classes and seasons (1988-1998)

Preferred habitat classes	Number of grizzly bear sightings				
	Spring	Early summer	Late summer	Fall	Total
1	47	103	173	20	343
2	1	9	15	4	29
3	2	10	11	3	26
4	4	3	10	0	17
5	18	41	57	10	126
6	18	71	83	9	181
7	14	53	75	4	146
8	22	46	50	18	136
Total	126	336	474	68	1 004

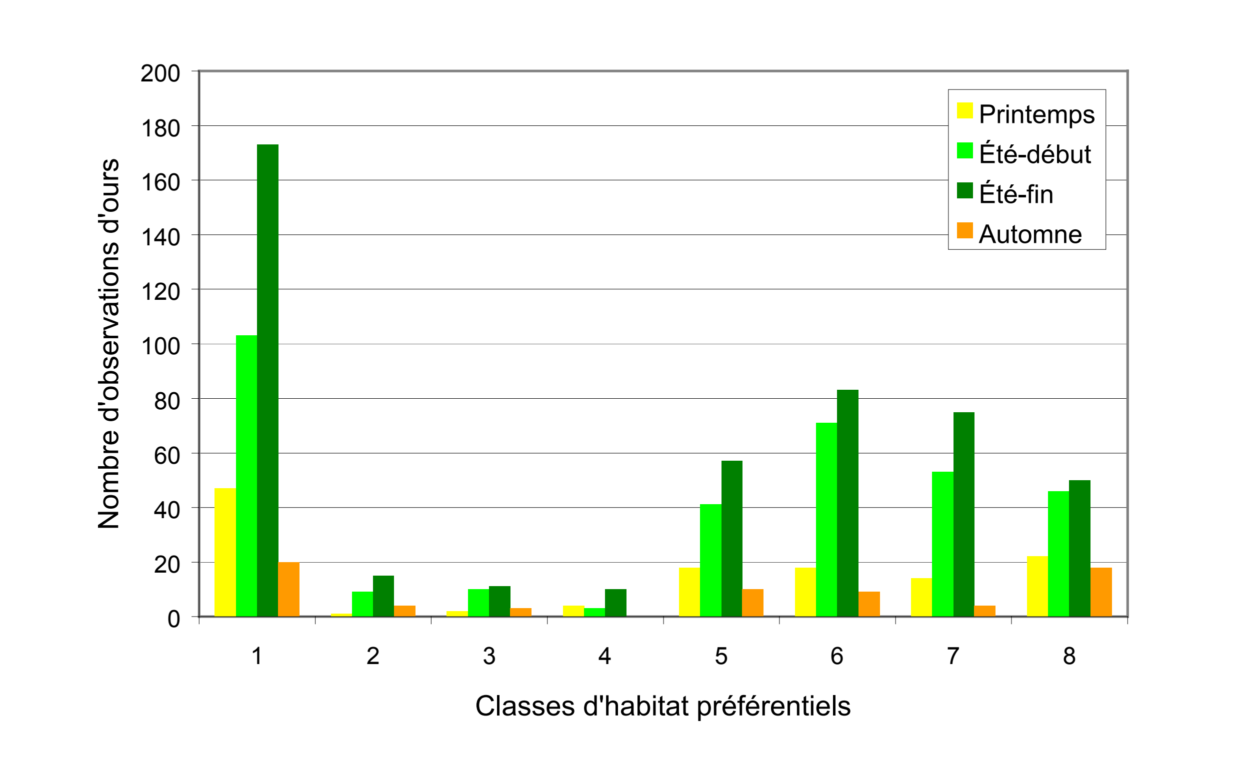


Figure 33 – Distribution of grizzly bear sightings by season and by preferred habitat classes

Tables 17 to 20 present the predicted distribution of sightings based on the area of each preferred habitat class and the actual observed distribution. With x^2 values of 41.3 ($P < 0.000\ 001$) for spring, 152.7 ($P < 0.000\ 000$) for early summer, 142.0 ($P < 0.000\ 000$) for late summer and 57.7 ($P < 0.000\ 000$) for fall, we are well above the threshold of $\alpha = 0.05$. The most favoured habitat classes (4 to 8) are almost always over-represented when compared to a distribution proportionate to the area of these classes. This clearly indicates that the preferred habitats are indeed the places where most grizzly bear sightings occur.

Table 17 – Grizzly bear sightings by preferred habitat classes (spring)

Classes	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Number of grizzly bear sightings: Expected frequencies (E)	O - E	(O-E)² / E
1	56.4	47	71	-24	8.1
2	1.7	1	2	-1	0.5
3	1.8	2	2	0	0.0
4	2.8	4	4	0	0.0
5	13.3	18	17	1	0.1
6	4.9	18	6	12	24.0
7	9.9	22	12	10	8.3
8	9.3	14	12	2	0.3
Total	100.0	126	126	0	41.3

Value of x^2 41.3, df = 7, $P < 0.000\ 001$, $\alpha = 0.05$

Table 18 – Grizzly bear sightings by preferred habitat classes (early summer)

Classes	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
1	56.4	103	190	-87	39.8
2	1.7	9	6	3	1.5
3	1.8	10	6	4	2.7
4	2.8	3	9	-6	4.0
5	9.3	41	31	10	3.2
6	9.9	71	33	38	43.8
7	13.3	53	45	8	1.4
8	4.9	46	16	30	56.3
Total	100.0	336	336	0	152.7

Value of x^2 152.7, df = 7, $P < 0.000\ 000$, α = 0.05

Table 19 – Grizzly bear sightings by preferred habitat classes (late summer)

Classes	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
1	56.4	173	267	-94	33.1
2	1.7	15	8	7	6.1
3	2.8	11	13	-2	0.3
4	1.8	10	9	1	0.1
5	4.9	57	23	34	50.3
6	9.3	75	44	31	21.8
7	9.9	83	47	36	27.6
8	13.3	50	63	-13	2.7
Total	100.0	474	474	0	142.0

Value of x^2 142.0, df = 7, $P < 0.000\ 000$, α = 0.05

Table 20 – Grizzly bear sightings by preferred habitat classes (fall)

Classes	Area %	Number of grizzly bear sightings: Observed frequencies (O)	Expected frequencies (E)	O - E	$(O-E)^2$ / E
1	56.4	20	39	-19	9.3
2	1.7	4	1	3	9.0
3	2.8	3	2	1	0.5
4	1.8	0	1	-1	1.0
5	4.9	10	3	7	16.3
6	13.3	4	9	-5	2.8
7	9.3	9	6	3	1.5
8	9.9	18	7	11	17.3
Total	100.0	68	68	0	57.7

Value of x^2 57.7, df = 7, $P < 0.000\ 000$, α = 0.05

When all seasons are considered together, it is apparent that 41.4 per cent of sightings occur in a less preferred habitat, compared to 58.6 per cent in a most preferred habitat. When the data are standardized based on the area of these two distinct environments, this yields a bear-sighting ratio of 1.3 bears seen per square kilometre in the less preferred area and of 3.2 in the most preferred area (Table 21). This confirms the higher sighting probability in the most preferred habitats (chi-square test $P < 0.000\,000$, $\alpha = 0.05$), in a ratio of more than two to one. It will be recalled that, according to preliminary telemetry-based studies, in Kluane a dominant male grizzly bear covers a territory of approximately 1000 km², while a female with her cubs covers approximately 300 km² (McCann, 1997b).

Table 21 – Grizzly bear sightings by preferred habitat classes, all seasons combined

Description	Area		Number of sightings		Ratio Bear/ km²
	km²	%	number	%	
Less preferred habitat	312	62,7	419	41	1,3
Most preferred habitat	186	37,3	594	59	3,2

5. Interpretation of the results

5.1. Biomass of importance in the grizzly bear's diet

Based on the results obtained for the plant species important in the grizzly bear's diet present in the Slims River Valley, several species formerly believed to be important were not on the list of the 12 species significantly present (out of a preliminary list of 20 species). The biggest surprise concerned the species *Hedysarum alpinum* and *Equisetum arvense*, two of the plants favoured by the grizzly bear in Kluane National Park, which were found to have a presence percentage lower than $\alpha = 0.05$. Yet, previous fecal analyses (Pearson, 1975; McLaughlin, 1981) suggest that these species form a favoured part of the grizzly bear's diet (the root of *Hedysarum alpinum* in the spring and in early summer and the foliage of *Equisetum arvense* throughout the summer season) (Figure 32). It should be noted that these two species are often more favoured in years when berries are less abundant, as McLaughlin (1981) points out.


Hedysarum alpinum


Equisetum arvense

Figure 34 – Photographs of *Hedysarum alpinum* and *Equisetum arvense*

In addition, we note the low presence in the Slims River Valley of the species *Vaccinium* spp., *Ribes* spp. and *Viburnum edule*, which are much more common in the other valleys of the park. These species are less abundant in this valley because of the semi-arid microclimate of the Slims River Valley, as well as the silty loess that is deposited on the surface.

The species *Salix arctica* and *S. reticulata*, which are found only in the alpine meadows and alpine barrens zones, merit particular attention. These species were inventoried and set apart from the remaining *Salix* species given their abundance in these environments, while the other species of the same family are virtually absent. However, it is not proven (by fecal analyses) that these species are part of the grizzly bear's diet, since no fecal sampling was conducted at these elevations (higher than 1 300 m). Still, biologists have reason to believe that these species are eaten in the same way as the herbaceous plants of the alpine zone (McLaughlin, 2000). For these reasons, it was agreed to keep these species on the list of species favoured as a food source by bears.

Therefore, in the Slims River Valley, the species significant in the grizzly bear's diet with the highest seasonal biomasses are *Arctostaphylos uva-ursi*, *Shepherdia canadensis* and *Oxytropis campestris.* The first two are sought after for their berries beginning in late summer and the third for its flowers, which bloom in early summer. Indeed, once the berries are ripe, they quickly become the most important food source. In fact, *Shepherdia canadensis* is the berry that provides grizzly bears with the most energy, of all the plants found in Kluane National Park (McCormick, 1999).

In terms of relative abundance, it is the species of the Poaceae family (Σ RA = 3.7), the *Carex* spp. (Σ RA = 3.2), *Shepherdia canadensis* (Σ RA = 3.1) and *Arctostaphylos uva-ursi* (Σ RA = 2.9) that are the most abundant throughout the Slims River Valley. Still in terms of abundance, the environments in which the significant species are the most abundant are, in order, open spruce forest (Σ RA = 5.0), alpine meadows (Σ RA = 4.9), gravel and/or alluvial deposits (Σ RA = 4.6) and deciduous shrubs (Σ RA = 4.6).

5.2. Preferred habitats

As has been pointed out by Pearson (1975), McLaughlin (1981) and several others, grizzly bear movements are conditioned by the abundance of bear food. The conclusions of this study are consistent with these findings. Indeed, bears chose their preferred habitat classes based on the quantity of food available rather than based on the habitat area. Hence, grizzly bear sightings are much higher than expected in certain environment classes.

In the spring, the preferred habitats are concentrated in the open spruce forest and deciduous shrub environments, at elevations ranging from 724 m to 940 m, on the south and east slopes where the snow melts first and where the first plant shoots are found. Hence, in early spring, the habitat available is significantly more important than the food found there (Servheen, 1983).

In early summer, the grizzly bear's preferred habitats are found in the alpine meadows (at elevations of more than 1 350 m), as well as on the alluvial cones and other forms covered with gravel and/or alluvial deposits. At this time of the summer season, grizzly bears are really looking for the plant species with the optimal phenological conditions (Waller and Mace, 1997).

In late summer, the most important season in terms of food abundance and environment biomass (EB), grizzly bears will tend to be found at varying elevations, in order to concentrate their diet on berries. These observations agree with the findings of Pearson (1975) and McLaughlin (1981). The most favourable environment is located in the areas covered with gravel and/or alluvial deposits (especially along the river, mainly on alluvial cones), closely followed by the open spruce forest environment, which is characterized by an undergrowth where berries are abundant (especially *Shepherdia canadensis*). It will be recalled that this period is the most favorable in terms of preferred habitat. It therefore becomes the most critical period in terms of potential interactions between bears and visitors.

Finally, in the fall the open spruce forest and deciduous shrub classes constitute preferred habitats (elevations between 724 m and 940 m). At this time of the year, bears are looking for the last ripening berries, as well as any other plants with a high energy content since their is to store as much energy as possible in order to survive the coming winter.

6. Discussion and limitations of the research project

6.1. Classification of vegetation

The ground truthing method proved to be very effective in carrying out the supervised classification of the vegetation, as the results show. The gravel and/or alluvial deposits class is sometimes arbitrary, given the very small spectral difference between gravel and bedrock. This loss of information and the resulting source of error are nevertheless considered minimal. Indeed, since we know that the image was acquired in early September 1996, some differences may be attributable to the time that elapsed between acquisition of the image and completion of the supervised classification. Furthermore, the state of the vegetation in September is not the same as it is in July, when the sampling of the vegetation was carried out. Although few changes have occurred in the vegetation cover of the Slims River Valley over a five-year period (no major forest fires, no epidemics, etc.), differences such as variabilities in water level in the marshes, must be taken into consideration. As well, certain classes were surveyed less thoroughly than others, particularly the alpine barrens and alpine meadows classes, because of the difficulty of access at high elevations.

A certain amount of error is associated with the classification of the image because of the morphology of the landscape, which is often a mosaic of habitats rather than a single heterogeneous environment. As well, the spatial resolution of the Landsat TM image is limited to 25 m, which does not make it possible to identify certain smaller components of the environment that could be relevant to the grizzly bear’s habitat, such avalanche slopes or scree slopes.

6.2. Grizzly bear’s diet

If the project were to be repeated I would ensure that all the fecal analyses did in fact come from the study site and from all the vegetation classes. In this case, the seasonal biomass values for each plant species important in the grizzly bear’s diet had to be compared in relative terms, by combining the results of several studies conducted in the park. The results would have been more accurate with the exact content of the samples collected only in the valley under study. However, this requires considerable collection time, as well as a large budget for the analyses.

6.3. Grizzly bear sightings

One of the most obvious biases of the research project is undoubtedly the validity of grizzly bear sighting data. As Stoms *et al.* (1993) point out, there is an error that is associated with the tendency of rare species observation data to be situated in locations most accessible to the observers. However, verifying the location of the sightings, as was done here, reduces the magnitude of this bias. Furthermore, the large quantity of information available cannot be overlooked. As Palma *et al.* (1999) state, one can hardly dispute that using sighting data has a role to play in the process of management and conservation of a threatened species. Furthermore, as Agassiz *et al.* (1994) point out, the use of information from the public is an economical way of obtaining geographic information on the distribution of a species.

6.4. Physical constraints of the landscape

Another factor must be taken into consideration, in terms of preferred bear habitats, where visitors are concerned: the physical constraints of the landscape. According to Nadeau (1987), there are three very important factors that increase the probability of confrontations between grizzly bears and hikers on the trails, namely trails with low visibility and/or that pass close to noisy streams and/or that run through preferred habitat areas. However, given the nature of the grizzly bear, even if none of these three conditions are present, this does not necessarily eliminate the risk of confrontation.

Indeed, factors such as visibility, the direction of the prevailing winds and the proximity of rivers or streams can influence the probability of a bear encounter. For instance, the visibility of an environment such as alpine meadows is very different from that of a denser environment such as the open spruce forest. This must be considered in the qualitative evaluation of the preferred habitats. If a grizzly bear is present in an alpine meadows environment, the hiker has a much greater chance of seeing it from a distance than when this hiker is crossing through open spruce forest. In fact, Nadeau (1987) even postulates that the visibility of the trails is undoubtedly directly responsible for a number of the interactions between humans and grizzly bears.

Therefore, when sections of routes or trails run alongside noisy rivers or streams, it is important to remind hikers of the importance of being more vigilant since the noises they make do not carry as far. Hence, the possibility of surprising a bear is greater.

Since the grizzly bear has a highly developed sense of smell, it may leave the area long before when it smells the presence of humans. Nevertheless, strong winds can carry away the hikers' scent, preventing it from reaching the grizzly bear, thereby increasing the possibility of chance encounters.

7. Conclusion

The results of this study clearly show that there is a direct relationship between the biophysical characteristics of the environment and the distribution of grizzly bear sightings in the Slims River Valley in Kluane National Park (Yukon). In addition, this relationship changes with the seasons, reflecting the grizzly bear's different feeding habits during the summer period.

The most critical season or the season during which grizzly bear food is most abundant is late summer, when the berries ripen. Special attention must be focussed on the distribution of *Shepherdia canadensis*, the key species in the grizzly bear's diet in Kluane National Park.

The environment in which bears are most likely to be found is the open spruce forest, particularly in the fall. In the spring, the deciduous shrub environment is its preferred habitat, while in early summer, they prefer alpine meadows, and in late summer, gravel and/or alluvial deposits environment. It is also in these four environments that the greatest concentrations of plant species of importance to the grizzly bear's diet, in terms of relative abundance, are found.

In terms of the distribution of the sightings, it will be recalled that approximately 100 grizzly bear sightings in the Slims River Valley are recorded every year and that visitors see on average 1.6 bears per sighting. This translates into one chance in three of making a bear sighting during a hiking trip of more than two days in the backcountry. These sightings do not occur randomly on the territory, but rather are concentrated in the habitats most favoured by bears. In fact, nearly 60 per cent of the sightings are made in the four most preferred habitat classes.

The most over-represented environments in terms of number of grizzly bear sightings are, in order, the open forest, alpine meadows and the deciduous shrub environment. Grizzly bear sightings are also more frequent at elevations of between 720 m and 940 m and between 1 380 m and 1 600 m, on slopes between 0 and 15 per cent, and on eastern and northeastern aspects.

This type of study is particularly valuable when it can be combined and compared with a second source of bear location data, namely the more traditional telemetry. In fact, the *Kluane Grizzly Bear Research Program* conducted this type of study, the results of which are expected soon. Comparison of the two approaches will be very informative for park managers. Although these conclusions can help better identify the most critical periods and locations in terms of preferred habitat and bear sighting probability, it is important to remember that this information will be useful only if combined with a visitor information and education campaign. Encouraging groups of six or more (Jope, 1985), making noise, especially when visibility is lower, when the trail runs along a river or stream or when the winds are very strong (Nadeau, 1987) and turning back when a bear is found on the trail are all recommendations that must be clearly indicated to all hikers. It is particularly important to make visitors realize that the primary purpose of wildlife sanctuaries such as Kluane National Park is to ensure the survival of the species and of the ecosystems found there.

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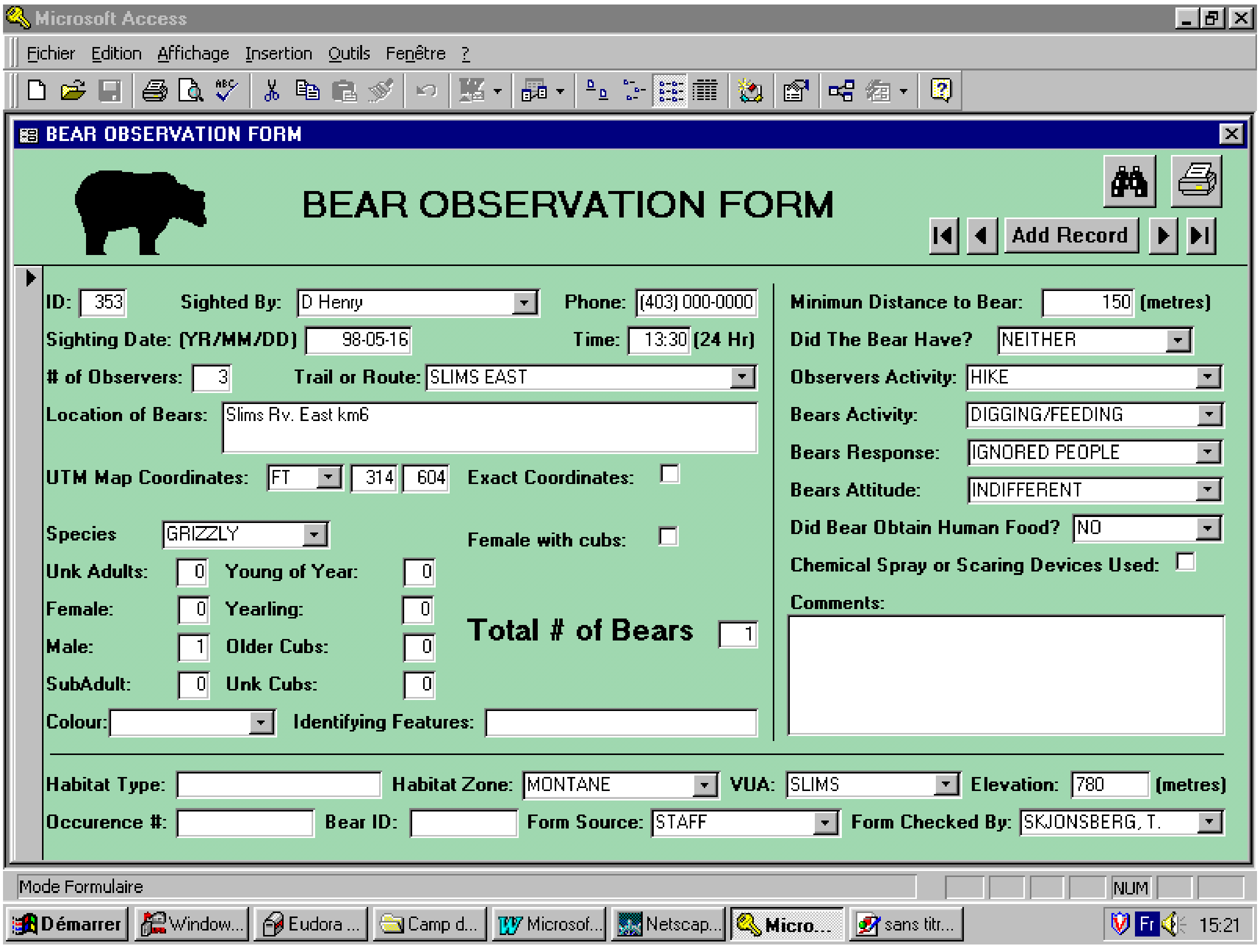
Appendix 1 – Example of bear observation form



Microsoft Access

Fichier Edition Affichage Insertion Outils Fenêtre ?

BEAR OBSERVATION FORM

BEAR OBSERVATION FORM

Add Record

ID: 353 Sighted By: D Henry Phone: (403) 000-0000

Sighting Date: (YR/MM/DD) 98-05-16 Time: 13:30 (24 Hr)

# of Observers: 3 Trail or Route: SLIMS EAST

Location of Bears: Slims Rv. East km6

UTM Map Coordinates: FT 314 604 Exact Coordinates:

Species GRIZZLY Female with cubs:

Unk Adults: 0 Young of Year: 0

Female: 0 Yearling: 0

Male: 1 Older Cubs: 0

SubAdult: 0 Unk Cubs: 0

Total # of Bears 1

Colour: Identifying Features:

Minimun Distance to Bear: 150 (metres)

Did The Bear Have? NEITHER

Observers Activity: HIKE

Bears Activity: DIGGING/FEEDING

Bears Response: IGNORED PEOPLE

Bears Attitude: INDIFFERENT

Did Bear Obtain Human Food? NO

Chemical Spray or Scaring Devices Used:

Comments:

Habitat Type: Habitat Zone: MONTANE VUA: SLIMS Elevation: 780 (metres)

Occurence #: Bear ID: Form Source: STAFF Form Checked By: SKJONSBERG, T.

Mode Formulaire NUM

Démarrer Window... Eudora ... Camp d... Microsof... Netscap... Micro... sans titr... Fr 15:21

Appendix 2 – Data sheets for vegetation characteristics

GREATER KLUANE GRIZZLY BEAR HABITAT ASSESSMENT 2000

Date : ______ / ______ / ______ Site # : ____________________

d m y Plot # : ____________________

Valley / Area description : ____

UTM (Map/GPS) E : ______________ Observer : ________________

N: ______________________ Map sheet # : ________________

Elevation : ________________ Air photo # : ________________

Landform : ______________________ Position on landform : ________________

Surface material : ________________ Slope : ____________ Aspect : __________

SITE PLAN	CROSS-SECTION
	↑ N

Classification type : ___________ Sheet # : _______________ Photo # : ___________

Transect_____________ Distance on Transect ____________________

Rock cover : _______ Mineral soil : _______ Water : _______ Snow/Ice : ________

FWD:_____ Litter con. : _____ Litter dec. : ______ Bear sign : __________________

Faunal food obs. (ants, ground squirrel, mega fauna signs) : ____________________

Diggibility : ______(s) ______(c) _______(w) _______n/a

#	Species	% Cover 1	2	3	4	Height class (m)	Stage
1	*Arctostaphylos uva-ursi*					0.5 - 1 - 2 - 3 - >3	
2	*Elaegnus commutata*					0.5 - 1 - 2 - 3 - >3	
3	*Empetrum nigrum*					0.5 - 1 - 2 - 3 - >3	
4	*Sheperdia canadensis*					0.5 - 1 - 2 - 3 - >3	
5	*Equisetum arvense*					0.5 - 1 - 2 - 3 - >3	
6	*Hedysarum alpinum*					0.5 - 1 - 2 - 3 - >3	
7	*Oxytropis campestris*					0.5 - 1 - 2 - 3 - >3	
8	*Astragalus* spp.					0.5 - 1 - 2 - 3 - >3	
9	*Carex* spp.					0.5 - 1 - 2 - 3 - >3	
10	Grass spp.					0.5 - 1 - 2 - 3 - >3	
11	*Salix* spp.					0.5 - 1 - 2 - 3 - >3	
12	*Heracleum lanatum*					0.5 - 1 - 2 - 3 - >3	
13	*Epilobium angustifolium*					0.5 - 1 - 2 - 3 - >3	
14	*Arctostaphylos rubra*					0.5 - 1 - 2 - 3 - >3	
15	*Vaccinium caespitosum*					0.5 - 1 - 2 - 3 - >3	
16	*Vaccinium vitis-idaea*					0.5 - 1 - 2 - 3 - >3	
17	*Vaccinium uliginosum*					0.5 - 1 - 2 - 3 - >3	
18	*Viburnum edule*					0.5 - 1 - 2 - 3 - >3	
19	*Ribes* spp.					0.5 - 1 - 2 - 3 - >3	
20	*Epilobium latifolium*					0.5 - 1 - 2 - 3 - >3	
21	*Eriophorum* spp.					0.5 - 1 - 2 - 3 - >3	
22	*Rosa* spp.					0.5 - 1 - 2 - 3 - >3	
23						0.5 - 1 - 2 - 3 - >3	
24						0.5 - 1 - 2 - 3 - >3	

Roll # : Frame # : Aspect : Description :	Roll # : Frame # : Aspect : Description :	Roll # : Frame # : Aspect : Description :
Roll # : Frame # : Aspect : Description :	Roll # : Frame # : Aspect : Description :	Roll # : Frame # : Aspect : Description :

Comments :

____

____

____

____

Tree Cover and Downed Wood Datasheet Kluane National Park 2000

% Tree Cover____________________ Valley ______________

% Shrub Cover >3m tall____________ Transect ____________

% Shrub Cover <3m tall____________ Plot Number __________

% Herb Cover (<0.5m)____________ Veg. Class. __________

Understory Density	North		South		East		West	
	coniferous	deciduous	coniferous	coniferous	deciduous	deciduous	coniferous	deciduous
0-1								
1-2								
2-3								

Tree Spp.	DBH	Height	Decay Class	Tree Spp	DBH	Height	Decay Class

CWD Transect 1 (25m) Diameter

CWD Transect 2 (25m) Diameter

Appendix 3 – Data sheet for bear food

Berry Biomass Datasheet Kluane Naitonal Park 2000 Field Season

Valley and Location:____________________ Transect:____________________

UTMs (Map/GPS) E:_________________ Distance on Transect: __________________
N:_________________ Date:_________________
Berry Counter:_______________________ Vegetation Type:_____________

#	Species	% cover	Height class (m)	Ripe (g)	Unripe (g)	Over-winter (g)	Stage
1	*Arctostaphylos uva-ursi*		0.5 - 1 - 2 - 3 - >3				
2	*Elaegnus communtata*		0.5 - 1 - 2 - 3 - >3				
3	*Empetrum nigrum*		0.5 - 1 - 2 - 3 - >3				
4	*Sheperdia canadensis*		0.5 - 1 - 2 - 3 - >3				
11	*Salix* spp.		0.5 - 1 - 2 - 3 - >3				
14	*Arctostaphylos rubra*		0.5 - 1 - 2 - 3 - >3				
15	*Vaccinium caespitosum*		0.5 - 1 - 2 - 3 - >3				
16	*Vaccinium vitis-idaea*		0.5 - 1 - 2 - 3 - >3				
17	*Vaccinium uliginosum*		0.5 - 1 - 2 - 3 - >3				
18	*Viburnum edule*		0.5 - 1 - 2 - 3 - >3				
19	*Ribes* spp.		0.5 - 1 - 2 - 3 - >3				
22	*Rosa gymnocarpa*		0.5 - 1 - 2 - 3 - >3				

Valley and Location:____________________ Transect:____________________

UTMs (Map/GPS) E:_________________ Distance on Transect: __________________
N:_________________ Date:_________________
Berry Counter:_______________________ Vegetation Type:_____________

#	Species	% cover	Height class (m)	Ripe (g)	Unripe (g)	Over-winter (g)	Stage
1	*Arctostaphylos uva-ursi*		0.5 - 1 - 2 - 3 - >3				
2	*Elaegnus communtata*		0.5 - 1 - 2 - 3 - >3				
3	*Empetrum nigrum*		0.5 - 1 - 2 - 3 - >3				
4	*Sheperdia canadensis*		0.5 - 1 - 2 - 3 - >3				
11	*Salix* spp.		0.5 - 1 - 2 - 3 - >3				
14	*Arctostaphylos rubra*		0.5 - 1 - 2 - 3 - >3				
15	*Vaccinium caespitosum*		0.5 - 1 - 2 - 3 - >3				
16	*Vaccinium vitis-idaea*		0.5 - 1 - 2 - 3 - >3				
17	*Vaccinium uliginosum*		0.5 - 1 - 2 - 3 - >3				
18	*Viburnum edule*		0.5 - 1 - 2 - 3 - >3				
19	*Ribes* spp.		0.5 - 1 - 2 - 3 - >3				
22	*Rosa gymnocarpa*		0.5 - 1 - 2 - 3 - >3				

Valley and Location:____________________ Transect:____________________

UTMs (Map/GPS) E:_________________ Distance on Transect: __________________
N:_________________ Date:_________________
Berry Counter:_______________________ Vegetation Type:_____________

#	Species	% cover	Height class (m)	Ripe (g)	Unripe (g)	Over-winter (g)	Stage
1	*Arctostaphylos uva-ursi*		0.5 - 1 - 2 - 3 - >3				
2	*Elaegnus communtata*		0.5 - 1 - 2 - 3 - >3				
3	*Empetrum nigrum*		0.5 - 1 - 2 - 3 - >3				
4	*Sheperdia canadensis*		0.5 - 1 - 2 - 3 - >3				
11	*Salix* spp.		0.5 - 1 - 2 - 3 - >3				
14	*Arctostaphylos rubra*		0.5 - 1 - 2 - 3 - >3				
15	*Vaccinium caespitosum*		0.5 - 1 - 2 - 3 - >3				
16	*Vaccinium vitis-idaea*		0.5 - 1 - 2 - 3 - >3				
17	*Vaccinium uliginosum*		0.5 - 1 - 2 - 3 - >3				
18	*Viburnum edule*		0.5 - 1 - 2 - 3 - >3				
19	*Ribes* spp.		0.5 - 1 - 2 - 3 - >3				
22	*Rosa gymnocarpa*		0.5 - 1 - 2 - 3 - >3				

Appendix 4 – Data sheet for image classification

Note: Montane to Alpine Transition zone occurs between the APPROXIMATE elevations of 1080m – 1400m.

Kluane Vegetation Classification Project - Data Collection Form

Collected by: ______________________ Data Sheet #: 00-________ Time: ______ Date: ___/___/___
day mo. year

CLASSIFICATION TYPE **Modifier** (type, approx. percentage coverage)

☐ 1. **SPRUCE FOREST – CLOSED** ______________________
(>60% crown closure)
☐ 2. **SPRUCE FOREST - OPEN**
(< 60% crown closure) (herb/shrub/grass) ______________________
☐ 3. **DECIDUOUS / SHRUB – HIGH** ______________________
(>3 metres high) (Poplar, willow, alder, shrub, grasses/sedge)
☐ 4. **DECIDUOUS / SHRUB - LOW** (<3 metres high)______________________
☐ 5. **MIXED FOREST** (classes 2 & 3) ______________________
☐ 6. **GRASSLAND** (dry, 20% exposed soil/rock) ______________________
☐ 7. **ALPINE MEADOW**
(<20% rock) (grasses, sedges) ______________________
☐ 8. **ALPINE TUNDRA**
(<20% rock) (mosses, lichens) ______________________
☐ 9. **ALPINE BARRENS** (>20% rock) ______________________
(exposed soil/rock, moss, lichen, grasses/sedges)
☐ 10. **AQUATIC VEGETATION** (>20% bed/emergent)______________________
☐ 11. **ICE / SNOW** ______________________
☐ 12. **WATER – CLEAR** ______________________
☐ 13. **WATER – TURBID** ______________________
☐ 14. **SCREE / TALUS** ______________________
☐ 15. **GRAVEL & ALLUVIAL DEPOSITS** ______________________
☐ 16. **UNCLASSIFIED**

LOCATION : ☐ UTM
☐ LAT./LONG

ELEVATION: ____________ ☐ m ☐ ft.
DATUM : NAD83 ☐ Other: ________

LOCATION QUALITY: HIGH ☐ (corrected rover file I.D.# **R**______________)
LOW ☐ (single GPS or averaged group)

DISTANCE TO POLYGON BOUNDARY FROM GPS COLLECTION POINT:

	<100m (specify)	>100m(check)
NORTH	________	________
SOUTH	________	________
EAST	________	________
WEST	________	________

RECENT EVIDENCE OF DISTURBANCE:

None ☐ Fire ☐ Fluvial ☐ Glacial ☐ Insect/Disease ☐ Geomorphic ☐ Wind ☐

PHOTOGRAPH: Yes ☐ No ☐ Direction of Photo from observer: ________ # ____________

COMMENTS: (Avalanche path, location, nearby features, etc.)

Appendix 5 - Description of the sampling transects

Transect	Localisation	Date	Time		Bearing	Distance	Coordinates start				Coordinates end			
			start	end	degrees	m	Zone UTM	Easting	Northing	Alt (m)	Zone UTM	Easting	Northing	Alt (m)
SE-1	5 km in	00-07-03	18:10	22:30	124	975	NAD 27 7V	630942	6760241	795	NAD 27 7V	631676	6759613	1020
SE-2	10 km in on alluvial fan	00-07-04	17:00	20:55	89	1458	NAD 27 7V	628787	6758268	794	NAD 27 7V	630013	6758359	1060
SE-3	16 km in	00-07-05	13:40	18:50	83	1000	NAD 27 7V	628943	6754989	803	NAD 27 7V	629808	6755212	1082
SE-4	16 km in, W of big lake on knoll	00-07-05	20:10	21:10	360	381	NAD 27 7V	628967	6754966	809	NAD 27 7V	628877	6755314	816
SE-5	20 km in	00-07-06	14:15	19:25	137	1270	NAD 27 7V	630249	6750768	811	NAD 27 7V	631254	6750078	960
SW-1	Near Sheppard's knoll	00-07-13	12:30	18:00	274	1725	NAD 27 7V	632798	6764869	807	NAD 27 7V	631182	6764747	962
SW-2	Mt Observation plateau	00-07-17	11:50	15:30	108	1425	NAD 27 7V	622422	6744827	1917	NAD 27 7V	623766	6744501	1655
SW-3	Side of Mt Observation plateau	00-07-17	17:15	18:00	279	250	NAD 27 7V	624189	6746820	1642	NAD 27 7V	623935	6746823	1613
SW-4	Canada creek fan (~23.5 km)	00-07-18	12:45	17:10	317	1125	NAD 27 7V	628793	6748601	822	NAD 27 7V	628340	6749020	817
SW-5	~16 km in (marker)	00-07-19	11:40	12:00	151	55	NAD 27 7V	627352	6753974	816	NAD 27 7V	627381	6753926	816
SW-6	15.4 km marker	00-07-19	14:10	15:50	265	650	NAD 27 7V	627215	3756303	813	NAD 27 7V	626595	6756157	827
SW-7	Bullion creek fan	00-07-20	11:50	13:30	154	925	NAD 27 7V	628438	6762172	850	NAD 27 7V	628918	6761410	814
SW-8	Between Bullion and Coin creek	00-07-20	15:25	16:45	356	500	NAD 27 7V	629222	6762726	828	NAD 27 7V	629072	6763195	886

SE Slims East, SW Slims West, date (yyyy-mm-dd), hour (hh:mm)