Spatial and Temporal Prediction Models of Alaska's 11 Species Mega-Predator Community:

Towards a First State-wide Ecological Habitat, Impact, and Climate Assessment

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Malte Semmler

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First Assessor: Prof. Dr. Falk Huettmann

Second Assessor: Prof. Dr. Christoph Kleinn

Contents

Abstract

In this study, eleven mega predators, coyote (*Canis latrans*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), arctic fox (*Vulpes lagopus*), black bear (*Ursus americanus*), brown bear (*Ursus arctos*), polar bear (*Ursus maritimus*), wolverine (*Gulo gulo*), marten (*Martes americana*), lynx (*Lynx canadensis*) and golden eagle (*Aquila chrysaetos*) were selected to represent an Ecosystem Unit entitled “Mega Predator”. The most influential factors affecting this Ecosystem Unit were determined using a machine learning algorithm (TreeNet) and a Geographic Information System (GIS). Public available range layers were corrected for errors and detectability using occupancy model, and several ‘robust’ hotspots of the predator community were identified. Anthropogenic variables, such as proximity to railways, together with regionalized IPCC climate variables (precipitation and temperature), Alaska SNAP data and spatial variables (e.g. distance to coast) proved to be the main predictors. A second predictive TreeNet model based on climate data forecasting the next 100 years was also performed to assess the resilience of these predators.

The results indicate that the Ecosystem Unit “Mega Predator” shall undergo extreme changes in the next decades, commencing in 30 years or less. The TreeNet model points to a complete shattering of the current mega predator community food chain within the next century as a direct consequence of climate change alone. Owing to the fact that IPCC models are underestimates and other factors co-occur, the findings displayed herewith are consequently underestimates.

The results of the first TreeNet model and the second predictive model were used to find the optimal potential protected areas for the predator community. This prioritization search was performed with the program MARXAN. Results of the MARXAN Model indicate that the main importance of protected areas for predators lies in the Brooks Range of Northern Alaska.

This study could serve as a first (digital) platform and a first step to provide a basis for landscape planners and conservationists to react properly to the upcoming impact of climate and other changes on entire ecosystems.

1 Introduction

Carnivores are keystone species and play an important ecological role in the landscapes they occupy. Predators represent an inherent part of the ecosystem (Begon 1996) and apex predators put forth considerable influence in the structure and function of ecosystems (Estes and Palmisano 1974; Spiller and Schoener 1990; McPeek 1998).

In this study a new view on predators is pursued whereby different predators are not considered as individual stand-alone species, but rather viewed as the so-called Ecosystem Unit “Mega Predator”. In the following introduction, different theories are briefly offered which demonstrate the relationship among predators and their joint effect on the ecosystem. Furthermore, the conclusions that lead to the definition of the Mega Predator Ecosystem Unit are presented. This approach makes for a new perception of a terrestrial ecosystem.

1.1 Ecological Role and Interactions of Predators

Table 1: Four main theories that describe the influence of predators upon the ecosystem and which are relevant for this thesis

Theory	**Definition**	**Essential Studies**
Food Web, Food Chain	Food webs are systems of food chains that are linked with one another (Oxford 2004)	Lindeman 1942
Trophic cascade	“Progression of indirect effects by predators across successively lower trophic levels.” (Levin 2001)	Hairston et al. 1960
Sympatric connection	In sympatric speciation, species diverge while inhabiting the same place (Feder 2005).	Poulton 1904.

Theory	Definition	Essential Studies
Predator-Prey Cycles	Simplest individual level model of predator-prey dynamics Interaction of two species (McKane 2005). (Not applicable due to the complexity of the study area).	Volterra 1990; McKane 2005

1.2 Influence of Predators upon the Ecosystem

The influence of predators upon the ecosystem is tremendously broad. One direct effect of predation seems obvious though: the decrease of a prey population by a predator. This simple approach leads to more complex predator-prey relations. Predation on snowshoe hare for example prolongs the cycles of increasing and decreasing hare populations (Hik 1995) and in most cases the predators are controlled by the abundance of prey as for example many classic studies on the Isle Royal show (McLaren and Peterson 1994; Peterson and Page 1988). Even a simple biological problem like the relation between prey and predator gets complicated if one is trying to understand it in detail and in space (Freedman 1980, Jost et al. 2005). As a matter of fact, and despite decades of study, the knowledge of this issue has advanced slowly and with many inconclusive findings that are difficult to generalize (Krebs et al. 2001). This poses major problems regarding science-based management.

Besides direct effects of predators and their prey, other more complicated interactions within the predator community and between predators and prey species can be found. Biodiversity and trophic-structure influence ecosystem functions interactively and across scales, though the effects are not predictable in isolation (Ricklefs 1987), such as in a classic single species approach still widely pursued in research even today. Regional and historical processes, as well as unique events and circumstances, profoundly influence the local community structure (Ricklefs 1987) as illustrated in an example by Ottersen et al.(2001) where the measurement of ecological responses on the North Atlantic Oscillation (NAO) included changes in timing of reproduction, population dynamics, abundance, special distribution and also predator and prey relationships. The effect of the NAO flows through trophic levels, including primary production to herbivores and to predators

In another study by Hegel et al. (2010) the recruitment of the population of mountain-dwelling caribou (*Rangifer tarandus)* in the Yukon Territory was best explained by the interaction of wolf (*Canis lupus* Taxonomic Serial No.:180596 [TSN])* density and April- Pacific Decadal Oscillation, with wolf density causing the most deviance.

In Post et al. (1999) it is concluded that the change of behavior of apex predators may be the essential link in the path of climate alteration on an ecosystem.

*Study species are described with Taxonomic Serial Numbers from ITIS (http://www.itis.gov/)

1.3 Food Web and Trophic Cascades

The presence of predators in an ecosystem without a doubt affects the diversity of prey species (Primack et al. 2002). In Marine ecosystems the food webs are identified and described e.g. with the Ecosim software (http://garyentsminger.com/ecosim/index.htm). Here predator absence leads to trophic cascade (Daskalov 2002).

- A trophic cascade is a chain-reaction within food webs that results from changing population densities at higher trophic levels, shifting the dominance and impact of consumers in lower levels-

-(AMNH 2010)-

It is also known that top predators influence prey behavior and distribution, as well as animal health and disease. As a consequence, different trophic cascades may emerge which are able to modify entire ecosystems (Creel et al. 2005; Preisser et al. 2005). The conclusion can be drawn that predators indirectly influence the vegetation and plant composition by altering the herbivore species in an ecosystem (Ballard et al. 1987), a circumstance which is most prevalent in Alaska, e.g. by maintaining high moose populations via predator control (as manifested in the Intensive Management Law from 1994 (ADF&G 2010a).

Research by Estes et al. (1998) shows the complex relations in the oceanic environment for instance. A trophic cascade between killer whales *(Orcinus orca)* and sea otters (*Enhydra lutris*) leads ultimately to a decline of sea otters if the chain of ecological interactions is disturbed. A top down trophic cascade is assumed: the chain of ecological interactions begins with the reduction or alteration of forage fish stocks. As a consequence, pinniped populations are sent into decline. Pinniped numbers eventually became so reduced that some of the killer whales which once fed on them expanded their diet to include sea otters. This leads to a connection between oceanic and coastal ecosystems where coastal kelp forests have changed from three- to four- trophic – levels. In this way, sea urchins are released from the limiting influence of sea otter predation and the unregulated urchin population rapidly increased and overgrazed the kelp forest. A host effect in the coastal ecosystem was thereby set into motion. These “top down” approaches are discussed with reference to “bottom up” ecological approaches (Frederiksen et al 2006). Another example of a top down cascade with a closer view on land, and comparable with Alaska, can be found on Isle Royal in Michigan/ USA.

The growth rates of balsam fir (*Abies balsamea*) are regulated by moose (*Alces alces*) density. The moose population, on the other hand, is controlled by predation of wolves (McLaren and Peterson 1994). If the wolf population declines for any reason, moose population reaches high densities and will suppress fir growth. Only in rare cases, when stand-replacing disturbances such as fire or a large windstorm occur at times when moose density is already low, is this regulative trophic cascade replaced by bottom-up influence (McLaren and Peterson 1994). In Alaska similar reactions of wolves and caribou (*Rangifer tarandus*) are observed due to the implementation of the mentioned Intensive Management Law (Rodney et al 1996). As marine examples show, the change from top down to bottom-up may not occur (Daskalov 2002), however this change only happens if the food chain is already altered. Finding locations in the world with unaltered food chains must be perceived as rare these days.

1.3 Reaction of the Ecosystem to missing Apex Predators

The importance of top predators is shown in anthropogenically-altered landscapes where the apex predators has been removed e.g. in central Europe. If top predators are missing, like for example in fragmented landscapes, high populations of opportunistic predators occur, leading to substantial predation on eggs and nestlings of forest songbirds (Wilcove et al. 1986). In Southern California heavy predation on bird nests in some canyons occurs due to the absence of coyotes (*Canis latrans* TSN 180599). As a result, populations of “opportunistic mesopredators” like gray foxes (*Urocyon cinereoargenteus*) and Feral cats (*Felis catus*) increase. Soule et al. (1988) also contended that smaller omnivores and predators undergo population explosions if top predators are missing. Sometimes mesopredators are ten times more abundant. The removal of top predators by human influence is a phenomenon that occurs in almost all the western world (Terborgh et al 2001). As a matter of fact, this is an explicit characteristic of the western “modern’ culture, which spreads with globalization but which has not learned to live with nature in a balanced and sustainable way (Diamond 1998).

Prey population increase due to the lack of top predators may lead to an outbreak of diseases in prey population and thus can even lead to disease transmission to humans (Ostfeld and Holt 2004).

Apart from the fragmentation of landscapes, humans influence the food web in many other ways. In urban regions the food sources for predators are widely altered. In most regions of the world anthropogenic food sources are available for predators near urban regions (Chapin 2009). These food resources can be more lucrative, stable and predictable than those in a natural environment.

Animals are subsidized (Soule 1988) through this food source and are able to increase in numbers and can expand their range (Boarman 2003). Around the houses cat and dog food, waste, and sometimes livestock can be found as food support (McClure et al. 1995; Herrero 1985). Nitrogen which is now globally abundant (Dentener 2006) functions as a fertilizer to increase the food abundance, e.g. via modified ecosystems and vegetation, for herbivores and through this predator occurrence. A good example is the increasing roe deer (*Capreolus capreolus)* population in Germany (Ellenberg 1986).

This leads to the conclusion that there are many relationships within the food chain of predators which we may not fully understand, but upon which humans have an inescapably major and global impact. The human footprint is probably much wider than it appears or is currently estimated. Examples for this are found with the human-caused alteration of the carbon cycles, with contamination such as the ‘big brown cloud’ (Ramanathan 2002) and with changed water levels, e.g. agriculture, hydro damns and loss of permafrost and glaciers. These impacts are found throughout Alaska and the Arctic (ACIA 2004).

1.4 Sympatric Connections of Predators in Alaska

Many of the mega predators of Alaska occur in identical or overlapping ranges. Among these predators, canidae like wolves, coyotes (*Canis latrans*; *Taxonomic Serial Number* [TSN]: 180599), foxes (e.g. *Vulpes vulpes* TSN 180604) or ursidae are closely related. This predator composition may be the result of sympatric speciation (Poulton 1904). Many of the niches are virtually shared: Bears and Wolves occur often together and are known to differentiate spatially or temporally in their use of a pulsed prey, causing minimized competition (Garneau et al. 2007). If resources are limited, a species of the predator community may be displaced by another, for example red foxes by coyotes (Randa et al. 2009) and arctic fox by red fox (Hersteinsson and MacDonald 1992): a phenomenon now widely seen in Norway, Alaska, Canada and Russia due to climate change (McCarty 2001).

As a result, the community of predators can also be seen as a sympatric-developed population and community with different speciation's. A good example of sympatric development is found in the instance of a coyote population which expanded after the extirpation of wolves in Yellowstone National Park. The coyotes assumed many of the ecological characteristics and functions of wolves, including pack formation and predation on large ungulates; however they were not able to substitute the wolves completely (Crabtree and Sheldon 1999). The vacant niches may also be occupied by other animals which have been introduced or have migrated to the area of their own accord (Simberloff 1981).

Such a case is assumed for Alaska, but is not well documented or studied, and deals with the expansion and invasion of coyotes, and to some extent wolves, on Kenai- Penisular (Huettmann pers com.).

1.5 Relevant Summarized Perspectives for this Study

1.5.1 The Mega Predators as an Ecosystem Unit "Mega Predator"

An ecosystem consists of all the living components as well as nonliving physical components of the environment with whom the organisms interact. The entire array of organisms inhabiting a particular ecosystem is defined as a community (Campbell 2009). Some newer studies describe parts of the ecosystem e.g. grassland as a community (Grime et al. 2008), while other concepts prefer to describe the community more on a regional level, characterized by evolutionary taxonomy and biogeography (Ricklefs 2008).

Among the mega predator species of Alaska, multiple and similar characteristics can be found. The term "predator" determines the animals as second or third consumer and defines the biological interaction of obtaining food by killing prey (Begon 1996).

The food web of the mega predators shows high complexity. Connection of wolves and bears and wolverines (Magoun 1985) are only an example on the length of the food chain. As part of the Alaskan food chain, Polar bears are on the fifth trophic level (Derocher and Stirling 1990; Hobson and Welch 1992) and are directly connected to the arctic fox in the food web (Stirling 1988). Food chain length of the predator community in Alaska is still rather high compared to other apex predator ecosystems of the world (Cohen 1979; May 1979).

1.5.2 The Predator Community in Alaska

The mega predator community in Alaska is globally unique (see species list at www.iucnredlist.org and Feldhammer et al. 2003). The amount of predator species is very high and in its base-composition nearly untouched even (SEDAC 2009). It can only exist because of the prey base that sustains it and has become so established because for thousands of years this base was unaltered. This community is important to investigate not only for conservation and ethical purposes, but also in order to find thresholds in the underlying ecological variables that determine the predator community, e.g. when compared with other regions. These identified habitat characteristics may lead to a better understanding of the ecosystem, the predator community and the forces which drive them. Furthermore, it is important to realize what will happen to this community as a consequence of the climate change, and which is more readily apparent already in northern regions.

Although the exact effects might be difficult to understand, grasping the major trends in a pro-active fashion would be very useful so that harm can be avoided or at least minimized.

A similar predator community on approximately the same latitude can only be found in Northeast Russia. This community includes the Eurasian lynx (*Lynx lynx*), wolf (*Canis lupus TSN:* 180596), polar fox, red fox, polar bear (*Ursus maritimus TSN: 180542*), European badger (*Meles meles*), and asian badger (*Meles leucurus*), while in the Southern parts of this community corsac fox (*Vulpes corsa*) are also prevalent (IUCN 2010). Further east, for instance in the Khabarovsk region, the diversity of the predators rises. The predators are e.g. bears *(Ursus arctos beringianus*, *Ursus thibetanus*), wolverine (*Gulo gulo* TSN 180551), tiger (*Panthera tigris altaica*), and leopard (*Panthera pardus orientalis*). Such predators are becoming absent when moving westward towards Europe.

Considering the native mammalian carnivores in the Rocky Mountains including grizzly bear (Ursus arctos TSN 180543), black bear (*Ursus americanus* TSN 180544), gray wolf, coyote, red fox , puma (*Puma concolor*), bobcat (*Lynx rufus*), lynx (*Lynx canadensis* TSN 180585), Wolverine, otter (*Lutra Canadensis*), fisher (*Martes pennant*), marten (*Martes americana* TSN 180559), and golden eagle (*Aquila chrysaetos* TSN 175407) this community is also comparable, but far more modified by human presence (SEDAC 2010). Similar compositions can be found in parts of Northwest Russia, Amazonia, central Africa, parts of Asia, and in some of the Oceans. However, central Europe has virtually lost these species and even more marginal zones like the Alps and regions in Scotland and Scandinavia might have lost by now the general ability to host such a diverse number of species already (Swenson et al. 2000; Breitenmoser 1998). The human alteration of Europe is underlined by a west to east increase of the gradient in animal diversity (Tomialojc 2000)

1.5.3 Assumptions for the Model

For this study, the mega predator community which was analyzed consisted of: coyote, wolf, fox, arctic fox, black bear, brown bear, polar bear, wolverine, marten, lynx, golden eagle, with the above being defined as an Ecosystem Unit “Mega Predator”. The underlying habitat and climate factors influencing the Ecosystem Unit are also studied.

In order to define the Ecosystem Unit, the distribution of each animal of the mega predators of Alaska was taken and congregated into one map layer. This has the potential to form the basis of a study of the habitat requirements and the possible alterations of the habitat due to upcoming climate and other change. The Ecosystem Unit “Mega Predator” thus contains only the occurrence and quantity of animals, with the individual species being dissolved.

1.6 Predator Conservation Management

The science of predators is a tool often used for conservation management and predators are often the focal species for conservation planners (Majka 2007). In this study, possible protected areas for the mega predator community in Alaska were examined. In the following part, theories are presented that describe predators as a main object for conservation.

Table2: Three theories that include predators in conservation planning

Theory	**Definition**	**Essential Studies**
Umbrella species	Umbrella species can be used to help select the locations of potential reserves, find the minimum size of these conservation areas or reserves, and to determine the composition, structure and processes of ecosystems (Roberge et al 2004)	Lindeman 1942

Management indicator	“Management indicator species” means that a single species is assumed to represent the status of all other species associated with the same habitat (Landres et al. 1988).	Hall and Grinnell 1919
Focal Species	Large carnivores are useful focal species for conservation planning (WWF 2010, Noss et al. 1996)	Majka 2007

1.6.1 Umbrella species

Most large predators need extended areas of relatively wild habitat and/or a food base (Noss et al. 1996). Therefore, mega predators, for example gray wolves and bears, are often considered umbrella species. An umbrella species is a species with large area requirements. When these vast territories are protected, this offers protection to other species that share the same habitat. This way of protecting an ecosystem does not include all necessary species, following the theory that the area of habitat that is required to support viable populations will also protect sufficient habitat of species with smaller area requirements (Noss et al. 1996). However a predator is usually easier to represent as a “Conservation goal” in the political field and among landscape managers when compared to, say, a fungus.

1.6.2 Management indicator

The “Management indicator species” means that a single species is assumed to represent the status of all other species associated with the same habitat. This approach has already been discredited for conservation because one species cannot cover the habitat requirements of all living animals in the same habitat (Landres et al. 1988; Noss 1990). However predators are accepted as important parts and indicators of the codependency of an ecosystem.

1.6.3 Focal Species

Large carnivores are useful focal species for conservation planning. When planning conservation measures it seems to be easier to deal with vertebrate species requirements and their habitats than actually trying to protect ecosystems and their processes (Noss et al. 1996). Large predators seem to have greater influence on ecosystems, and their presence should be considered as an important protection goal in the conservation of wilderness.

1.7 Science-based Conservation Management of the Mega Predator Community

Ecosystems are complex systems and cannot be managed easily. They require valid scientific studies to feed into valid decisions. Such a science must be explicit in time as well as space, include social factors and be pro-active to assure the best possible decisions can be made. Mostly the management identifies vegetation or habitat types as management units. These units can be mapped and evaluated in terms of current area and extent changes. In addition, historical conditions can be identified and the changes within a habitat can be traced (Crumpacker et al. 1988; Scott et al. 1993; Noss et al. 1995). As a matter of fact, the protection of large animals alone for ethical reasons can be as inspiring for conservation staff as it is for the general public (Noss et al.1996).

As a second issue, this study intends to identify areas which are suitable for the predators nowadays and in the future, and also deals with the question: which parts of these areas should be considered for conservation purposes.

1.8 The Mega Predator Community

1.8.1 Canidae

1.8.1.1 Coyote (*Canis latrans*)

Picture 1: *Canis latrans* (Source: R. Richardson 2008)

1.8.1.1.1 Distribution

Coyotes are distributed through the range 10°N (Costa Rica) and 70°N (Northern Alaska) latitude, this includes the whole mainland of Alaska (Gese and Bekoff 2003). With their high ability to adapt to human transformed landscapes they can now also be found in large cities (Grinder and Krausman 1998; Finkel 1999).

Figure 1 Distribution of Coyote (*Canis latrans*) in source Alaska from Patterson et al 2007

1.8.1.1.2 Ecology

Coyotes occupy a variety of habitats, including grassland, deserts and mountains. They do not compete well with larger carnivores and may be killed by them and thus avoid areas and habitats occupied by these species. Studies have documented direct and indirect competition with larger carnivores such as wolves (Fuller and Keith 1981; Crabtree et al. 1981; Crabtree and Sheldon 1999).and cougars (Murphy 1998).

Interspecific killing commonly occurs in carnivore communities (Peterson 1955; Palomeres and Caro 1999). In Yellowstone National Park wolves caused a decline of coyotes of about 33%. An increase of 32% for coyote population was measured with no wolves around (Crabtree and Sheldon 1999; Gese 1996a; 1996b). Great annual variation in population is caused by the changes in food abundance, mainly in cyclic lagomorphs populations (O´Donguhue et al. 1997). Under certain environmental conditions, direct predation and competition for food and space with wolves may limit coyote numbers in some areas (Peterson 1995; Arjon and Pletscher 1999).

Coyotes are competing with red foxes and may not tolerate them in some areas (Voigt and Earle 1983; Sargeant and Allen 1989). Red foxes are more tolerated if food is abundant (Gese et al. 1996d). Many of the small canids, like kit foxes and gray foxes, are killed by coyotes. They control smaller predators like foxes and feral cats. If coyotes are absent, the abundance of the smaller predators increases and which may affect the avifauna negatively. Therefore coyotes were considered a keystone predator in Western Texas in the role of shaping fauna community structure (Bryant 1999).

Coyotes have a land- tenure system of exclusive territories (Camenzin 1978; Bowen 1981, 1982; Knowlton and Gese 1995). Within the packs, they show a dominance hierarchy similar to that of wolves (Camenzin 1978; Gese et al 1996a). Transient or nomadic coyotes also exist across the landscape (Gese et al. 1988a). Coyotes live as long as 18 years in captivity (Young 1951), life expectancy is considerably shorter in nature. Coyotes are active throughout the day, but tend to be more active in crepuscular times (Woodruff and Keller 1982; Gese et al. 1989b).

1.8.1.1.3 Home Range and Density

Density of coyotes varies geographically and seasonally in response to changing food resources. Most regulating factors are occurrence of rabbits, rodents, and ungulates (Gier 1968; O`Donoghue et al. 1997). Also, their home range size varies geographically and seasonally (Gipson and Sealander 1972; Laundré and Keller 1984).

1.8.1.1.4 Feeding Habits

Coyotes are opportunistic, generalist predators and feed on a variety of food items in relation to changes in availability (Windberg and Mitchell 1990), amongst others fruits, birds, rabbits, insects, but also large native and domestic ungulates (Gipson 1974; Gese and Grothe 1995). The reproductive status can influence their feeding habits. Coyotes that are provisioning pups may switch to larger, more energetically “profitable” prey (Harrison and Harrison 1984; Bromley 2000). Those which occur in suburban areas are adapted to human remains and eat dog food as well as other human leftovers (McClure et al. 1995).

1.8.1.2 Arctic Fox *(Alopex lagopus)*

Picture 2: Arctic fox (Source: Canadian Museum of Nature 2010)

1.8.1.2.1 Distribution

The Arctic Fox *(Alopex lagopus)* has a circumpolar distribution in North America, Europe, and Asia. The prime habitats are tundra, pack ice, and occasionally boreal forests (Garrott and Eberhardt 1987).

Figure 2: Distribution map of Arctic Fox *(Alopex lagopodus)* in Alaska from Patterson et al. 2007

1.8.1.2.2 Ecology

Foxes are usually not the top terrestrial predators in the ecosystems in which they appear. Larger predators like bears and wolves almost co-occur with foxes. Therefore the foxes are considered to be “meso-predators”.

1.8.1.2.3 Habitat

Arctic Foxes occur primarily in arctic habitats. They can also be seen near urban regions were they are attracted by anthropogenic food sources (Eberhardt 1976).

Their habitat can be divided in four groups: coastal, inland, alpine and marine (Garrot and Eberhardt 1987).The coastal habitat is associated with islands. In this habitat animals feed also on carrion near beaches and intertidal zones. Nesting seabirds are the main diet, while in inland habitat the primary food sources are rodents and ptarmigans *(Labopus spp.).* This habitat is characterized by the lack of trees and a prevalence of low-growing shrubs, herbs, and grasses. Marine habitat is the pack ice in the Arctic Ocean. Alpine habitat, which does not really occur in America’s Artic Fox habitat, is characterized by alpine-style tundra

1.8.1.2.4 Home Range

Foxes occupy particular ranges during spring and summer while bearing and raising cubs. The home range size of Arctic Foxes depends on the abundance of its prey which they follow. They move seawards in fall and early winter, and landwards in late winter and early spring. In order to find more food, foxes move out to open sea after leaving the land based home ranges. The movements in this period can be extensive and go up to 24km per day. Foxes have been observed 800 km away from solid land (Wrigley and Hatch 1976).

1.8.1.2.5 Feeding Habits

In the tundra region, Arctic Foxes rely on lemmings as a food source (Angerbjörn et al. 1999). Other rodents can be important dietary constituents where they are abundant. Furthermore other food like birds, eggs, arctic ground squirrels, arctic hares, insects, snails, fish, berries and carrion of caribou is also taken by the arctic fox (Eberhardt 1977; Garrot et al. 1983b). Marine mammals appear to be primary foods on pack ice in winter. Arctic Foxes scavenge seal carcasses left by Polar Bears (Elton 1949) and may even routinely follow Polar Bears.

As a consequence of the human settlement, Arctic Foxes also scavenge on refuse in human-occupied areas. They may become quite dependent on such food when natural foods are scarce (Garrot et al. 1983b). Arctic Foxes may kill and cannibalize adult animals and cubs when food availability is low (Chesemore 1975).

1.8.1.2.6 Human Impact and Conservation Status

Arctic foxes were and are still important as an income in arctic regions, although the importance of fur as an income has strongly declined (Chesemore 1975). Arctic Fox populations appear secure throughout their range in North America. But they now are considered to be rare in Finland, Sweden, Norway, and some parts of Russia (Ginsberg and MacDonald 1990).

1.8.1.3 Red Fox *(Vulpes Vulpes)*

Picture 3: *Vulpes vulpes* (Source: US National Park Service 2004)

1.8.1.3.1 Distribution

The Red Fox is the most widely distributed of the North American fox species (Hall 1981). It has the most extensive natural distribution of any terrestrial mammal except humans (Nowak and Paradiso 1983), although its origin in North America has been disputed. It is suggested by evidences that the Red Fox was native to North American boreal and mixed hardwood habitats north of 40-45° (Kamler and Ballard 2002). Red Foxes from England were introduced into the southeastern United States and New England region in the 1700s for hunting (Churcher 1959; Gilmore 1946).

Several factors including interspecific competition, adaptability, habitat modification, and human influence determine the current distribution of the Red Fox (Sargeant 1982). In the southeastern United States the Red Fox population is increasing caused by the reduction of Gray Wolf (*Canis lupus*) and Red Wolf (*Canis rufus*) as well as the clearing of forests (Churcher 1959; Godin 1977). Furthermore, foxes colonized prairie regions following the elimination of wolves and the significant reduction of coyotes (*Canis latrans*) by humans.

Figure 3: Distribution of Red Fox *(Vulpes vulpes)* in Alaska from Patterson et al. 2007

1.8.1.3.2 Habitat

Red foxes have an immense ecological plasticity; they inhabit forests, prairie, arctic tundra, deciduous landscapes, and urban environments. Heterogeneous and fragmented landscapes characterized by high habitat diversity and interspersion are preferred (Catling and Burt 1995). Such areas include landscapes where woodlots are interspersed with cropland and pastures (Ables 1975; Catling and Burt 1995).

The food availability may be the most important factor for choosing a habitat (Halpin and Bissonette 1988; Phillips and Catling 1991). Habitats with a higher diversity may provide more food. Foxes are well adapted to inhabit urban regions (Lewis et al. 1993). Although red foxes are usually associated with more mesic environments, they may not require open water, but can obtain sufficient water from food (Sargeant 1978).

1.8.1.3.3 Feeding habits and home ranges

The home range size of foxes varies between environments habituated and the variation among those environments. Home ranges in tundra regions seem to be larger due to lower food abundance (Jones and Theberge 1982).

Foxes are primary, secondary, and tertiary consumers and also scavengers. They are mainly carnivorous animals by consuming a diversity of prey species. The red fox is frugivorous and consumes a variety of wild fruits (Sargeant et al. 1993). Although rodents and leporids are the commonly primary diet, red foxes feed on a diversity of items, depending on the location for example birds as well as reptiles, amphibians, and a variety of insects (MacDonald 1980a). The most frequently consumed rodents include voles, woodchucks, pocket gophers, and deer mice, whereas leprids include cottontails, black-tailed jackrabbits, and snowshoe hares (Scott and Klimstra 1955). Especially in autumn, red foxes feed on fruits that can constitute up to 100% of the diet. Moreover, human refusals provide a good food source if abundant (Doncaster et al. 1990; Cypher and Yahner 1996)

1.8.1.3.4 Human Impact and Conservation Status

The population status of the red fox is relatively secure in most regions (Feldhamer et al. 2003). Rabies outbreaks affect them though. Like other predators, red foxes are subject to population fluctuations which are a function of food-mediated variation in reproductive success (Lindström 1980).The subspecies *Vulpes vulpes necator* was listed as “threatened” in California in 1980 (Feldhamer et al. 2003).

1.8.1.3.5 Interspecific interactions of foxes

Red foxes interact with several other fox species because of their wide distribution. In the arctic region they compete with the Arctic fox. Red foxes are more aggressive and Arctic foxes generally avoid them (Rudzinski et al. 1982; Schamel and Tracy 1986).

Wolves have been reported to occasionally kill foxes (Mech 1966; Chesemore 1975; Laviviere and Pasitschiak-Arts 1996). However, this is neither common, nor does it affect fox population dynamics much. In general, red and arctic foxes scavenge on the carcasses left by the wolves (Hersteinsson et al. 1989).

1.8.1.4 Gray Wolf *(Canis lupus)*

Picture 4: *Canis lupus* (Source: C. Muiden 2006)

1.8.1.4.1 Distribution

The gray wolf (*Canis lupus*) has one of the most extensive distributional ranges of any mammal (Nowak 1983). The subspecies coastal wolf (*Canis lupus occidentalis*) is distributed throughout Alaska and its islands (Paquet 2003).

Figure 4: Distribution map of Gray Wolf (*Canis lupus*) in Alaska from Patterson et al. 2007

1.8.1.4.2 Habitat

The gray wolf can be regarded as a habitat generalist. Wolves move long distances and require large home ranges. They occur in all major habitats including deserts, grasslands, forests, and arctic tundra (Mech 1970; Fuller et al. 1992; Mladenoff et al. 1995). Like for other predators the habitat use of wolves is strongly influenced by the availability and abundance of prey (Weaver 1994; Paquet et al.1996). The foraging habitat and prey selection is adapted to local conditions. Moreover, the local populations are adapted to physiography and den-site use (Mladenoff and Sickley 1998; Callaghan 2002).

The occurrence of wolves is also strongly dependent on snow condition (Fuller 1991a; Paquet et al. 1996), absence or low occurrence of livestock (Bangs and Fritts 1996), road density (Fuller 1989; Thurber et al. 1994; Mladenoff et al. 1995), human presence and topography (Paquet et al.1996; Callaghan 2002). Wolves are not longer present in areas with dense human population; however they are still present in Alaska (Mladenoff and Sickley 1998; Haight et al. 1998; Callaghan 2002).

1.8.1.4.3 Home Range

The home range size depends on the type and density of prey, and varies from area to area. Some packs of wolves occupy stable home ranges. These home ranges are exclusive territories (Mech 1970, Peterson et al. 1984; Messier 1985a; 1985b). Wolves show territorial behavior, but home ranges are dynamic and related to the availability of food (Carbyn 1981; 1982b, Mech et al. 1995a). Territory and home range seem to be more correlated with pack size than with prey density (Peterson et al 1984; Messier 1985b).

1.8.1.4.4 Hunting and Diet

Wolves are specialized on vulnerable individuals of large prey like ungulates. The important ungulate species of North America are deer (*Cervus elaphus*), moose (Ballard and von Ballenberghe 1997) caribou (Ballard et al. 1997) elk (Kunkel et al. 1999), muskoxen (Mech 1999a) mountain goat (Festa-Bianchet et al. 1994) and mountain sheep (Paquet et al. 1996).

If ungulates are not available, they are able to supplement their diet by using different prey and habitats (Mech 1991; Weaver et al. 1996), beavers, hares (*Lepus americanus),* and other smaller mammals are taken as food. Moreover, wolves complement their diet with scavenging (Forbes and Theberge 1992) and some wolf packs in Alaska and Western Canada have been observed to feed on salmon (Woodford 2010).

1.8.1.4.5 Human Impact and Conservation Status

The interaction of wolves and humans is affected by multiple factors. Trapping plays a role in Alaska. The reaction of the wolves on humans depends on their use of the landscape and their response to people (Carrol et al. 2001; Duke et al. 2001). The history of disturbance seems to be critical for wolves, since they learn through social transmission. The intensity of response to humans seems also to vary with social context and environmental conditions (Curatolo and Murphy 1986).

1.8.2 Ursidae

1.8.2.1 Black bear *(Ursus americanus)*

Picture 5: *Ursus americanus* (Source: K. Thomas 2008)

1.8.2.1.1 Distribution

The Black bear is the most distributed of the three bears in North America. Its distribution covers the forested areas of North America and also Mexico. Distribution covers today 62 % of the historical range. The distribution is restricted to the less settled regions of the forested areas. In North America status and density vary considerably within the existing range (Pelton and Vanmanen 1994).

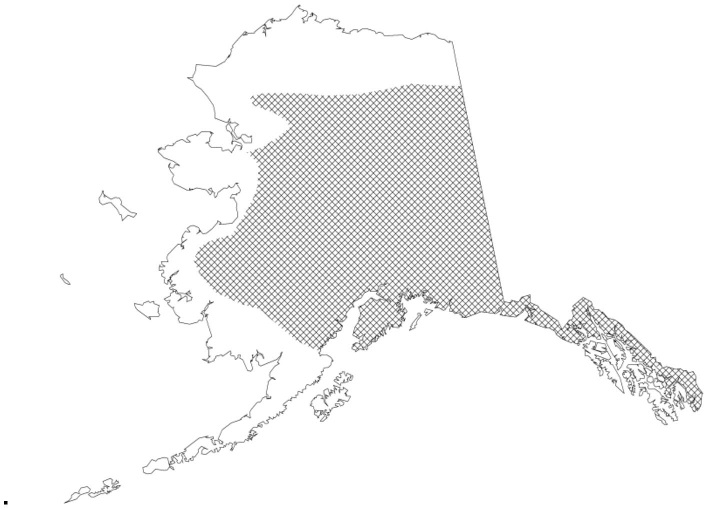


Figure 5: Distribution Map of Black Bear (*Ursus americanus*) in Alaska from Patterson et al. 2007

1.8.2.1.2 Habitat

Black bears are difficult to census due to their generally sparse numbers, shy and secretive nature and the inaccessible habitat (Pelton 2003). If not overharvested, the population of black bears stay stable when close to urban regions. However, if no refuge is available, the local population succumbs to intolerance of humans.

The primary habitat is characterized by relatively inaccessible terrain, thick understory vegetation and abundant sources of food in the form of shrub or trees, soft or hard tree mast. If the bears are forced to leave relatively protected areas in order to forage on less protected sites, the mortality increases and which results in a declining population.

1.8.2.1.3 Home range and movement

Size and shape of black bears´ home ranges depend on the capability of an area to provide the animal´s annual needs (Hamilton 1978; Garshelis et al. 1983). Home ranges change dramatically if food resources vary. They also depend on such factors as sex, age, season, and population density. It is reported that individuals have moved more than 160 km to take advantage of isolated pockets of available food (Rogers 1977).

Concentration of soft mast (Piekielek and Burton 1975), hard mast (Sauer et al. 1969), or artificial food sources (Rogers 1977) provide, at least temporarily, the stimulus for extensive movements and consequent range expansion. Home range size of males is three to eight times larger than that of adult females (Pelton 2003)

1.8.2.1.4 Feeding Habits

Black bears are no active predators and feed only on vertebrates if the opportunity arises, however mostly in the form of carrion. Generally only a small portion of their diet consists of animal matter, and then primarily in the form of colonial insects and beetles. Black bears consume primarily grasses and forbs in spring, soft mast in the form of shrub and tree-borne fruits in summer, and a mixture of hard and soft mast in fall. Their diet consists predominantly of food high in carbohydrates, protein and fat. When feeding on aliment rich in protein, a significant weight gain and an enhanced fecundity can occurr. Moreover they like food and garbage of humans (McLean and Pelton 1990).

1.8.2.1.5 Behavior

The black bear is normally a solitary animal; however, they are social animals and interact with each other. Exceptions are female groups, with an adult female and cubs. Other groups are breeding pairs and congregations at feeding sites.

Commonly the black bear is crepuscular, feeding activities and breeding can delay the activities seasonally (Gershelis and Pelton 1980). The activities are depressed when above 25°C or below freezing. Most activity is shown after the passage of a low pressure weather front (Garshelis and Pelton 1980). Black bears exhibit a high level of curiosity and exploratory behavior, they also possess a high level of intelligence (Bacon and Burghardt 1976; Pruitt 1976). Generally they are shy and secretive towards humans, but considering the actual physical contact, black bears are less aggressive than the other North American *Ursidae* (Tate and Pelton 1980).

1.8.2.1.6 Human Impact and Conservation Status

The status of the black bear ranges from a pest to threatened in North America. In regions with large expanses of forested areas like Alaska and relatively sparse human population, the bear population is stable. The species has a tendency to adapt to the presence of humans if it is allowed. Around 40.000 black bears are harvested each year in North America (Pelton et al. 1999). In 2007, 3,250 bears were killed in Alaska (ADF&G 2010). The mortality of the black bear population is in many cases human-related and includes hunting, poaching, road kills and depredation control. Other factors are less well known and studied.

1.8.2.2 Polar Bear (*Ursus maritimus*)

Picture 6: *Ursus maritimus* (Source: USGS 2010)

1.8.2.2.1 Distribution

Polar bears are distributed exclusively in the circumpolar Arctic. Their range is limited to regions with sea ice cover for most of the year (Amstrup and Gardner 1994). Polar bears are most abundant near shore in shallow-water areas and in other areas with currents and upwellings where ice cover is not becoming too solidified in winter (Stirling and Lunn 1997; Amstrup et al. 2000). Animal distribution changes in most of the areas due to the changes and extensions of the ice. In areas were the ice melts completely, polar bears stay ashore during this period (Stirling 1988).

Figure 6: Distribution of the Polar Bear in terrestrial Alaska (Map derived from WWF & PBSG 2009; The Arctic Sounder 2010)

1.8.2.2.2 Habitat

The main habitat of the polar bear is the annual sea ice covering the waters over the continental shelf and the Arctic inter-island archipelagos (Stirling 1988, Derocher et al. 2004). Because the Polar bear spends many months of the year at sea, it is classified as a marine mammal (Stirling 1988). This feeding habitat is known as the “Arctic ring of life” with high biological productivity in comparison to the deep waters of the Arctic (Stirling 1988, Derocher et al. 2004). Polar bears follow the migrating seals during the year. Seals have to change their position due to weather changes throughout the year, and the change of ice content in the sea.

1.8.2.2.3 Feeding Habits

The polar bear is the apical predator of the arctic marine ecosystem. Polar bears are more predatory than other bears. The main prey are ringed seals (*Phoca hispida)* and to a lesser extend, bearded seals (*Eignathus barbatus*). Polar bears also kill larger animals like walruses (*Odobenus rosmarus*) and belugas (*Delphinapterus leucas)*. Observations confirm that polar bears feed on a variety of other wild foods, including muskox, reindeer, birds, eggs, rodents, shellfish, crabs, and also other polar bears. However, none of these are a significant part of their diet (Clarkson and Stirling 1994). Polar bears are poorly equipped to digest plants, and except for the fruiting bodies, plants will contribute little to their energy balance (Bunnell and Hamilton 1983). If available, they also take human refuse as supplemental food (Lunn and Stirling 1985).

1.8.2.2.4 Interspecific Interactions

Several animal species, particularly arctic foxes, Snowy Owl (*Bubo scandiacus*)and glaucous gulls (*Larus hyperboreus*) routinely scavenge polar bear kills (Stirling 1988).

Ringed seals have been a principal food of polar bears for a significant portion of their co-evolutionary history (Stirling 1977). The relationship between ringed seals and polar bears is so close that the abundance of ringed seals in some areas appears to regulate the density of polar bears, while polar bear predation in turn regulates density and reproductive success of ringed seals. Although wolves are rarely encountered, there are at least two records of wolf packs killing polar bear cubs (Richardson and Andriashek 2007).

1.8.2.2.5 Human Impact and Conservation Status

Key danger comes from global warming resulting in habitat loss and as a consequence in malnutrition or starvation. Main hunting grounds are the platforms of sea ice.

Rising temperatures cause the sea ice to melt earlier in the year, driving the bears to solid land before they could build sufficient fat reserves to survive the period of scarce food in late summer and early fall (Regeher et al 2007). On 14 May 2008 the U.S. Department of the Interior listed the polar bear as a threatened species under the Endangered Species Act (ESA, but with a special reference to the Marine Mammals Act), citing the melting of Arctic sea ice as the primary threat to the Polar bear (Wenzel 2004).

1.8.2.3 Grizzly Bear (*Ursus Arctos*)

Picture 7: Brown bears (Source: Chris Servheen, U.S. Fish and Wildlife Service)

1.8.2.3.1 Global Distribution

The brown bear was widely distributed throughout the North American continent before the European settlement (Schneider 1977; Craighead and Mitchell 1982). With the beginning of the European settlement, the range of the Grizzly bear was drastically reduced (Mattson et al. 1995). During just a 100- year period, Grizzlies were extirpated from 98% of the historical range in the lower 48 States (Mattson et al. 1995). In contrast, Alaska (coincidentially carrying a very low human population) stil has the largest population of brown bears of any state in North America (Miller and Schoen 1999). This population is considered overall stable and has probably remained relatively unchanged since the mid 1700 (Miller 1993). However, the Kenai Peninsula population of brown bears is declared as “Species of Special Concern” since 1998 (ADF&G 2010), and many local issues exist.

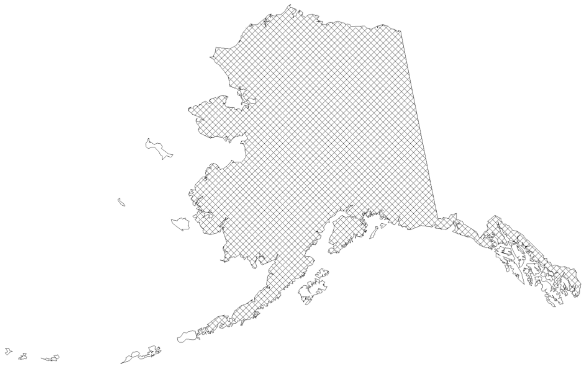


Figure 7: Distribution Map of Grizzly Bear (*Ursus arctus*) in Alaska from Patterson et al. 2007

1.8.2.3.2 Ecology

Brown bears have relatively broad environmental limits. They occupy a variety of habitats throughout North America (Craighead 1998). The omnivorous general lifestyle and intelligence help the bears to adapt and use vastly different landscapes. The active landscape season for brown bears is compressed to 5-7 months. During this period the bears must gain sufficient weight to supply their energetic needs for the next denning cycle. In Alaska bears use a variety of habitats including meadows, coastal sedge, old growth forests and south-facing avalanche slopes. Bears use alpine and subalpine meadows in early summer and during midsummer. Through early fall the bears move to coastal habitats to feed on spawning salmon (LeFranc et al. 1987, Schoen et al.1994). This movement is not shown by all bears, some do not visit salmon streams but remain in higher habitats (Schoen et al.1986). In late fall bears alternately fish or use berry-producing habitats (Le Franc et al. 1987; Schoen et al . 1994). In consistently similar appearing habitats, the habitat selection of individual bears differs (Mace and Waller 1997).

Although in Alaska and northern Canada habitats occupied by the Grizzly are not significantly altered by humans, most of the productive lands is dominated by humans in the contiguous 48 states and some portions of southern Canada. This drives the grizzly bear population in remote and rugged mountain area habitats. These habitats may not represent what historically were the best habitats (Craighead and Mitchell 1982; Gibeau 1998). As a result the human settlement alteration of landscape is a limiting factor for habitat choices of bears (Feldhammer et al. 2003).

1.8.2.3.3 Home Range

Movement is influenced by many factors like key food items, breeding, reproductive and individual status, and it can be extremely variable within and among populations of brown bears. Ranges of adult male bears are typically several times larger than those observed for adult females with cubs (Blanchard and Knight 1991). Due to the lack of mobility of the cubs home range of females and cubs are the smallest (Blanchard and Knight 1991). Late summer and fall ranges are more variable. They coincide with the hyperphagic period of intense foraging. Foraging opportunities are temporally and spatially unpredictable (Nelson et al. 1983b)

1.8.2.3.4 Feeding Habits

Brown bears are omnivorous opportunistic feeders. They find their food in multiple taxa, from insects to vertebrates and fungi to angiosperms. They have adaptations for a herbivory diet, including expansion of molar chewing surfaces and longer claws for digging. Their unspecialized digestive system is capable of digesting protein with efficiency equal to that of carnivores (Bunnel and Hamilton 1983).

During spring and early summer Grizzlies consume herbaceous vegetation in many ecosystems. In areas with abundant meat or fish resources, grasses, forbs, and sedges are preferred diet in spring and early summer (LeFranc et al. 1987). Male bears need more protein because of their body size, consequently they are more carnivorous than females (Jacoby et al. 1999): Apart from the coastal environments with abandoned fish prey, meat is less available and more difficult to obtain for interior brown bear populations. Instead of fish, ungulates as prey and carrion are used seasonally.

In contrast to coastal environments with abandon fish as protein supply, meat is much less available and more difficult to obtain for interior brown bear populations, Use of ungulates as prey and carrion is common and seasonally important. Winter- starved ungulates including caribou, moose *(Alces alces)*, *Cervus elaphus* and bison (*Bison bison*) are a welcome diet.

Bears can also be effective predators, in early summer neonates are actively hunted. Moose, caribou and elk calves are seasonally important foods (Green et al. 1997; Mattson 1997; Gau 1998).

Were bear territory crosses human settlement, anthropogenic foods (i.e. garbage, livestock feed, pet food, bird seed, human foods, garden crops, honey) are used by brown bears (Herrero 1985). Food is often found in garbage dumps. This food can be a source of highly nutritious supply for the brown bears (Meagher and Phillips 1983), and can become a big driver for bear behaviour.

1.8.2.3.5 Intraspecific killing

Grizzly bears are known to kill one another (McLellan1994), cubs of the year are the greatest victims, but adult females are also killed. Bears of all age and sex classes are killed, which indicates that intraspecific killing is not limited to infants (McLellan 1994). It is arguably a big factor for bear populations even.

1.8.2.3.6 Human Impact and Conservation status

In Alaska and all Canadian provinces exists a legal hunting season that includes Grizzly bears. However, south of Canada the species is protected as threatened under the ESA since the populations have been dramatically reduced in abundance and distribution. They are now only left in the Rocky mountains near Canada and in the Yellowstone Ecosystem. Grizzlies occupy only 1-2% of their historical range south of Canada. A truly viable population remains only in Alaska, but even there excessive mortality and habitat destruction in areas such as the Kenai peninsula are leading to decimation. In the same way the population south of Canada, and globally, has been placed at risk (Feldhammer et al. 2003).

1.8.2.4 Wolverine (*Gulo gulo*)

Picture 8: *Gulo Gulo* (Source: Zefram 2006)

1.8.2.4.1 Global Distribution

Wolverines are a circumpolar species, occurring from Scandinavia eastwards across the taiga and forest-tundra zones of Eurasia north of 48° N latitude (Copeland 2003). In North America the current distribution is limited to the mountainous regions of the western United States, north of 37°N latitude, extending north along the Rocky Mountain corridor into and across the boreal- tundra regions of Canada and Alaska (Copeland 2003). Alaska has a viable wolverine population (Copeland 2003) and no documented range reductions. The wolverine extends throughout the state except of islands in the Bering Sea, the Aleutian chain, Kodiak, Prince William Sound, and outer islands in the Alexander Archipelago.

Figure 8: Distribution Map of Wolverine (*Gulo gulo*) in Alaska from Patterson et al. (2007)

1.8.2.4.2 Habitat

Wolverines occur most commonly within boreal forest and taiga communities dominated by black spruce (*Picea mariana*) white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), jack pine (*Pinus baksiana*), tamarack (*Larix laricina*), alpine fir (*A.lasiocarpa*), lodgepole pine (*Pinus contorta*), white birch (*Betula papyrifera*), and balsam poplar (*Populus balsamifera*), as well as in tundra ecosystems. They are most common in regions that receive regular annual snowfall; thus, a connection with climate can be expected. Across the Arctic of northern Alaska and Canada, Wolverines occur from sea level to 2000 m elevation. Their presence at southern latitudes appears restricted to high-elevation habitats. In south-central Alaska, wolverines prefer spruce (*Picea* spp.) habitats during winter (Gardner 1985, Whitman et al. 1986) and rocky areas during summer. Elevational and habitat shifts in wolverine distribution may be related to prey availability (Gardner 1985, Whitman et al 1986; Copeland 1996), human avoidance (Hornocker and Hasch 1981; Copeland 1996) or thermoregulatory needs (Hornocker and Hasch 1981). Wolverine populations are most viable where human activities have done little to alter the landscape (Hatler 1989; Copeland 1996). Whether human presence has forced wolverine into remote regions is not well understood. It is likely, however, that large tracts of pristine habitat may be the only assurance of their continued existence (Copeland 2003). The role of road kills and garbage dumps is not so well understood for wolverines, yet.

Elevational and habitat shifts in wolverine distribution may be related to prey availability (Gardner 1985; Whitman et al. 1986; Copeland 1996) or thermoregulatory needs (Hornocker and Hash 1981). No particular components typify wolverine habitats, and that lack of large scale refugia may be the limiting factor in their distribution (Hatler 1989). Dens in Alaska occur in deep snowdrifts along minor drainages at elevations of 560-625 m (Magoun and Copeland 1998).

1.8.2.4.3 Feeding Habits

Wolverines are opportunistic feeders, with a variety of prey and carrion as contents of their diet (Pasitschniak-Arts and Lariviere 1995). Despite its relatively small size, *Gulo gulo* has been observed hunting and killing full-sized caribou and deer.

In Alaska, wolverines feed on moose and caribou. Near the coast the consumption of walrus was reported. During the summer months the diet consists of berries (Rausch 1959). Often, the wolverine uses carcasses of caribou or moose that were left by wolf packs or bears, furthermore whale, walrus, and seal carcasses. Caribou and arctic ground squirrel carrion are the most important winter food (Magoun 1985). Sleeper (1995) stated that they will also eat eggs, wasp larvae, and berries. In areas with low concentrations of other scavengers, wolverines often cache their food in snow crevices or trees for later consumption (Murray 1987). Hunters and trappers have reported many stories of mountain lion, bears, and wolves retreating from their kills at the approach of wolverine (Jameson and Peters 1988; Caras 1967). It makes the wolverine the strongest dominating mammal predator! However,there have been reports of mountain lion, black bears, and wolves attacking and occasionally killing wolverines, most likely the young and inexperienced (Hornocker and Hash 1981).

1.8.2.4.4 Human Impact and Conservation

Wolverines occur in a generally low density (see Table 1.3). The populations are most viable where human presence has done little to alter the landscape. As a converse argument large tracts of pristine habitat may be the only assurance of continued existence of Wolverines.In Alaska 600-1000 wolverines are harvested annually where most wolverine are probably taken as incidental catches during other fur-trapping activities. (Copeland 2003)

1.8.2.5 Pine marten (*Martes americana*)

Picture 9: *Martes americana* (Source: Tom Walker 2010)

1.8.2.5.1 Distribution

Martes americana has a circumboreal distribution. The species is distributed like the fisher with an extension further north, to the northern limits of trees. In the pacific states the marten occurs as far south as southern Sierra Nevada.

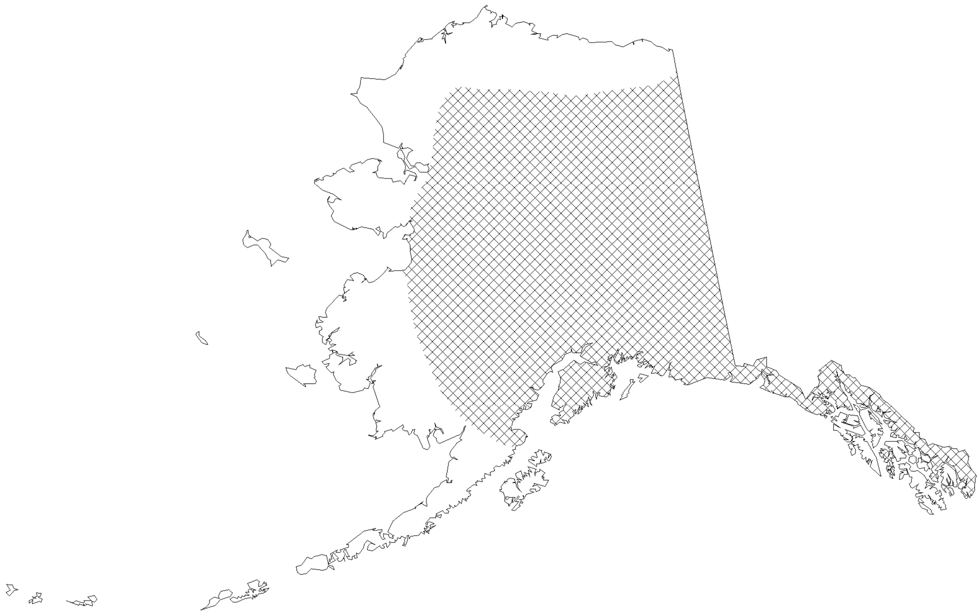


Figure 9: Distribution Map of Marten *(Martes americana)* in Alaska from Patterson et al. 2007

1.8.2.5.2 Habitat

Martens occupy mesic, conifer-dominated forests with abundant physical structure near the ground. They avoid areas lacking overhead cover (Buskirk and Powell 1994). Talus or boulders, subterranean lava tubes, or shrubs provide suitable overhead structure, where in open areas shrubs are sufficient to provide suitable overhead structure.

1.8.2.5.3 Density, Spatial Organization,Home Range and Management

The density is about 1.5 marten/ km², the home range depends on densities of prey (Powell 1994a). Home ranges are smaller when prey density is high (Thompson and Colgan 1987) and are about 8.1 km² for males and 2.3km² females. As a response to fluctuation in prey populations, the marten population changes in an order of magnitude (Powell 1994a). Martens population fluctuate in response to the roughly 10-year cycle in snowshoe hare density, their main prey (Bulmer 1974; 1975).Martens are trapped for their fur in all but a few states and provinces in the United States and Canada (Ruggiero et al. 1994;Ray 2000)

1.8.3 Felidae

1.8.3.1 Lynx Canadensis

Picture 10: *Lynx canadensis* (Source: U.S. FWS 2010)

1.8.3.1.1 Global Distribution

The lynx is distributed throughout the boreal forests of North America from approximately the border of the United States / Canada up north to the treeline (Feldhammer et al. 2003). The lynx was once found in 24 states of the United States. (McKelvey et al. 2000a). Changes in habitat and human persecution probably extirpated the lynx from a large area of the contiguous United States.

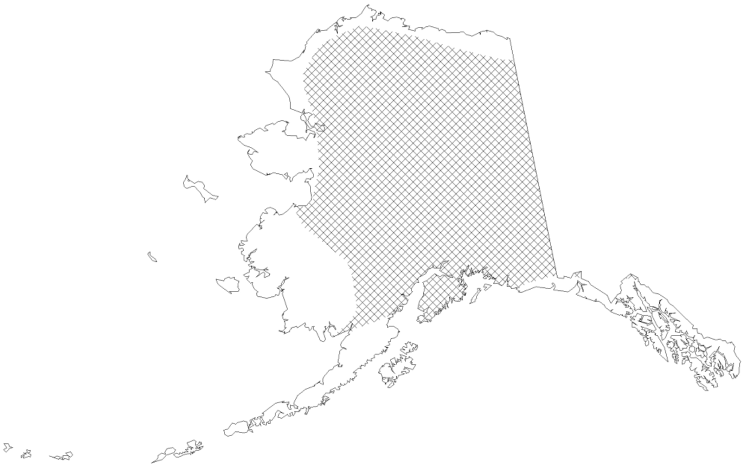


Figure 10: Distribution Map of Lynx *(Lynx canadensis*) in Alaska from Patterson et al. 2007

1.8.3.1.2 Habitat

Lynx generally occur in association with boreal forests. In Alaska on the Kenai Penisula the dominant tree species are white spruce (*Picea glauca*), black spruce (*Picea mariana*), paper birch (*Betula papyrifera*), willow (*Salix spp.)* and quaking aspen (*Populus tremuloides*) (Bailey et al. 1986). To a large extent, snowshoe hare habitat is also lynx habitat. High stem density is directly related to the presence of hares, and thus lynx (Litvaitis et al. 1985). Other important habitat factors are protection from severe weather, availability of resting and denning sites, dense cover for hunting and escape, and lack of disturbance (Bailey 1974). An optimal habitat for lynx provides a suitable forest environment for snowshoe hares and adequate blowdown for den and kitten-rearing sites.

For the lynx itself habitat is an uneven-age forests with relatively open canopy as well as « patchy » areas of disturbed forest. Although strip or block cutting within dense forest provides that ideal habitat mix, extensive clear cuts would not meet lynx habitat requirements (Quinn and Parker 1987). A creation of early-successional forest might not be the best way to provide habitat for lynx prey (Buskirk et al. 2000b).

Lynx appear to avoid large open areas, even though they have abundant potential prey (Koehler and Aubry 1994)

1.8.3.1.3 Home Range

Lynx home range size appears to be linked to prey availability in a non-linear way. The home range size of lynx increases when hare density falls under 0.5-1.0 hare/ha (Mowat et al. 2000). In the northern Yukon, Lynx become nomadic when hare densities decrease to >0.5 hare/ha (Ward and Krebs 1985).

The movement of Lynx depends on snow characteristics and prey density and is highly variable (Nellis and Keith 1968). The average distance between consecutive 24-hr relocations of lynx was 2.7 km up to 5.4 km, depending on the hare density (Ward and Krebs 1985). Lynx is considered nocturnal, the major activity is centred during the period of sunrise and sunset. Lynx are good swimmers, one account records a Lynx swimming two miles across the extremely cold Yukon River (Kobalenko 1997).

1.8.3.1.4 Hunting and diet

Lynx` diet constitutes 35-100 % of snowshoe hare. Hares are influencing significantly the distribution and abundance of lynx. Lynxes increase their numbers with a higher hare density

, as well as their individual kill rates (Keith et al 1977). With low hare density the hunt on other species like red squirrel increases (Staples 1995, Krebs et al. 2001).

1.8.3.1.5 Impact of Humans and Conservation

Lynx occur less likely in areas with year-round human habitation, but they are tolerant of human presence and disturbance (Staples 1995; Mowat et al. 2000). In several ways the lynx is affected by roads and trails. On one hand Lynx use some roads for hunting and travel (Koehler and Aubry 1994). On the other hand roads give access to areas by hunters and trappers and may provide access for competing carnivores (Feldhamer et al. 2003). For translocated individuals traffic becomes a significant cause of death (Brocke et al. 1991). Since 2000 the Lynx is listed as threatened in the contiguous U.S. (U.S.Fish and Wildlife Service 2000). Nonetheless trapping and hunting is still allowed in Alaska (ADF&G 2010b)

1.8.4. Aves

1.8.4.1 The Golden Eagle (*Aquila chrysataeus*)

Picture 11: Golden Eagle (Source: http://www.manausa.com/wp-content/uploads/golden-eagle.jpg)

1.8.4.1.1 Distribution

In North America, the golden eagle occurs in the western half of the continent, from Alaska to central Mexico including some small numbers in eastern Canada and scattered pairs in the eastern United States. Within its holarctic distribution the golden eagle occurs also throughout Eurasia and Northern Africa (Kochert et al. 2002).

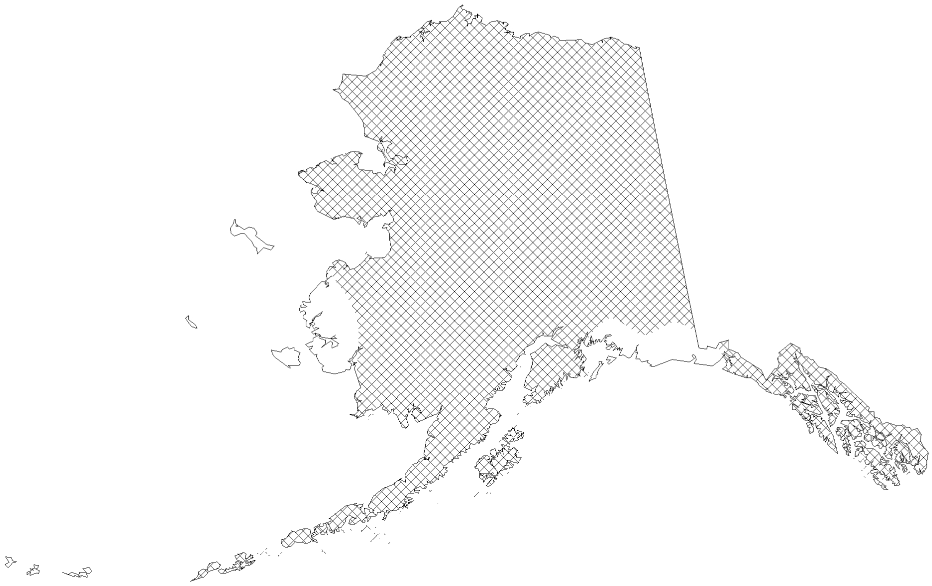


Figure 11: Distribuiton Map of Golden Eagle (*Aquila chrysataeus*) in Alaska from Patterson et al. 2007

1.8.4.1.2 Habitat

The Golden Eagle occurs in appropriate seasons from forested areas to deserts including Death Valley and Salton Sea, during the warmest season he is absent here. The habitat of the Golden Eagle has the need of open areas in any seasons for hunting. In the nesting season the Golden Eagle needs a small distance from shelves on cliffs, large trees, or equivalent nesting possibilities. Many nests are build in niches, in cliffs, escarpments and bluffs, some in steep dirt banks along boreal rivers but not restricted to these. Nesting takes generally place in lower elevations but can go up to 2500 m. (Palmer 1988). Moreover the habitats needs the availability of small to medium sized mammalian pray, in particular ground squirrels and rabbits (Zeiner et al. 1990, Kochert et al. 2002).

Wintering golden eagles in the western Unites States use a variety of open habitats dominated by native vegetation. The eagles tend to avoid urban, agricultural, and forested areas (Craig et al. 1986, Marzluff et al. 1994, Kochert et al. 2002).

1.8.4.1.3 Home Range

The size of the home range varies with the quality of the habitat and the season. In North America the home range is from 20 up to 33 km² of size. The boundaries of the home range is defended against intruders by flight displays (Kochert et al. 2002). It has been seen in Alaska that birds from Nome can cross the ocean and go to Russia virtually daily, back and forth (McIntyre unpublished).

1.8.4.1.4 Ecosystem Roles

The hunting of the golden eagle impacts the local populations of the hunted prey. They also compete with other species for prey and habitat, for example with bald eagles and coyotes or common ravens and other species for territories (Kochert et al. 2002).

1.8.4.1.5 Food Habits

The primary diet consists of small mammals such as rabbits, hares, ground squirrels, prairie dogs and marmots. Additionally the golden eagle feeds also on birds, reptiles and fish. Occasionally it catches seals, ungulates, coyotes and badgers, large flying birds such as geese or cranes. A pair often hunts together by chasing the prey to exhaustion and one go down to kill the prey(Kochert et al. 2002).

1.8.4.1.6 Predation

Wolverines and grizzly bears are the only recorded predators of golden eagle nestlings (Kochert et al. 2002). The role of diseases should not be underestimated though.

1.8.4.1.7 Conservation Status

The golden eagle is federally protected under the Bald Eagle Protection Act of 1962. Recreational activities may disturb breeding, migration and wintering activities. Like most birds, Golden Eagles are likely to abandon nests during incubation if they are disturbed (Terres 1980). Birds have been known to suffer from pesticides, lead shot contamination and poaching. The role of road kill for prey and distribution is likely very big, making them directy affected by humans.

Table 3: Brief overview of the Predator Community of Alaska, Home Range and Conservation Status

Name	**Main Prey (adapted from Feldhamer et al. 2003)**	**Max Min**	**Home range size m (SD)**	**Home range size f (SD)**	**Density**	**Status Red List (IUCN 2010)**	**Status U.S.**
Coyote	Omnivorous		**7.7** km² British Columbia	**17.0** km² British Columbia (Atkinson and Shackleton 1991)	**0.01-0.09**/km² (winter) (O´Donoghue et al. 1997)	Least concern (IUCN 2009)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*
Wolf	Omnivorous	**Min**	Homerange size of **packs 283km²** in the boreal areas(Carbyn 1981)		Alaska **1/50-91 (n/100 km²)** (Peterson et al. 1984)	Least concern (IUCN 2010)	Endangered *(U.S. Fish & Wildlife Service 2010)*
		Max	>2500km² arctic region (Mech 1987,1988)		**1/ 227-667** (n/100 km²) Alaska south central (Ballard et al 1997)		
Arctic Fox	Omnivorous		**1022** km² in Alaska (Anthony 1997)	Home range f **457** (Anthony 1997)Home range of both sexes combined 2080 Eberhardt et al. 1982)	**0,086**/km² (Hersteinsson and Macdonald 1982)	Least concern (IUCN 2010)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*

Name	**Main Prey (adapted from Feldhamer et al. 2003)**	**Max Min**	**Home range size m (SD)**	**Home range size f (SD)**	**Density**	**Status Red List (IUCN 2010)**	**Status U.S.**
Red fox	Omnivorous		**1610** (both sexes) in British Columbia (Jones and Theberge 1982)		**0,1**/km² (Voigt 1987)	Least concern (IUCN 2009)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*
Polar bear	Ringed seals *(Phoca hispida)*		Unclear most mobile of all quadrupeds (Amstrup et al. 2000)			Vulnerable A3c (IUCN 2010)	Threatened *(U.S. Fish & Wildlife Service 2010)*
Grizzly bear	Omnivorous	**Min**	**71** km² Kodiak Island (Feldhammer et al 2003 after Mc loughlin et al 1999)	**185** km² Kodiak Island (Feldhamer et al 2003 after Mc loughlin et al. 1999)	**1,5/100**km² Alaska Range (Miller 1988)	Least concern (IUCN 2009)	Endangared *(U.S. Fish & Wildlife Service 2010)*
		Max	**132** Alaska range (Feldhamer et al 2003 after Mc loughlin et al 1999)	**710**km² Alaska range (Feldhamer et al 2003 after Mc loughlin et al. 1999)	**28/100** km² Kodiak island (Feldhamer et al. 2003 adapted from McLellan1994)		
Black bear	Omnivorous mainly plants		**112.1** km² in Idaho (Amstrup and Beecham 1976)	**48.9** in Idaho (Amstrup and Beecham 1976)		Least concern (IUCN 2010)	Similarity of Appearance (Threatened) and Status Undefined *(U.S. Fish & Wildlife Service 2010)*

Name	**Main Prey (adapted from Feldhamer et al. 2003)**	**Max Min**	**Home range size m(SD)**	**Home range size f (SD)**	**Density**	**Status Red List (IUCN 2010)**	**Status U.S.**
Wolverine			**666**km^2 arctic Alaska (Magoun 1985)	**104**km^2 Alaska (Magoun 1985)	**1/192** km^2 Kenai peninsula (Golden 1996)	Least concern (IUCN 2010)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*
Marten			**8.1**km^2 (Powell 1994)	**2.3**km^2 (Powell 1994)	**0.6**/km^2 Yukon Territory (fall) (Archibald and Jessup 1984)	Least concern (IUCN 2009)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*
Lynx	Snowshoe hare	**Max**	Max **266(106)** Northern boreal forest with low hare density (Slough and Mowat 1996; 95% minimum convex polygon from Mohr 1947)	Max **506(297)** Northern boreal forest with low hare density (Slough and Mowat 1996; 95% minimum convex polygon from Mohr 1947)	**45** (n/100 km^2) Northern boreal forest with low hare density (Slough and Mowat 1996)	Least concern (IUCN 2009)	The Canadian Lynx is a *threatened species in the US (U.S. Fish & Wildlife Service 2010)*
		Min	Min **14(1)**Northern boreal forest high hare density ((Ward and Krebs 1985 90% minimum convex polygon)	Min **13(7)**Northern boreal forest high hare density (Ward and Krebs 1985 90% minimum convex polygon)	**3** (n/100 km^2)Northern boreal forest with low hare density (Slough and Mowat 1996)		
Golden eagle	Rodents and Birds	**Min** **Max**	**20** km^2 (Kochert et al. 2002) **33** km^2 (Kochert et al.2002)			Least concern (IUCN 2009)	Status Undefined *(U.S. Fish & Wildlife Service 2010)*

2. Methods

2.1 Software

All computations of this thesis were performed with a PC and the Windows XP operating system. For the Geographic Information System (GIS) processing ArcGIS 9.3 (ESRI ArcMap 9.3; www.esri.com) was used. Data Mining, analysis, calculations and predictions were applied with TreeNet (Salford Systems 2009; www.salford-systems.com) Marxan 2.1.1 (Possingham et al. 2000; http://www.uq.edu.au/marxan/) was used for the calculation of the protected areas. This study is based on the distribution maps of eleven Alaskan predator species: coyote, wolf, red fox, arctic fox, black bear, brown bear, polar bear, wolverine, marten, lynx, and golden eagle. The distribution maps used in this study are free open access data and can be downloaded at www.naturserve.org. Moreover, in part, the “Digital Distribution Maps of the Mammals of the Western Hemisphere Version 3.0“ (Patterson et al. 2007) and “Digital Distribution Maps of the Birds of the Western Hemisphere Version 3.0“ (Ridgely et al. 2003; www.natureserve.org/getData) were used.

A distribution map of the mega predator ecosystem was needed to show not only one individual distribution of a single animal, but instead a more ecologically meaningful ecosystem community involving eleven predators. Here we chose to use eleven predators to represent the main Habitat- Variables in a Top down view of an ecosystem part. Therefore, a new GIS layer was created as an ArcGIS 9.3. ESRI grid, which combined all distribution maps in one single map. This layer shows a map of the mega predator community in Alaska, revealing how many predator species can be found at one specific point. It further can be brought into a presence/ absence shapefile layer for the community as such.

For further calculations, a layer with discrete information about the predator community and environmental variables was created. This layer was basically an overlay of GIS based maps of Alaska with different information, for instance a layer of the Streets of Alaska, climate factors etc. The mega predator community layer was used to grab the underlying parameters for a regular point layer (=lattice, resolution of c. 57,000 points).

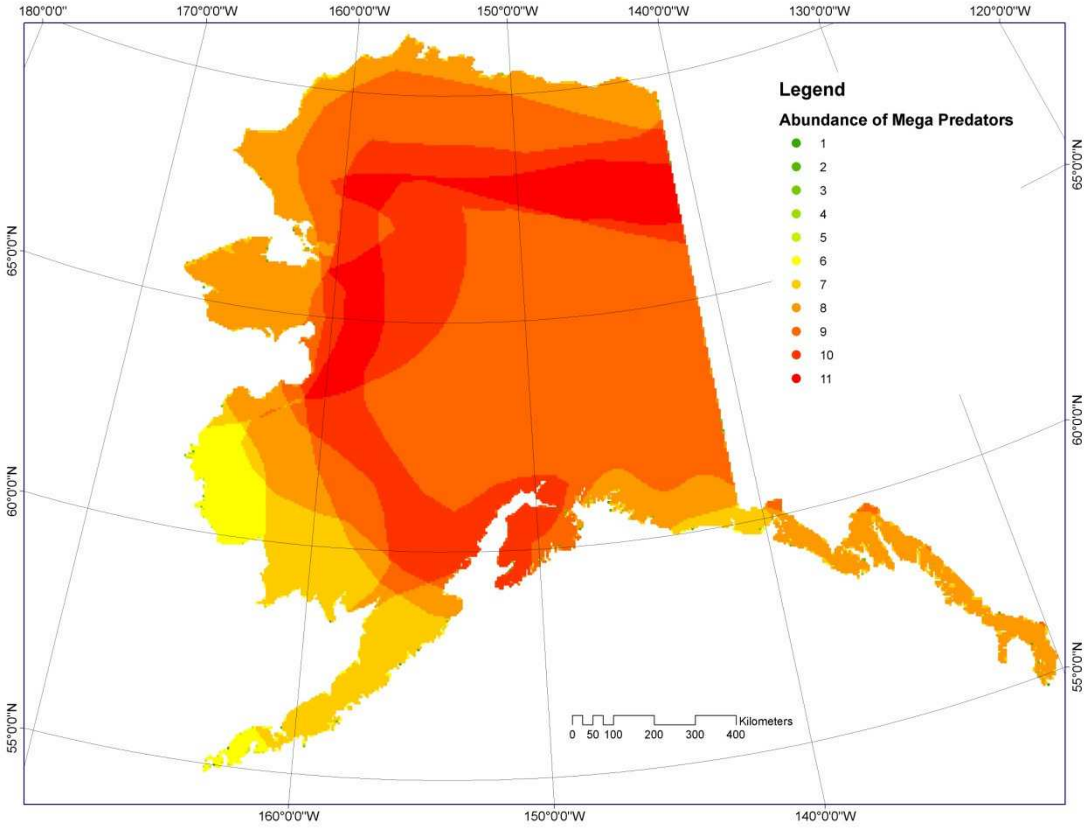


Figure 12: Overlay of distribution maps of 11 predators in Alaska

Using the publicly available Hawths Analysis Tools for ArcGIS (2009; www.spatialecology.com /htools/tooldesc.php), a regular point lattice layer with a grid size of 5 km was created, resulting in a total of 57,435 measuring points for the whole of Alaska. The actual information of this map is determined by the underlying data layers and their resolution. Five km is a decent resolution to achieve highest possible performance in that regard.

At a large scale view like the state of Alaska, this lattice point layer then resulted into 57,435 measuring points. With shorter distance between the points, the amount of data would be rising, and calculations take significantly longer. On the other hand, it is assumed that a more detailed layer would not provide further necessary information for this study.

2.2 Building an Occupancy Model of eleven Predators in Alaska

Ecology is frequently defined as: The understanding of distributions, relations and abundance of organisms and their interactions with the environment (Begon et al. 2006). It includes the study of the distribution and abundance of plants and animals (Andrewartha und Birch 1954; Krebs 1972). In this study, the estimation of the occupancy of eleven predators was used as a theoretical method by describing the predator community as a probability of occurrence. The key goal was to correct the detectability (=errors in range maps for the predator community as such), allowing eventualy for more precise population estimates. The single species distribution is not longer the main value and focus, but instead the “Ecosystem unit” of eleven predators becomes the information to portray, and corrected for points that are “outliers” or which do not fit detection model assumptions. The key goal was to correct the detectability. This should allow for a more realistic picture of predators in Alaska.

Occupancy can be estimated as: $\hat{\psi} = \frac{\hat{x}}{s}$

Equation 1

where ψ is the probability that a randomly selected site or sampling unit in an area of interest is occupied by a species (i.e. the site contains at least one individual of the species), x is the number where the species has been detected and s is the total number of sights. x is typically not known, instead it is the count of sites where the species has been detected, but this count will likely be smaller than x.

2.3 Building the Model Ecosystem Unit “Mega Predator”

The conceptual model is based on whether the species (=predator community in our case) is detected at a site or not. A site might be occupied with the probability ψ or unoccupied with the probability $(1-\psi)$. If the site is unoccupied the species cannot be detected there. (If the location is occupied there is a probability p_j for each survey (j) that the species is detected, whereas the probability of not detecting the species in the survey is 1 - p_j .This assumption implies that the occupancy status of sites does not change between surveys.)

A detection history with h_i =01010101010 indicates the presence/ absence of 11 species for a given site, meaning the species was not detected in survey 1, it was detected in survey 2, was not detected in survey 3, …, was not detected in survey 11. A survey is in this specific case an overlay of distribution map of the 11 predators.

This verbal example can be translated into a mathematical description through a series of equations.

Pr(h_i =01010101010)= $\psi\ (1-p_1)p_2\ (1-p_3)p_4\ (1-p_5)p_6\ (1-p_7)p_8\ (1-p_9)p_{10}\ (1-p_{11})$

$$\psi\prod_{i=1}^{11}(1-p_j)$$

Equation 2

There are two possibilities for a non-occupied site. Firstly, the site may not be occupied at all. This probability can be described with the equation $(1-\psi)$. Secondly, the site may be occupied by the species, but the species was not detected in any of the surveys. These two possibilities cannot be distinguished from each other, which leads to the probability statement:

$$\psi\prod_{i=1}^{11}(1-p_j)+(1-\psi)$$

Equation 3

For this study, the model described was implemented with the program PRESENCE 2.3 with the present model 1 group, constant p. The software can be freely downloaded at http://www.mbr-pwrc.usgs.gov/software/presence.html. The eleven predators considered “one species” were detected at all sites with a single probability (p).

Out of the distribution layers and the regular point lattice layer an observation history was obtained. The observation history had 57.355 sites and eleven visits on every site.

The occupancy model implied describes the eleven predators as one single species with the probability of occurrence (MacKenzie et al. 2006). This is a rather ecological, but probably a more realistic view for predator distributions, than previously done when using single species maps drawn by experts.

2.4 Geological and Environmental Variables

2.4.1 Mean Normalized Difference Vegetation Index (NDVI)

The NDVI (Gates 1980; NASA 2010) is calculated using the visible light and near-infrared light reflected by vegetation (biomass, chlorophyll). Healthy vegetation absorbs most of the visible light and reflects a large portion of the near-infrared light. Damage, sparse or unhealthy vegetation reflects more visible light and less near-infrared light. For use in photosynthesis, the chlorophyll in plants absorbs visible light from 0.4 to 0.7 µm. On the other hand, the cell structure of the leaves strongly reflects near-infrared light from 0.7 to 1.1 µm. These wavelengths highly depend on the number of leaves of a plant (Weier and Herring 2000).

To determine the NDVI, the National Oceanic and Atmospheric Administration (NOAA) uses an Advanced Very High Resolution Radiometer (AVHRR) .The AHVRR instrument of NOAA has five detectors, two of which are sensitive to the wavelengths of light ranging from 0.55–0.70 and 0.73–1.0 micrometers. Out of these values the NDVI is calculated. To calculate NDVI the near-infrared radiation (NIR) is subtracted by the visible radiation (VIS) and then divided by near-infrared radiation plus the visible radiation (Weier and Herring 2000, Tucker et al. 2005).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{VIS})}{(\mathrm{NIR} + \mathrm{VIS})}$$

Equation 4

2.4.2 Vegetation Classes

The Vegetation map of Alaska (Fleming 1997, http://agdc.usgs.gov/data/projects/fhm/index.html#G) has 23 classes from which 19 are vegetated. The classification was developed by Michael Fleming (1997) using the phenology of a vegetation index, the AVHRR and NDVI. Data for the map were collected during the growing season 1991. For classification and accuracy see Appendix 1.

2.4.3 Alaska Ecoregions Mapping

In order to include the ecoregions in the model, the identified ecoregions of Alaska from 2001 were taken from the USGS webpage (USGS 2010). We used a shapefile obtained from agdc.usgs.gov/data/usgs/erosafo/ecoreg/index.html. The ecoregion map combines the approach from Bailey and Omernik (1997) for ecoregion mapping in Alaska. Presumably, no real and consistent statistics such as clustering has been used to derive and assess these ‘ecoregions’. The ecoregions were developed cooperatively by the U.S. Forest Service, National Park Service, U.S. Geological Survey, The Nature Conservancy, personnel from many other agencies, and private organizations (Nowaki et al. 2001). The datasets used for this map were: climate parameters, vegetation, and surficial geology and topography. Additional datasets incorporated in the mapping process were lithology, soils, permafrost, hydrography, fire regime and glaciations. The ecoregion units are based on the newly available datasets and field experience of ecologists, biologists, geologists and regional experts. Out of this knowledge the major ecosystems have been expert-assembled, mapped and described for the State of Alaska and nearby areas.

Thirty-two units are mapped using a combination of the hierarchical (Bailey 1983) and the integrated (Omernick 1987) approach. The ecoregions are grouped into two higher levels using a blended "triarchy" based on climate parameters, vegetation response and disturbance processes (USGS 2010). For accuracy estimations see Appendix 1.

2.4.4 Distance to roads, railways, airways, lakes, coast and towns and topographic maps

Topographic maps were obtained from ESRI (2009), airways from the Alaskan Department of Natural Resources (1995). These maps were used in ArcGIS 9.3 to calculate the distances to roads, railways, airways, lakes and coast lines.

The distances were calculated in 1000 meter intervals in the Alaska State Albers NAD 1983 projection (see Table 1). Moreover, each of the factors (slope, aspect, and elevation) of the digital elevation model (DEM) was included. The DEM was obtained from the USGS (2009) .

Maps of the National Parks of Alaska (National Park Service 2002) and National Wildlife Refuges (USFWS 2001) were used to show the status of protected wildlife in Alaska.

2.4.5 Computation of the Human Influence Index and the Human Footprint

With an overlay of a number of global data layers (see Appendix 1 for details) representing various factors presumed to exert an influence on ecosystems, the layers of the Human Influence Index and the Human Footprint were produced. The combined influence of the factors human population distribution, urban areas, roads, navigable rivers, and various agricultural land uses yield the Human Influence Index (see Appendix 1 for details). The Human Influence Index (http://sedac.ciesin.columbia.edu/wildareas/) in turn, is normalized by global biomes to create the Human Footprint dataset. Human Footprint values range from 1 to 100. A score of 1 indicates that the grid cell is part of the 1% least influenced “wildest” area in its biome. Though the absolute amount of influence in places like moist tropical forests and temperate broadleaf may be different, all areas with less than 1% influence are defined as ”wildest” (SEDAC 2010). For detailed information on the Indices see Appendix 1 and Sanderson et al. (2003).

2.4.6 Climate layers, the General Climate Model, future Climate Prediction and Climate Change

“*Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.*”

- IPCC AR4 synthesis report, Page 30, 2007 –

General Atmospheric Circulation Models (AGCMs) are numerical/ mathematical models that simulate three- dimensional global atmospheric flows. Combined with an oceanic general circulation model (OGCMs) and a land surface model, they form the coupled model that is used for climate prediction of global warming (SATOH 2004). The coupled ocean-atmosphere GCMs use climate simulations to project and predict future temperature and precipitation changes under various scenarios.

Most commonly in the predictive climate scenarios, an increase of 1% of CO_2 per year is assumed. There are more realistic assumptions like the IS92a (Leggett et al. 1992) and the Special Report on Emissions Scenarios (Nebojsa et al. 2001) developed for the AR4-Fourth Assessment Report from the IPCC,that state a higher increase of CO_2 (Pachauri and Reisinger 2007).

In all non- mitigated models that were assessed by the IPCC, an increase of a global mean surface air temperature (SAT) continuing over the 21st century is projected. This increase is mainly driven by increases in anthropogenic greenhouse gas concentrations, with the warming proportional to the associated radiative forcing (The mean SAT warming for the early 21st century, averaged for 2011 to 2030 compared to 1980 to 1999 is between +0.64°C and +0.69°C, with a range of only 0.05) (Meehl et al. 2007). This warming rate is little affected by different scenario assumptions or different model sensitivities, and is consistent with the observed warming for the past few decades (Meehl et al. 2007).These scenarios do not include unknowable events like volcanic eruptions, human landcover transitions, insect outbreaks or a change in solar forcing. Although these effects are believed to have a smaller effect, volcanic eruptions for example are known to have a temporary cooling and global effects (Self et al. 1996). However, this is not man-made. It became clear by now that IPCC consistently underestimates (conservative models, but not correct), which can be seen on the yearly sea ice estimates for instance (Vellinga et al. 2009, Richardson et al. 2009).

The climate data used in this study were projections for the state of Alaska based on downscaled (‘regionalized’) outputs from five IPCC Global Circulation models. The outputs were downscaled from a two-degree resolution to two kilometre resolution for Alaska with the PRISM methodology.

These were performed by Dr. John Walsh and SNAP, more detailed Information can be found on the website: http://www.snap.uaf.edu (Walsh et al. 2008).

Out of 15 professional IPCC climate models that are usually available, five models have been ranked as the best models for Alaska: ECHAM5, GFDL21, MIROC, HAD, CCCMA. Of these five models a composite using the mean values from the outputs of all five models are available. The ‘five model composite’ was used in this work with the A1B- scenario. In the A1 storyline a world of very rapid economic growth is assumed. The global population will peak in mid-century. It is also assumed that new and more technologies will be introduced rapidly. The A1B scenario implies a balance across the used fossil and non fossil energy resources (Nakicenovic 2000, IPCC 2009).

Air temperature and precipitation are monthly mean values of a decade, as an example mean values of December temperatures for 2030-2039. The air temperature is specified in degrees Celsius, the precipitation in total monthly millimetres (snow water equivalent).

Table 4: Geological and environmental variables used and their dimensions, source and processing

Name of The Variable	**Dimension of the variable**	**Format and Source**	**Processing**
Elevation	Meter	ArcView Image File (USGS 2009 http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz	To raster
Aspect	Degree (360°)	ArcView Image File (USGS 2009) http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz	To raster
Slope	Non dimensional	ArcView Image File (USGS 2009 http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz)	To raster
Distance to Towns	Meter (1000 Meter Steps)	Tom Paragi, AK Fish & Game Dept Shapefile: http://dnr.alaska.gov/SpatialUtility	Topographic map to a distance raster file
Distance to Roads	Meter (1000 Meter Steps)	Shapefile http://dnr.alaska.gov/SpatialUtility	Topographic map to a distance raster file
Distance to Coast	Meter (1000 Meter Steps)	Shapefile: http://dnr.alaska.gov/SpatialUtility /SUC?cmd=vmd&layerid=56	Topographic map to a distance raster file
Distance to Railways	Meter (1000 Meter Steps)	Shapefile http://dnr.alaska.gov/SpatialUtility	Topographic map to a distance rasta file
Distance to Airways	Meter (1000 Meter Steps)	Shapefile http://dnr.alaska.gov/mlw/index.htm	Topographic map to adistance raster file
Ecoregions 1 and 2	Categorial (0-3/0-8)	Shapefile http://agdc.usgs.gov/data/usgs/erosafo/ecoreg/index.html)	To raster
Mean NDVI from 2000	Non dimensional	Shapefile D. C. Douglas US GS Alaska Science Center, Biology & Geography Sciences, Juneau Office download at: (http://glcf.umiacs.umd.edu/data/)	To raster
Vegetationclasses	Categorial (1-23)	Shapefile http://agdc.usgs.gov/data/projects/fhm/index.html#G	To raster
Distance to Rivers	Meter (1000 Meter Steps)	Shapefile	Topographic map to a distance raster file

Name of The Variable	Dimension of the variable	Format and Source	Processing
Temperature	Celcius	ASCII (SNAP 2009) http://www.snap.uaf.edu/	To raster
Percipitation	mm day $^{-1}$	ASCII (SNAP 2009) http://www.snap.uaf.edu/	To raster
Human Footprint	Categorial (Range 1-100)	Shapefile (CIESIN 2009) http://sedac.ciesin.columbia.edu/wildareas/	To raster
Human Influence Index	Categorial (0-64)	Shapefile (CIESIN 2009) http://sedac.ciesin.columbia.edu/wildareas/	To raster

2.5 Using TreeNet Algorithm for Data Mining and Climate Predictions

TreeNet® is a data mining tool, capable of consistently generating prediction models. TreeNet can work with regression and classification as well as with varying sizes of data sets (Salford Systems 2009; www.salford-systems.com). To achieve this, TreeNet uses a decision tree learning algorithm. In general, decision tree learning is widely applied in data mining and machine learning.

TreeNet uses a decision tree as a predictive model which maps observations about an item to draw conclusions about the item's target value.

The model generated in TreeNet is similar to a long series expansion, such as a Fourier of Taylors series (Salford Systems 2009; Taylor 1715). The model becomes progressively more accurate as the expansion continues. This can be written up as:

$$F(X) = F_0 + \beta_1 T_1(X) + \beta_2 T_2(X) + \ldots + \beta_M T_M(X)$$

Equation 5

Every T_i is a small tree. The expansion is a weighted sum of terms, each of which is obtained from the appropriate terminal node of a small tree.

As an example, a regression model begins with an estimate of a mean value, e.g. predator occurrence. It then uses this as a baseline from which adjustments will be made in order to reflect characteristics of other pedictor variables, e.g. temperature and distance to watersheds.

In the first term, the model states that the mean value would be adjusted upwards for warmer temperature and then adjusted upwards again for the distance to watersheds.

In practice, the adjustments are usually small and hundreds of adjustments may be needed in a model run. The final model is thus a collection of weighted and summed trees, summarized in a (digital) code. For binary classification problems, with a „yes“ or „no“ response determined by climate the predicted outcome is positive or negative. For multi-class problems a score is developed separately for each class via class specific expansions, the scores are converted into a set of probabilities of class membership. Continuous applications employ specific regression optimizations.This description of TreeNet is very rudimentary but shows the concepts. The method used in TreeNet is called stochastic gradient boosting and was developed 1999 by J.H. Friedman (http://www-stat.stanford.edu/~jhf/).

Examples for the use of these decision-trees for ecological analysis examples can be found in Elith et al. (2009), Popp et al. (2007), Craig and Huettmann (2009), and others. These types of analyses are not limited to the program TreeNet, other programs like CART from Salford Systems and BRT, MART for R can be used as well (Elith et al. 2008). This group of analysis and algorithms is fastly raising.

2.6 Marxan Model Methods

2.6.1 Implementing Conservation Areas for eleven Predators in Alaska

Marxan is a software that delivers decision support for reserve system design (http://www.uq.edu.au/marxan/). A planner for a big reserve system for instance has to choose between large numbers of potential sites to select new conservation areas. To make a good decision, ecological, social and economic criteria and principles have to be included. Marxan is primarily intended to solve a particular class of reserve design problem known as “minimum set problem” where the goal is to achieve for instance some minimum representation of biodiversity features for the lowest possible costs (McDonnell et al. 2002). If relatively comprehensive data on species, habitats and/ or other relevant biodiversity is given, Marxan aims to identify the best reserve system (a combination of planning units), by minimizing the costs to its lowest possible level and meeting the user defined biodiversity targets at the same time.

Finding “the best” or the near best solution for a reserve system is very complex, and often not possible and not even needed for real world solutions. Marxan helps to prioritize the solutions according to the goals and penalties set by the user and stakeholder community.

The number of possible (spatial) solutions of even a small reserve selection is vast. If one considers 200 planning units, there are over 1.6x 10^{60} possible ways a reserve system could be configured. To solve the selection problems of conservation areas, computer algorithms such as MARXAN and SITES have been developed (Ball et al. 2009; Ward et al. 1999); much research is done on this subject, and more is found in the (economic) discipline of Operations Research and Decision-Support Systems.

There are at least two possible types of reserve design solutions with a computer program. One works with an exact algorithm, the other one works according to the heuristic method. Heuristic solutions do not provide an exact solution, but a number of good, near-optimal solutions, which not only offer a set of options for planners and stakeholders to consider, but can also be generated very quickly (Possingham et al. 2000; Cabeza 2003). The Marxan software uses simulated annealing as a heuristic method.

2.6.2 Simulated annealing

The term *Simulated annealing* actually derives from the annealing in metallurgy, which is a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects (Kirkpatrick et al. 1983) Transferred to the optimization process from the simulated annealing, ”temperature” here corresponds to the probability that an intermediary result of the optimization can change for an outcome that is worse. Unlike to a local search algorithm, this procedure can leave a local optimum again. This safes the method of being stuck at a local minima, thus a better optimum can be found in the data, or for the global optimum of the entity. The “temperature” decreases in a fixed rate during the iterations of the process.

In order to compare different solutions in Marxan, it must have a basis. Marxan does that by testing alternate selections of planning units, aiming to improve the whole reserve system value. The reserve system value is not connected to an already established conservation area (Ball and Possingham 2000). Every planning unit in Marxan has a cost. Marxan tries to meet all the biodiversity and other constraints for a minimum total cost.

These costs are usually calculated either as a simple reflection of area or as an economic cost. Moreover the costs can represent an ecological issue where high cost sites are the ones the program tries to avoid (Ardron et al. 2008).

The core equation Marxan tries to minimize is:

$$\sum_{PUs} Cost^{1} + BLM^{2} \sum_{PUs} Boundary^{3} + \sum_{ConValue} SPF^{4} xPenalty^{5} + CostThresholdPenalty(t)^{6}$$

Equation 6

1.

As described above, these are the total costs of the reserve network.

2.

The Boundary Length Modifier (BLM) is used to determine how much emphasis should be placed on minimizing the overall reserve system boundary length.

3.

The total reserve boundary length is multiplied by the modifier (2.).

4. and 5.

The penalty for not adequately representing conservation features.

SPF is the Species Penalty Factor or conservation feature penalty factor. The SPF is the penalty of not including a species or another conservation feature in the reserve system. If the setting it higher than 1, it will increase the motivation for the system to perfectly represent that conservation feature.

6.

Number 6 describes the penalty for exceeding a preset cost threshold (not used in this study).

2.6.2 Questions to be answered from Marxan

Based on real and best available data, here the question is pursued: How efficient is the current Alaskan reserve network system to fulfill the conservation objectives and protect the eleven mega predators? Are there gaps in the current network system and can they be closed?

- How much area must be conserved in order to achieve that 10% of the ecosystem unit is protected and where are these areas specifically located, and connected?
- How comprehensive is the existing network in relation to the conservation targets?
- Where will the focus of conservation effort be located in a particular region/ tenure?
- How should a planner proceed to maximize conservation for minimum socioeconomic impact?

2.6.3 Implementation of Marxan

A raster grid with pixel sizes matching the regular point lattice layer with a grid size of 5 km (described in part 3: Results) was created in order to calculate the optimal conservation areas for the eleven predators

2.6.4 Defining the costs for eleven predators

Two approaches to find preferable areas for conservation in Alaska were utilized.

Approach 1:

TreeNet offers in the solution a ranking of variable importance. The first 11 out of 21 variables with the highest score were used to build a cost equation for Marxan.

$$Cost = \sum_{i=1}^{n} a_i \, b_i$$

Equation 7

a= variable threshold cost; b= TreeNet ranking; n= 11

Variable threshold costs (a) were determined by the partial dependence of each variable. If the partial dependence of a variable is negative, the cost is 1 which equates to a poor habitat for the community. If the Partial Dependence is positive, the costs are 0. This approach reflects the ecological thresholds for a predator community for instance.

The different variables (a) are weighted after their importance for the predator community by the factor (b). This approach determines the optimal habitat for predators with low costs, while regions with minor habitat have high costs.

Only taking the first variables had two reasons: The ranking of the last 10 variables was low, therefore having small influence on the equation. Furthermore, the thresholds for the last 10 variables were not as clear as the first ones. The cost function is based on thresholds which made it difficult to imply all variables.

Approach 2:

For the cost function in MARXAN it was first assumed that the implementation of a conservation area is more expensive near urban regions. Therefore, the distances to towns, distance to roads, to railways and airports were calculated. The costs were decreasing the further the grids were away from urban regions. It was assumed, that the implementation of a conservation area was cheaper if it is away from human settlement.

Because the numerical value (in meters) of the distance to urban regions was too high, the maximum value was set to 100. From this value, the reciprocal value was taken. As a consequence, all grids which are lying on urban regions have the cost value 100. This results in a “wilderness solution”.

3 Results

3.1 Descriptive Maps of the Ecosystem Unit “Mega Predator”

Figure 13 shows the combination of predators, the deep red colour illustrates the highest predator diversity, on the other hand, the yellow areas indicate lesser diversity.

This map is based on the raw data overlays, and then modelled and corrected for detectability to correct for errors in the expert maps. It is meant to be a more realistic and ecologically correct indicator of the ‘presence of the eleven predator community’; being less flawed/biased by expert-derived species range maps outlining general ecological processes on an Alaskan Landscape scale.

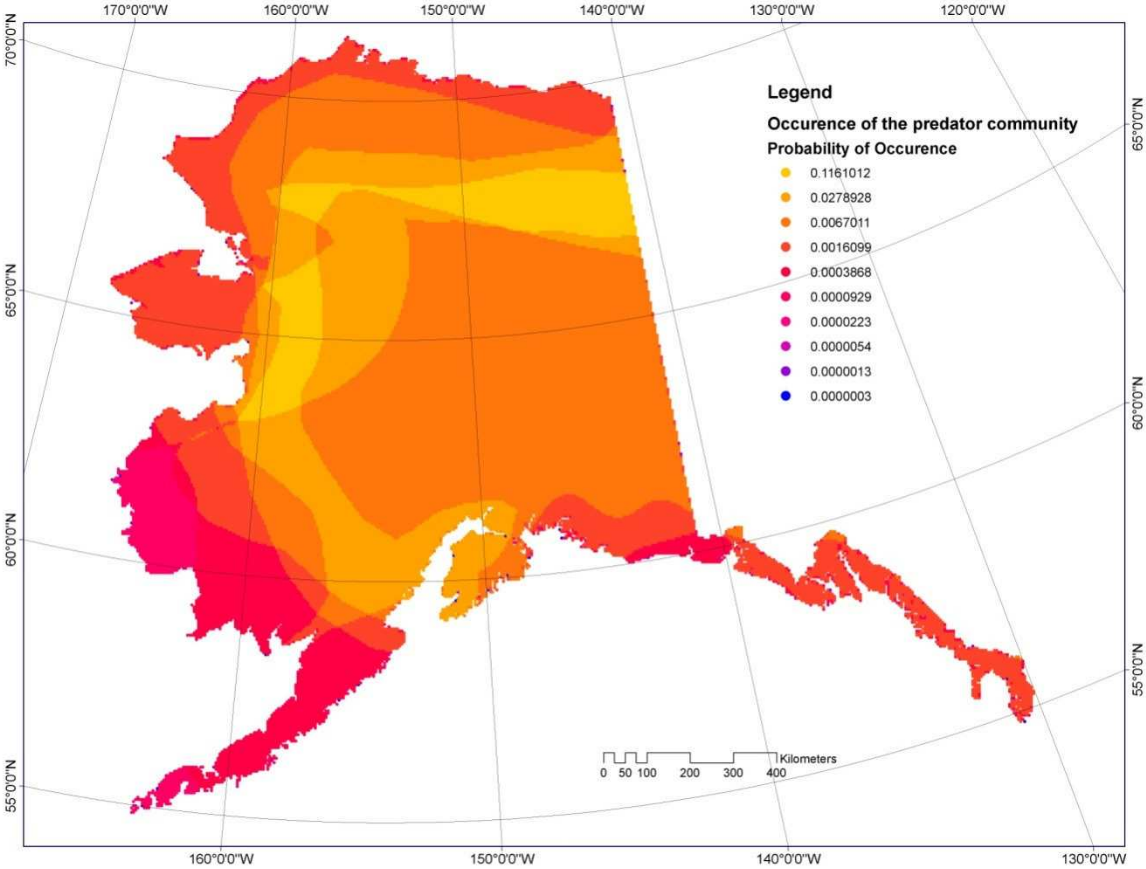


Figure 13: Map of the occurrence of the Ecosystem Unit “Mega predators of Alaska”. The colours show the probability of occurrence of the Ecosystem Unit Yellow indicates a high probability, were purple and orange indicates low density of predators.

The numbers from 0.12 to $3*10^{-8}$ in the legend indicate the mathematical probability of occurrence of the predator community. The area in yellow shows that the probability of occurrence is high, hence many predators can be found in this region, whereas the purple and blue colors demonstrate that the probability of predator occurrence is low.

The highest occurrence of the predator species is approximately a band with some hotspots forming the interior coastal line with a distance between 50 and 300 km from the coast of Alaska. A decreasing gradient of mega predator species towards the coast of Alaska and towards the center can be seen in the map.

This map indicates the highest density of predators within and around the southern Brooks Range, and near the Seward Peninsula; both areas can be described as “far away from modern human influence”; arguably, it represents one of the key wilderness areas in North America. This requires more study and management attention. The band of high density tops on the Norton Sound from the East, from there it is crossing the Kuskokwin Mountains and the Alaska Range in the South and goes around the Cook inlet.

Within this band we can make the assumption that the interactions and sympatric connections between the predators are highly evolved and the food chain and interactions with other parts of the ecosystem is still complex and as undisturbed as it gets on a landscape level anywhere in the U.S., and partly on the American continent.

3.2 Ranking of Value Importance for the Predator Community

The model for the ranking of the variables shows a high precision, where 75% seem to be correctly predicted. The optimal tree number was 9904.

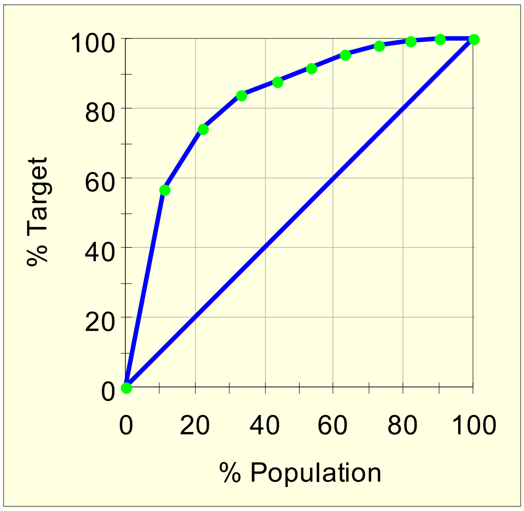


Figure 14: ROC-Curve of the value ranking model

The occurrence data from the eleven predators was taken for an analysis of the importance of the variables. The internal score of TreeNet shows the importance of the variables. The most important variable here has always the value 100 %.

As it can be seen in Table 5, in this model "Distance to Railways" seems to be most important while for example "Distance to towns" has a lower importance.

However, taken together, human factors seem to be major drivers one way or another (railways, airways, roads and towns). Arguably, the climate in Alaska is "man-made" too (Hinzman et al. 2005).

Table 5: Variables of the model and their score

<table>
<tr><th>Variable</th><th>Score</th><th>Visualization</th></tr>
<tr><td>Distance to railways</td><td>100.00</td><td>||||||||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>Mean precipitation in June 2000 - 2009</td><td>63.17</td><td>||||||||||||||||||||||||||</td></tr>
<tr><td>Distance to coast</td><td>57.80</td><td>||||||||||||||||||||||||</td></tr>
<tr><td>Mean temperature in December 2000 - 2009</td><td>55.88</td><td>|||||||||||||||||||||||</td></tr>
<tr><td>Distance to airstrips</td><td>45.75</td><td>|||||||||||||||||||</td></tr>
<tr><td>Mean precipitation in December 2000 - 2009</td><td>44.02</td><td>||||||||||||||||||</td></tr>
<tr><td>Eco region 2</td><td>43.43</td><td>||||||||||||||||||</td></tr>
<tr><td>Vegetation classes</td><td>41.94</td><td>|||||||||||||||||</td></tr>
<tr><td>Mean temperature in June 2000 - 2009</td><td>32.06</td><td>|||||||||||||</td></tr>
<tr><td>Distance to roads</td><td>28.12</td><td>|||||||||||</td></tr>
<tr><td>Distance to towns</td><td>27.32</td><td>|||||||||||</td></tr>
</table>

The importance of the different factors decreases slowly. Other variables with importance under 25 % of the internal TreeNet Score are Human Footprint, Height, and Distance to lakes, Human Influence Index, Distance to Rivers, Mean NDVI from 2000, Slope, Aspect and other two Ecoregions (see Appendix 3).

The first six variables with the highest score are shown with their partial dependence (response curves) in the results, other variables with less importance can be found in Appendix 3.

In addition, the variable “Distance to Railways” has a positive dependence between 250 km and approximately 550 km of distance; the optimum lies around 360 km (Figure 15). The green line shows the linear fitting as provided by TreeNet. In this figure a real peak and a clear avoidance area is shown. The “Distance to Railway” seems to be an important factor for the predator occurrence.

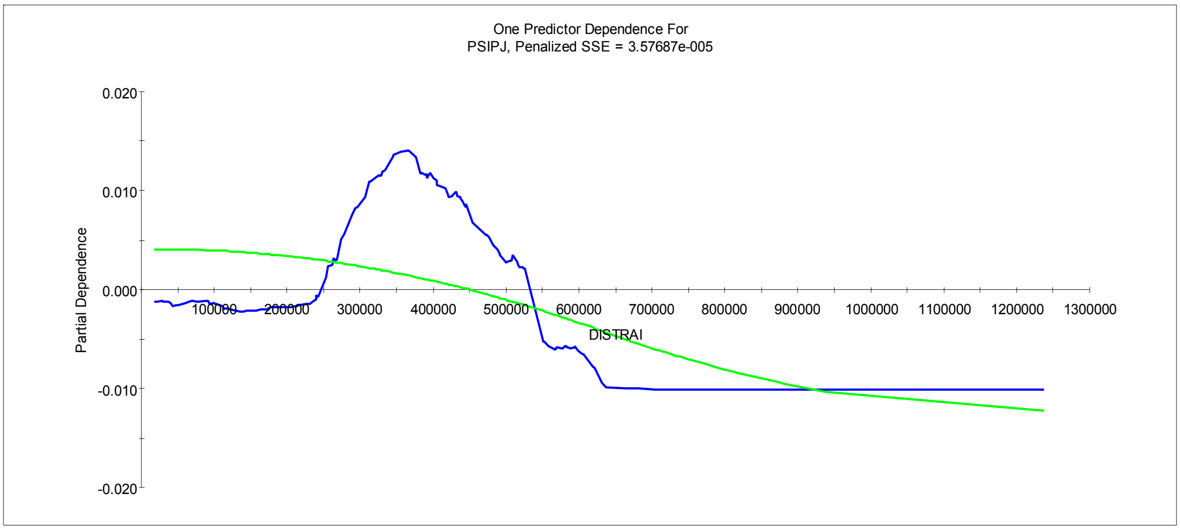


Figure 15: Partial Dependence for “Distance to Railway” (in meters)

The Variable “Mean Precipitation in June during the decade “2000-2009” has a positive partial dependence between 0 cm/m² and approximately 30 cm/m². The apparent avoidance and preferred areas of the mega predator community can clearly be seen.

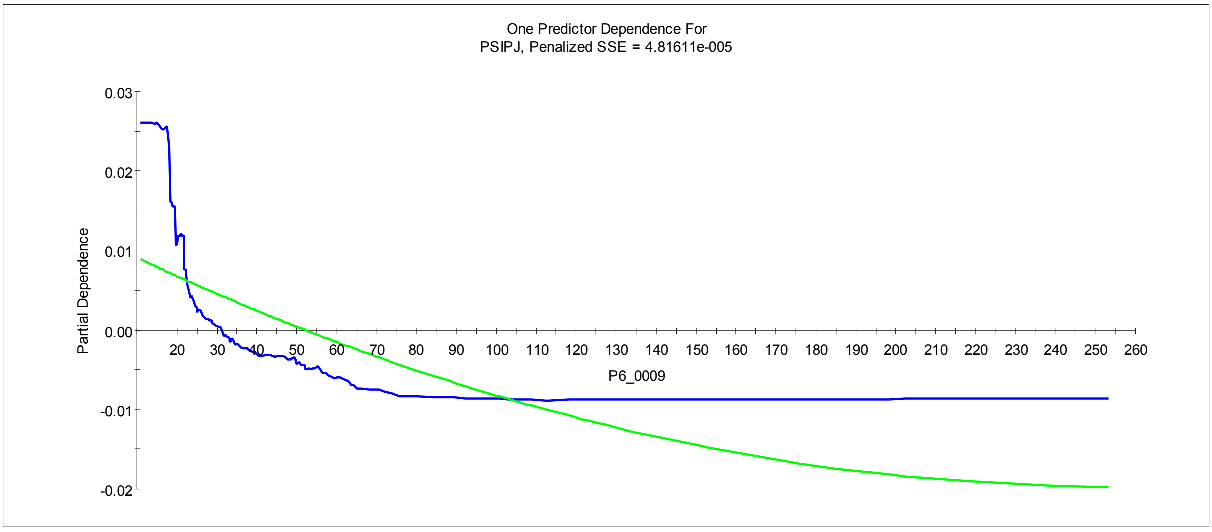


Figure 16: Partial dependence for precipitation in June during the decade 2000-2009 (in cm)

The variable “Distance to coast” shows a positive dependence within approximately 170 to 325 km distance, the peak lies around 260 km away from the coast. As a visual proof the dependence of this variable can also be presumed in Figure 13.

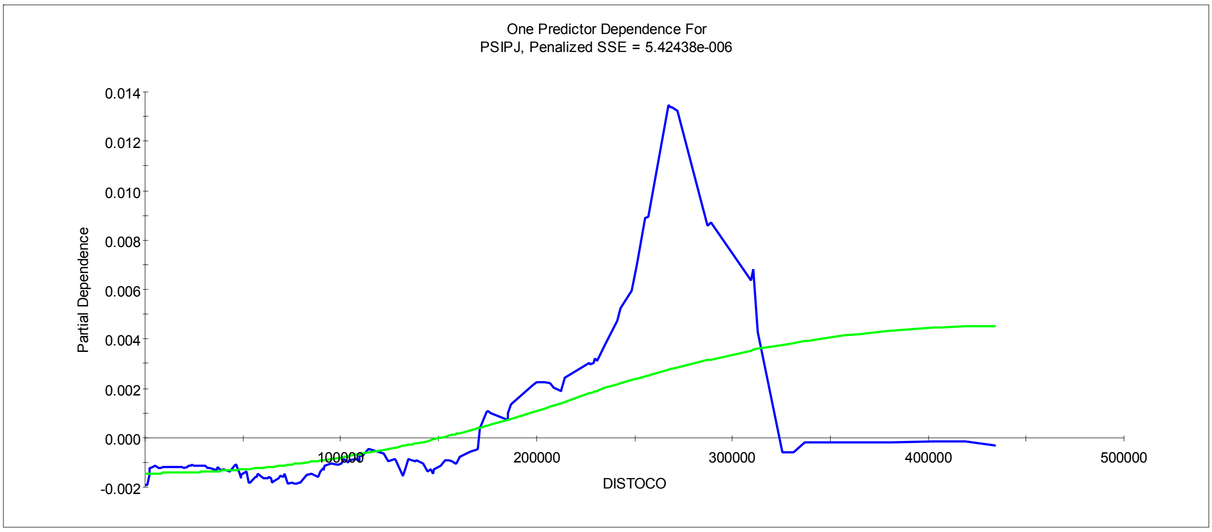


Figure 17: Partial dependence for distance to coast (in meters)

Mean temperature in December shows a positive partial dependence between app. -19°C and -28°C. The temperature -19°C seems to be a threshold for the mega predator community. The curve of the partial dependence decreases drastically around this temperature.

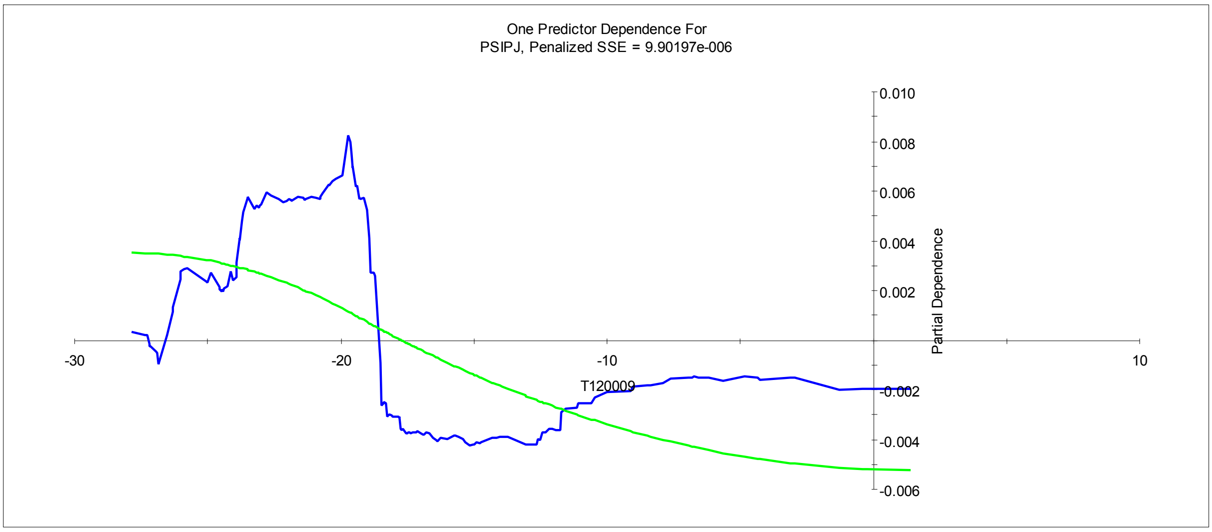


Figure 18: Partial dependence for temperature in December during the decade 2000-2009 (in Celsius)

Airways seem to have a small negative effect on predators in the first 150 km of distance. The partial dependence of this variable seems to be weaker as in the other variables (Figures 15-18).

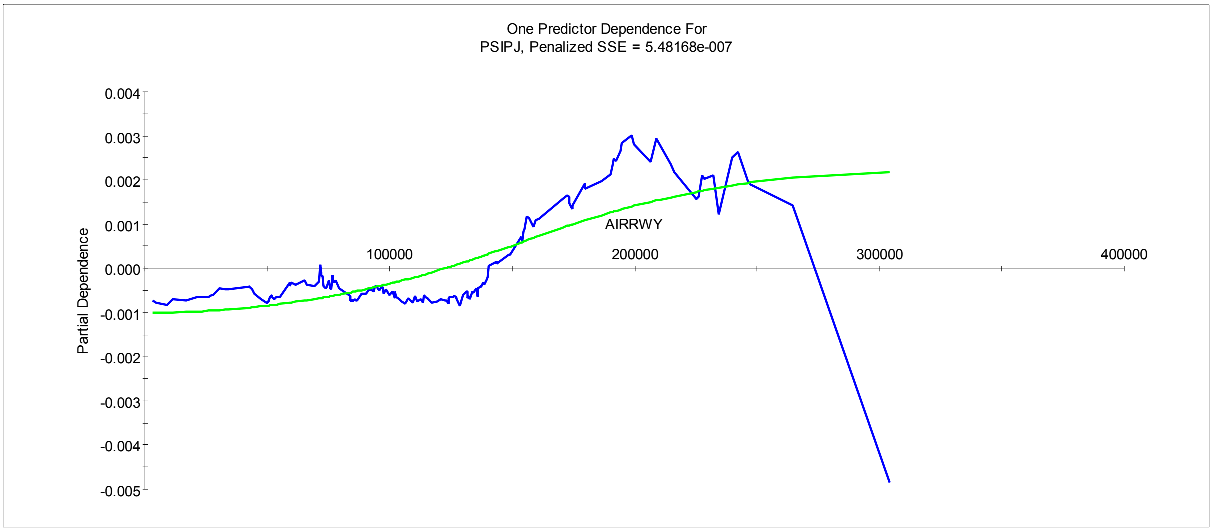


Figure 19: Partial Dependence for „Distance to Airstrips“ (in meters)

Precipitation seems to have only a positive dependence from 0 cm/m² up to 25-50 cm/m ². This result is shown in Figure 16 and Figure 22 in the second model. Between the mean precipitations for June and December, the precipitation in December during the decade 2000-

2009 shows almost the same result. Positive partial dependence is shown between 0 and 23 cm/m².

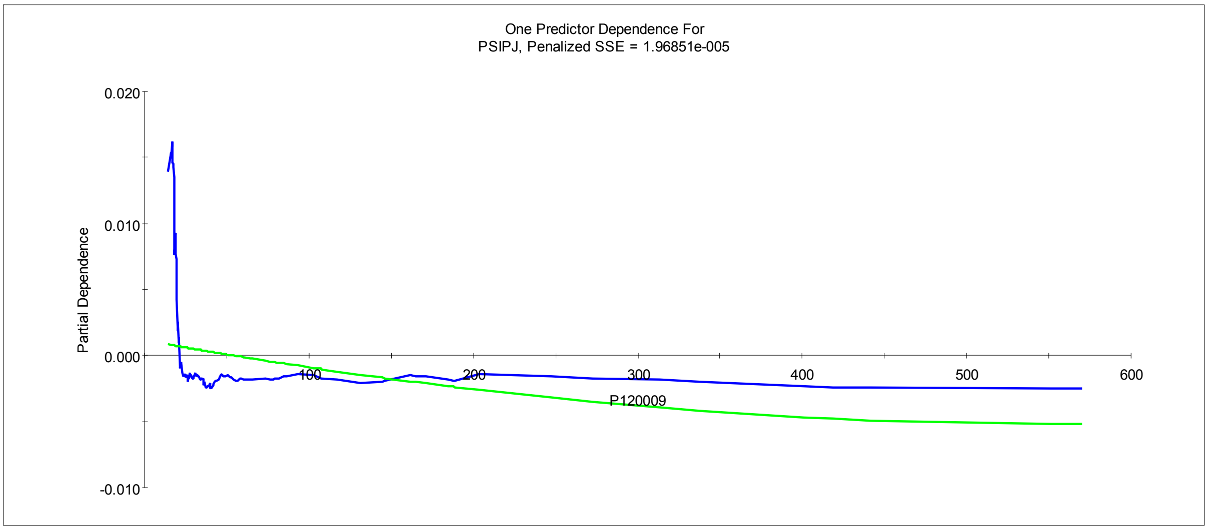


Figure 20: Partial Dependence for „Precipitation in December“

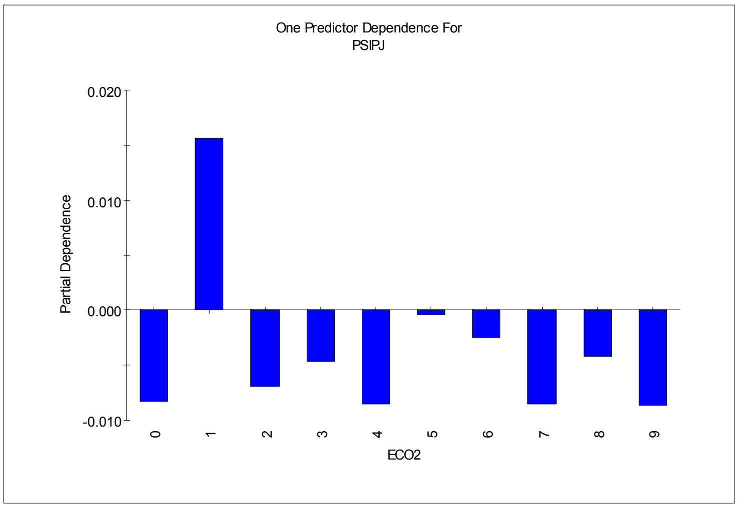


Figure 21: Partial dependence for Ecoregions

As it can be seen in Figure 21, the only positive partial dependence is the Bering Taiga. Other Ecoregions have almost no, or negative partial dependence for the predator community.

Table 6: Ecoregions of Alaska

ID	Ecoregion
0	Bering Taiga
1	Aleutian Meadows
2	Alaska Range Transition
3	Coastal Rainforest
4	Bering Taiga
5	Pacific Mountain Transition
6	Intermontane Boreal
7	Coastal Mountain Transition
8	Bering Tundra

(Nowaki et al. 2001)

A positive partial dependence of the different variables is shown in Table 7. After the variable "Distance to town" the partial dependence of the variables becomes more and more unclear (see Figures 2 to 11 in Appendix 2)

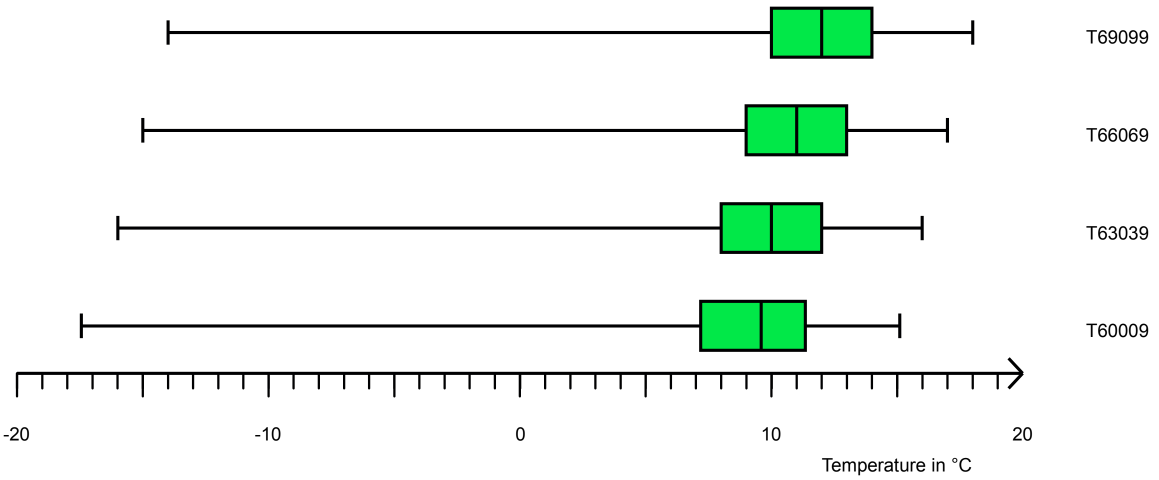
Table 7: The variables and their range of positive partial dependence

Variable	**Positive dimension**	**Dimension**
Distance to railways	250-550	Km
Mean precipitation in June 2000 - 2009	0-25	cm/m²
Distance to coast	170-325	Km

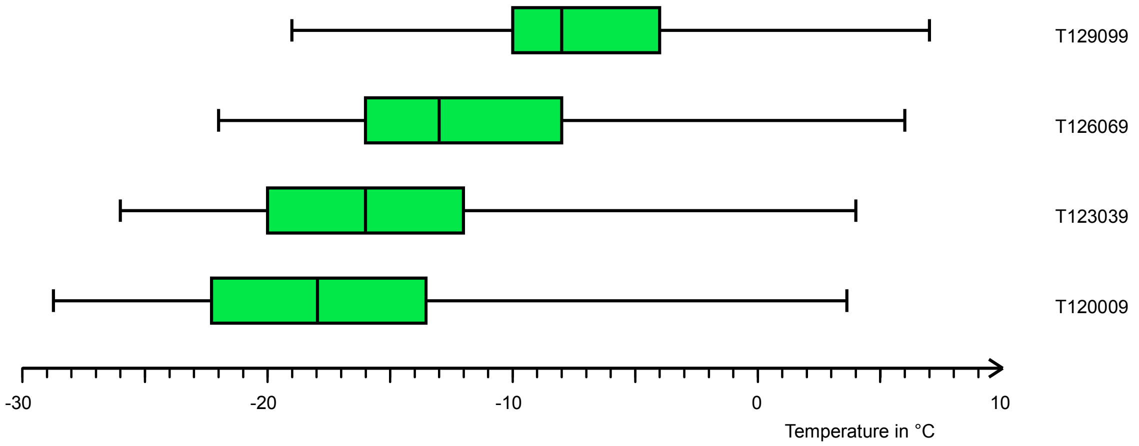
Mean temperature in December 2000 - 2009	-28°- -19°	Celsius
Distance to airways	150-275	Km
Mean precipitation in December 2000 - 2009	0--24	cm/m²
Eco region 2	Bering Taiga	---
Vegetation classes	- Alpine Tundra & BarrensDwarf Shrub Tundra - Closed Mixed Forest - Spruce Woodland/Shrub - Open Spruce Forest/Shrub/Bog Mosaic - Spruce & Broadleaf Forest - Open & Closed Spruce Forest - Open Spruce & Closed - Mixed Forest Mosaic -Tall & Low Shrub	---
Mean temperature in June 2000 - 2009	7-12,5	Celsius
Distance to roads	From 50	Km
Distance to towns	From 64	Km

3.3 Climate Predictions for the Model

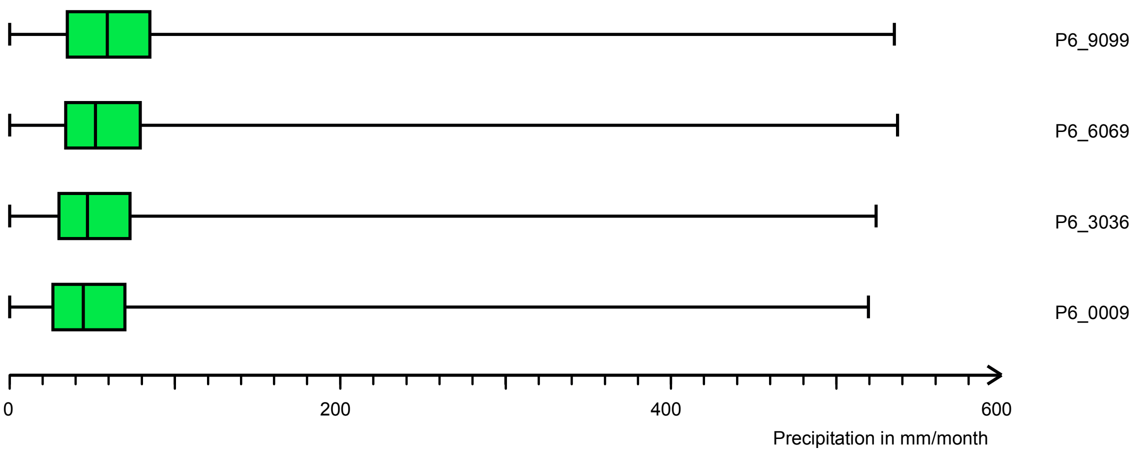
In the Boxplots 1-3 the temperature development is shown as a main base for the prediction model of the predators. It can be seen that the median/ average temperature is increasing; as well as the minima and maxima temperature. During four decades - from 2000-2009, 2030-2039, 2060-2069, and 2090-2099 - precipitation increases but not as much as the temperature. The temperature and precipitation is obtained from the SNAP scenarios provided by John Walsh (see Methods 2.4.6 for details).



Boxplot 1: Temperatures of the four decades in Alaska. The vertical line in the middle of the green boxes shows the median, the horizontal line shows the minima and maxima. The green box shows the quartiles. (T129099= Mean temperature in June of the decade 2090-2099, T126129= Mean temperature in June of the decade 2120-2129, T123039= Mean temperature in June of the decade 2030-2039, T120009= Mean temperature in June of the decade 2000-2009).



Boxplot 2: Temperatures of the four decades in Alaska. The vertical line in the middle of the green boxes shows the median, the horizontal line show the minima and maxima. The green box shows the quartiles. (T129099= Mean temperature in December of the decade 2090-2099, T126129= Mean temperature in December of the decade 2120-2129, T123039= Mean temperature in December of the decade 2030-2039, T120009= Mean temperature in December of the decade 2000-2009).



Boxplot 3: Precipitation in mm/ month in the four decades in Alaska. The black line in the middle of the green boxes shows the median, the horizontal line show the minima and maxima. The green box shows the quartiles (T129099= Mean precipitation in December of the decade 2090-2099, T126129= Mean precipitation in December of the decade 2120-2129, T123039= Mean precipitation in December of the decade 2030-2039, T120009= Mean precipitation in December of the decade 2000-2009).

In addition to the Boxplots 1-3, the mean and median temperatures of the decades up to 2099 as well as the minima and maxima values for each decade are shown in Table 4.

Table 8: Precipitation and temperature means and 50% medians, with minimum and maximum values. Precipitation is shown in cm/ m² and temperature in Celsius.

Variable	Mean	Min	Max	50% Median
December precipitation from 2000-2009	71.08	0	1561.30	35
December precipitation from 2030-2039	71.32	0	1557.00	36
December precipitation from 2060-2069	74.24	0	1564.00	37
December precipitation from 2090-2099	91.18	0	1587.00	55
June precipitation from 2000-2009	61.10	0	519.28	45
June precipitation from 2030-2039	63.43	0	524.00	47
June precipitation from 2060-2069	68.49	0	537.00	52

June precipitation from 2090-2099	73.69	0	535.00	59
Mean temperature in December 2000-2009	-17.26	-29	3.64	-18
Mean temperature in December 2030-2039	-15.30	-26	4.00	-16
Mean temperature in December 2060-2069	-11.92	-22	6.00	-13
Mean temperature in December 2090-2099	-6.89	-19	7.00	-8
Mean temperature in June 2000-2009	9.05	-17	15.10	10
Mean temperature in June 2030-2039	9.57	-16	16.00	10
Mean temperature in June 2060-2069	10.49	-15	17.00	11
Mean temperature in June 2090-2099	11.81	-14	18.00	12

3.4 Predictions until 2099 of the 11 Mega Predator Community based on Climate Data

TreeNet found the optimum after creating 9736 trees. The model shows high predictive values.

Table 9: Variable importance of the four different climate factors in the decade 2000-2009. June precipitation, December precipitation, Mean temperature in June, Mean temperature in December

<table>
<tr><th>Variable</th><th>Score</th><th></th></tr>
<tr><td>June precipitation from</td><td>100.00</td><td>|||||||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>Mean temperature in December from</td><td>94.57</td><td>||||||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>Mean temperature in December</td><td>85.90</td><td>||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>December precipitation</td><td>82.54</td><td>||||||||||||||||||||||||||||||||||</td></tr>
</table>

As well as in part 3.1, the four variables are presented with their partial dependence. Positive Partial Dependence indicates the preference of the predator community, negative values indicate avoidance in relative units. The precipitation has a positive partial dependence near the ordinate in-between approximately 0 mm/ month and 50 m/m²per month.

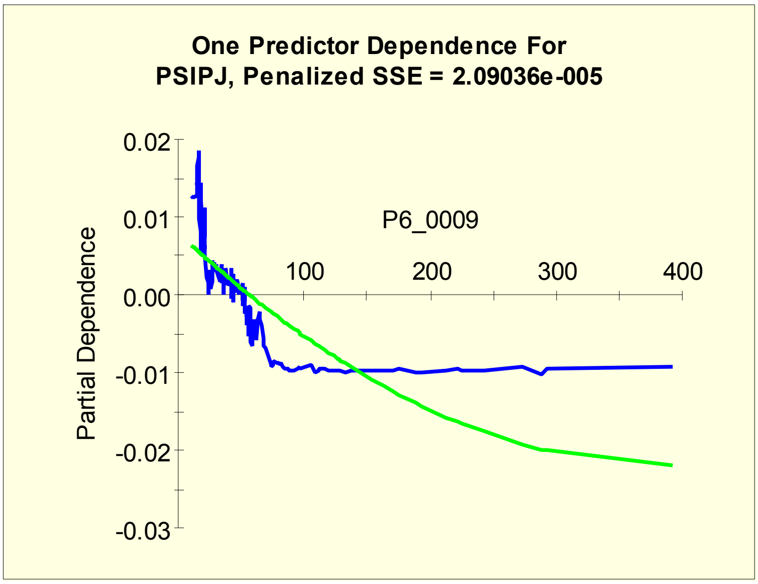


Figure 22: Partial Dependence for “Mean precipitation in June during the decade 2000-2009” (in cm/m²)

The mean temperature in June has a positive dependence between approximately 10.7 and 13.6°C, with a strong negative dependence towards the end.

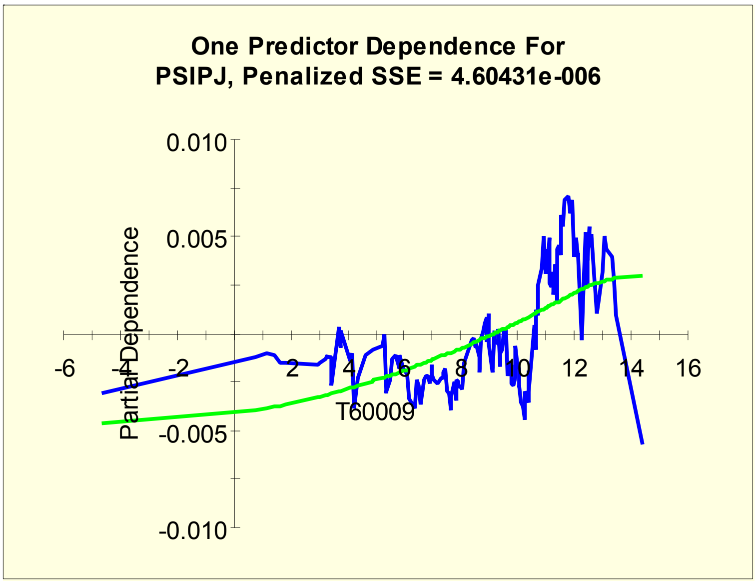


Figure 23: Partial Dependence for “Mean temperature in June during the decade 2000-2009” (in Celsius)

As shown in Figure 23, the temperature is more important in-between the minus degrees.

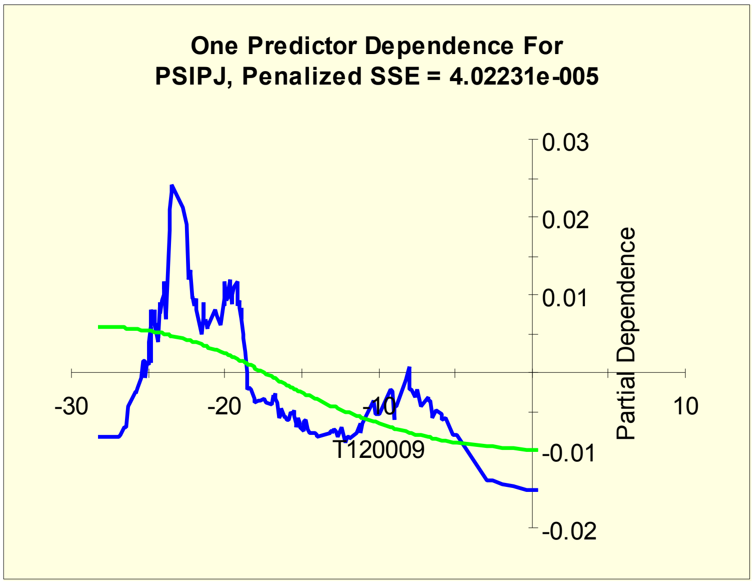


Figure 24: Partial Dependence of the “Mean temperature in December during the decade 2000-2009” (in Celsius)

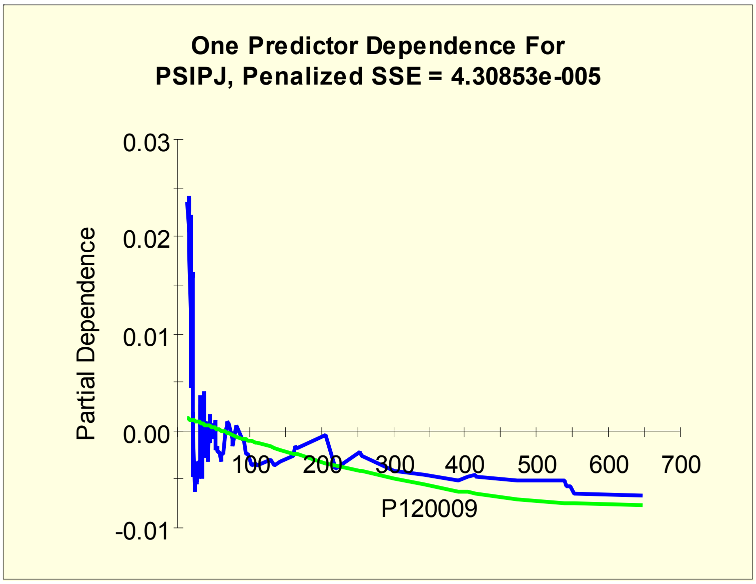


Figure 25: “Mean Precipitation in December during the decade 2000-2009” (in cm/m²**)**

The precipitation during June and the temperature during December seem to have the highest importance for the predator community, whereas the temperature of the month June and the precipitation during December have less importance.

3.4.1 Model accuracy

The model was evaluated by taking a 50 % subsample of the 57340 measure points. It has been built with the 50 % subsample and was then evaluated by comparing the constructed model with the original data of the other 50 % subsample.

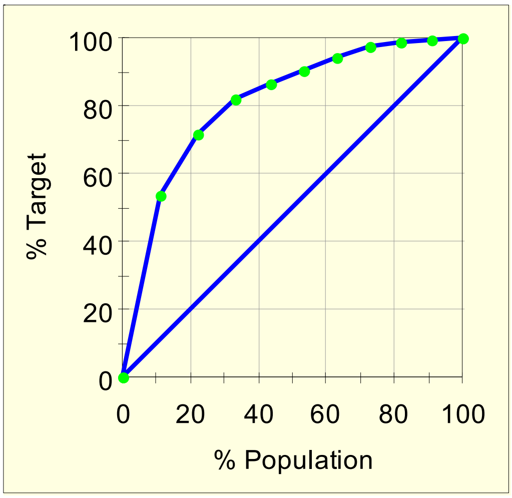


Figure 26: ROC-Curve of the scored 50 %-subsample with a relatively high precision

In order to visualize the precision, the whole data is scored as shown in Figure 27. The legend demonstrates the scores of TreeNet, divided in ten categories.

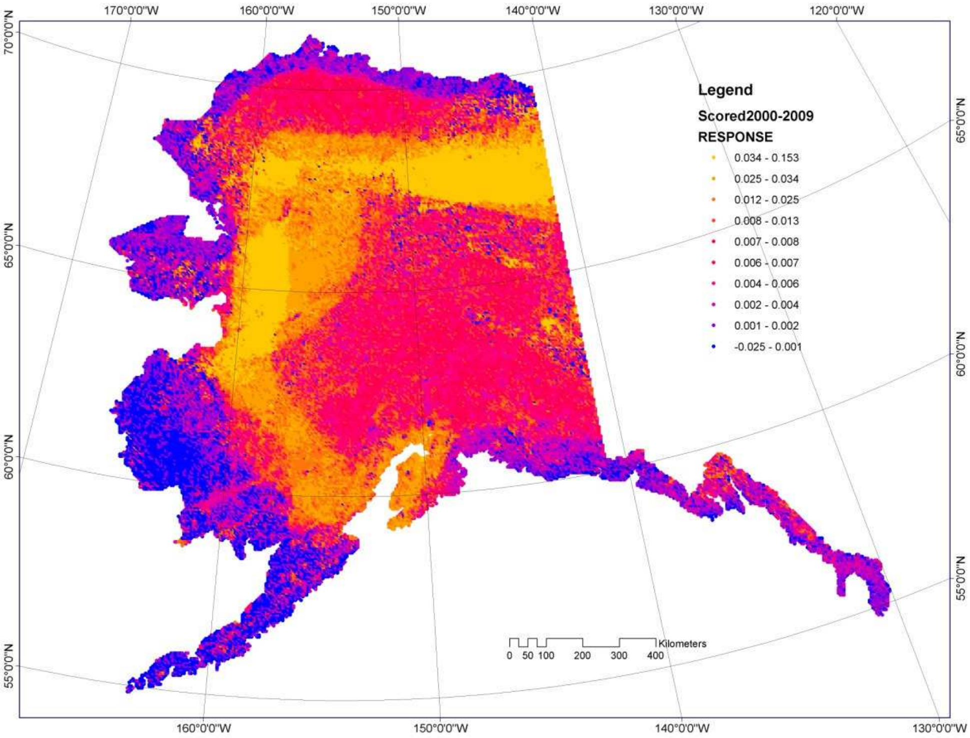


Figure 27: Map of the modeled probability of occurrence of the eleven predators of Alaska. During the period from 2000 to 2009 climate data from SNAP scenarios has been used. For better visualization, the "Response"-data from the TreeNET model is divided in 10 levels. The division is categorized in 10% Quartiles applied from the ArcMap GIS program.

3.4.2 Prediction of the decade 2030-2039

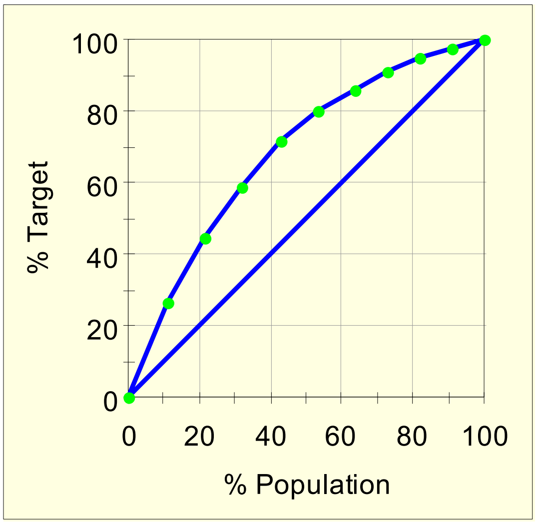


Figure 28: ROC-Curve of the scored climate data of the decade 2030-2039 with a relatively high precision.

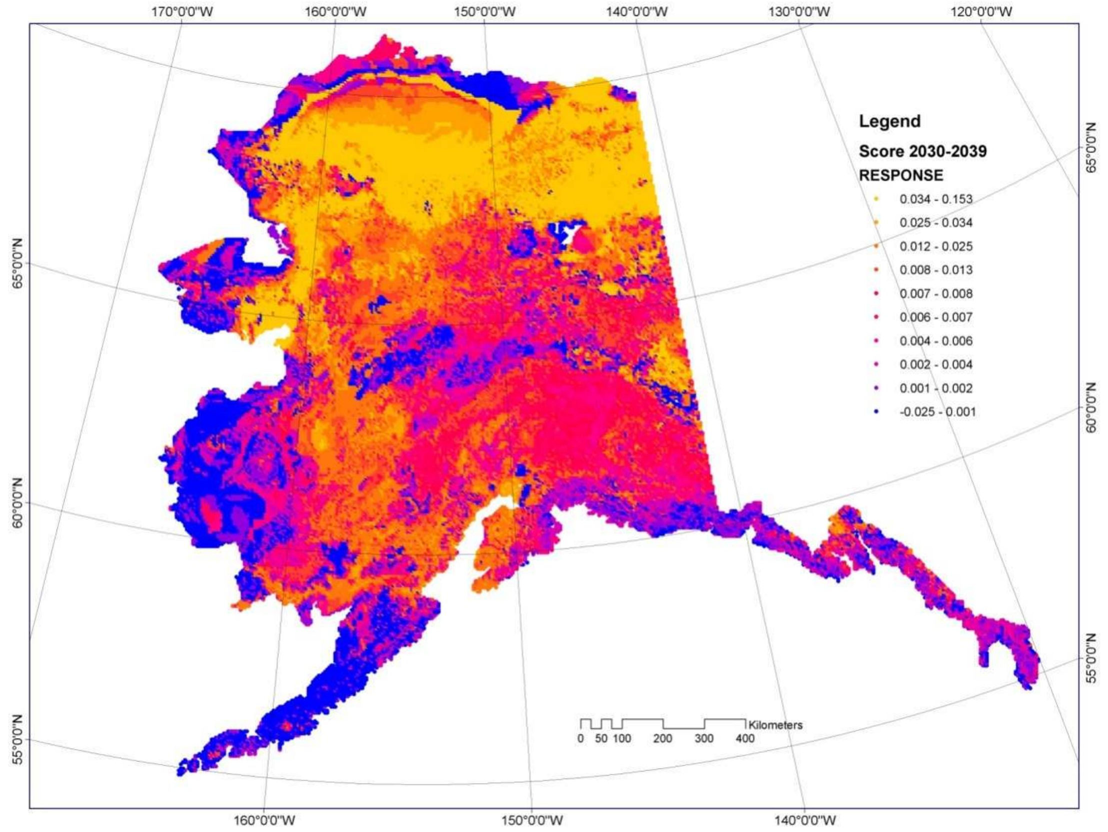


Figure 29: Map of the modeled probability of occurrence of the eleven predators of Alaska during the period from 2030 to 2039 with climate data from SNAP scenarios. For better visualization, the "Response"- data from the TreeNET model is divided in 10 levels. The division is categorized in 10% Quartiles applied from the ArcMap GIS program.

The map shows that the predator community will start to undergo change during the decade from 2030 to 2039. The region with the occurrence probability of eleven predators shows an increase in the northern regions of Alaska, while the probability of occurrence in the southern parts decreases. Much fragmentation starts already.

3.4.3 Prediction of the decade 2060-2069

This changes more drastically in the decade 2060-2069 as it can be seen in Figure 18. The prediction map shows a movement of predator-occurrence towards the northern regions of Alaska, and a simultaneous expansion towards the South. The former "band" of predator occurrence seems to be completely broken. The middle of Alaska seems to be no longer preferable for the predator community.

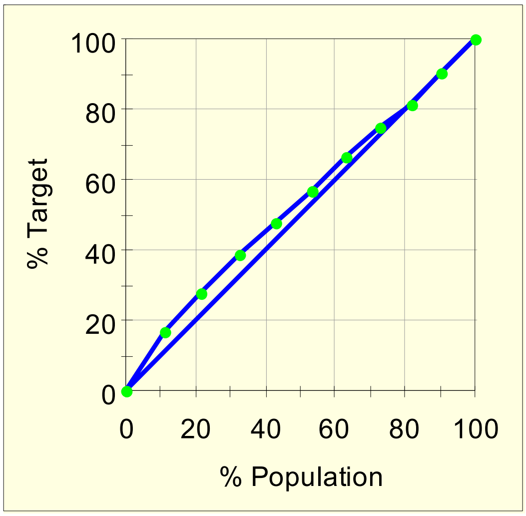


Figure 30: ROC- Curve of the scored climate data from the decade 2060-2069

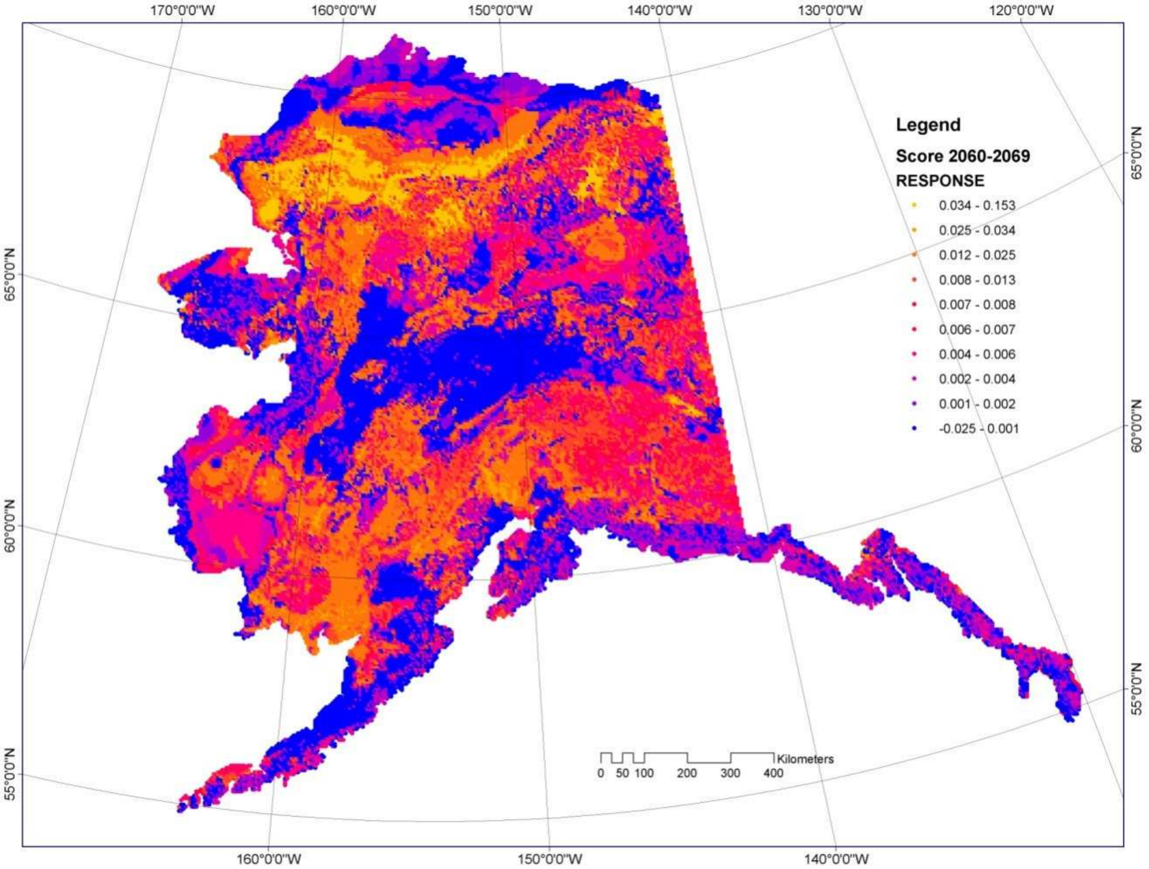


Figure 31: Map of occurrence of the 11 predators of Alaska during the period from 2060 to 2069 with climate data from SNAP scenarios. For better visualization, the “Response”- data from the TreeNET model is divided in 10 levels. The division is categorized in 10% Quartiles applied from the ArcMap program.

3.4.4 Prediction of the decade 2090-2099

The last simulation, in Figure 33, shows the predator community spread out over Alaska with a dense population in middle-east Alaska. The structure from the decade 2000-2009 cannot be found anymore.

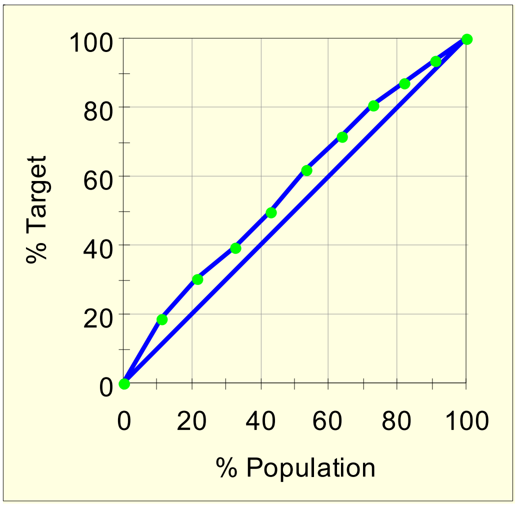


Figure 32: ROC-Curve of the scored data from the decade 2090-2099

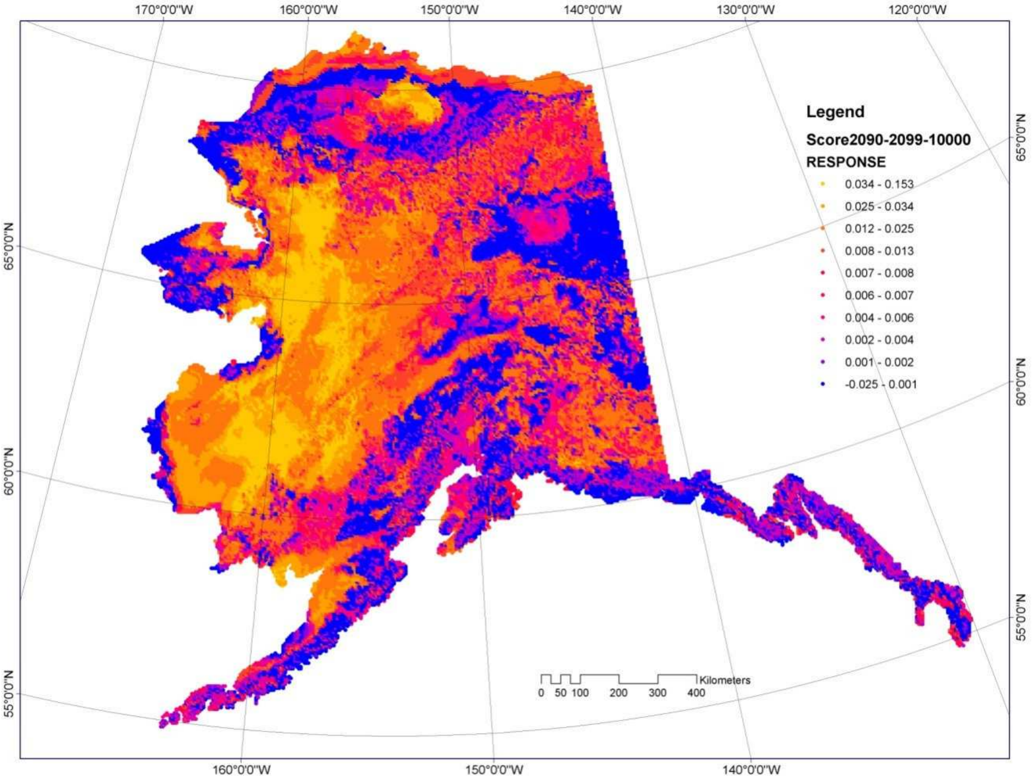


Figure 33: Map of occurrence of the 11 predators of Alaska during the period from 2090 to 2099 with climate data from SNAP scenarios. For better visualization, the "Response"- data from the TreeNET model is divided in 10 levels. The division is categorized in 10% Quartiles applied from the ArcMap program.

Table 6 shows the classification of the prediction maps (Figures 27, 29, 31, and 33) and the percentage of grid points in the classes. The changes in the first two categories (0.034-0.153 and 0.012-0.025) are very obvious. The change in these categories seems to be extensive for the habitat of the predator community. The categories 3, 4, and 10 (0.012-0.025; 0.008-0.0130 and 0.025-0.001 respectively) are increasing during the models, while others like 5 and 6 (0.007-0.008 and 0.006-0.007 respectively) are continuously decreasing.

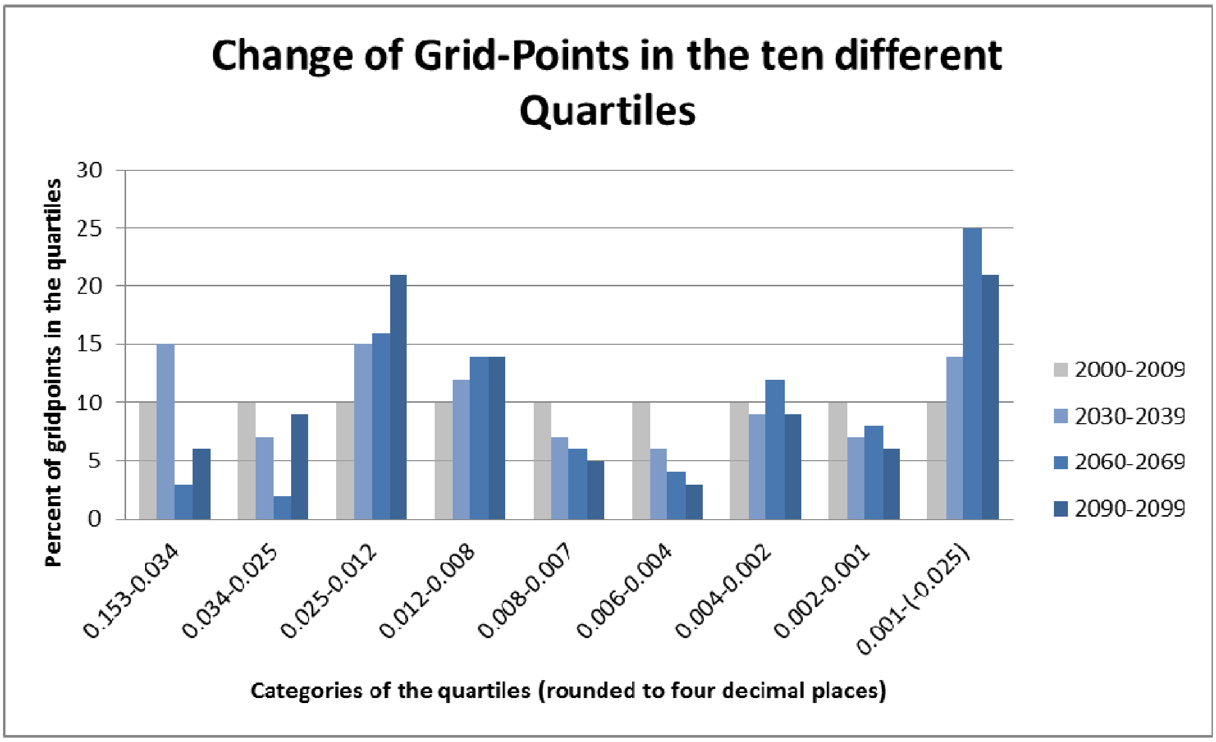


Figure 34: Change in the 10 quartiles from the TreeNet model of the decade 2000-2009

3.5 Near-best Solution of Protected Areas for the Eleven Mega Predator Community provided by Marxan

Figure 34 shows the potential protected areas in Alaska derived from the cost function (Equation 7) described in the Methods. The protected areas encompass among others the previous described band of predators in the North of Alaska with the main areas around the Brooks Range of Alaska.

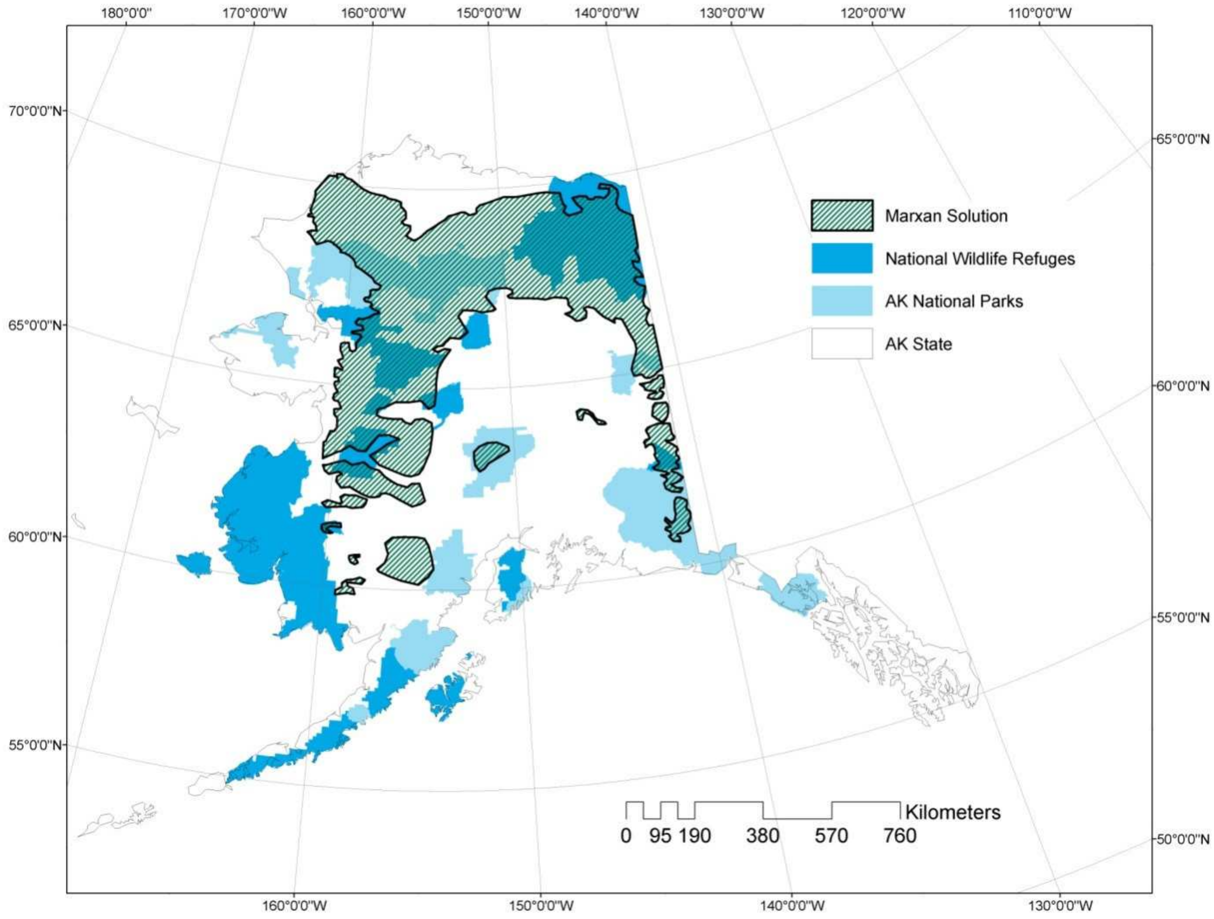


Figure 35: Map of Alaska with Marxan solution 1 for potential protected areas for the predator community. The potential protected areas of Alaska found with Marxan are illustrated by black/ green patches, the blue patches are the National Parks and National Wildlife Refuges.

Southern Alaska provides smaller potential protected areas in this solution.

In a second approach the occurrence data from the scenario 2090-2099 was taken, to find future potential protected areas for the predator community. The same cost function as in the first approach was taken Only the climate data from 2090-2099 was used instead of the climate data from 2090-2099.

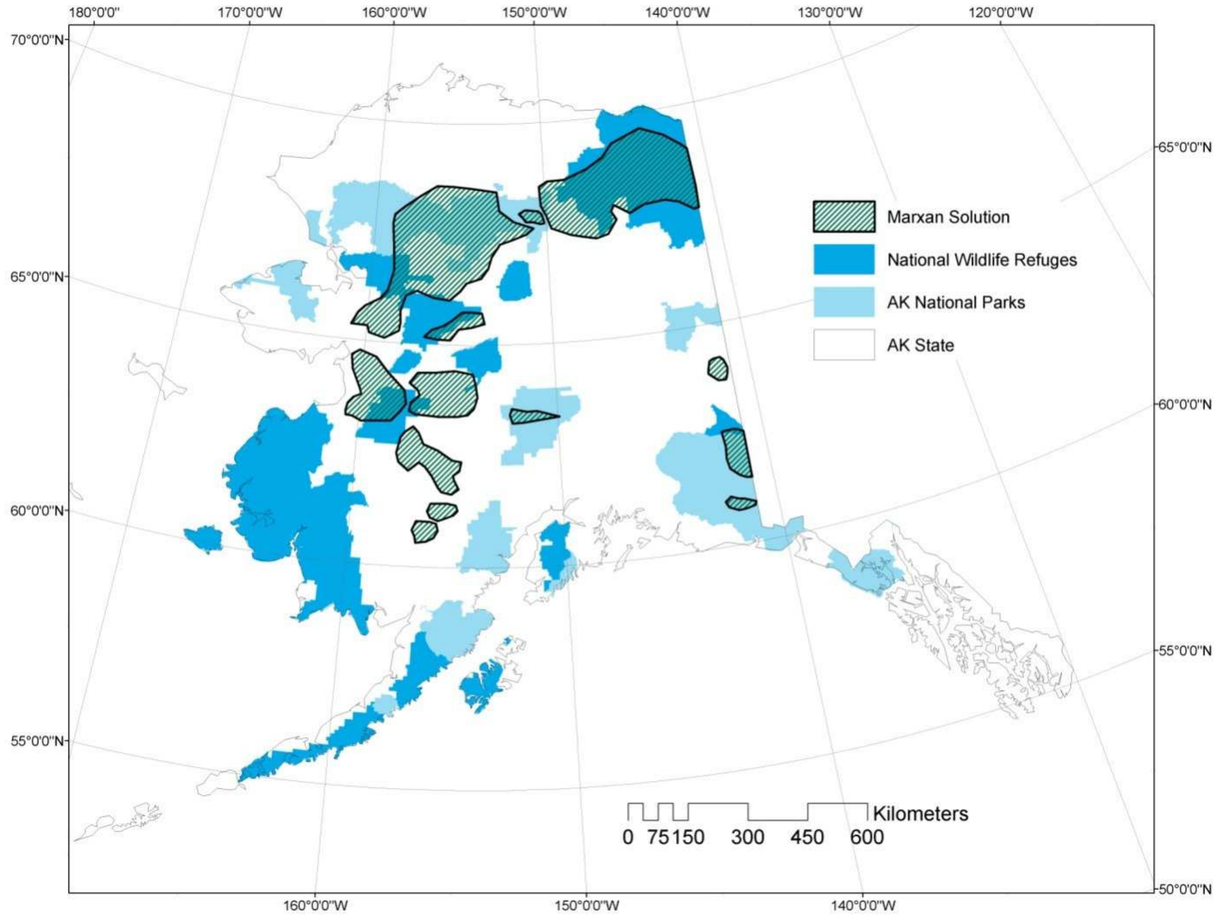


Figure 36 : Map of Alaska with Marxan solution 2 for potential protected areas for the predator community. The potential protected areas of Alaska found with Marxan are illustrated by black/ green striped patches, the blue patches are the National Parks and National Wildlife Refuges

As a third approach of potential protected areas the “cheapest” solutions for protected areas are shown in Figure 36. It is assumed here that protected areas are preferred by landscape planners if they are far away from urban structures, and also that the predator community is better protected in wilderness areas without human disturbance.

The potential protected areas are found near the areas of the other two approaches. For this approach the presence absence data from 2009 was taken.

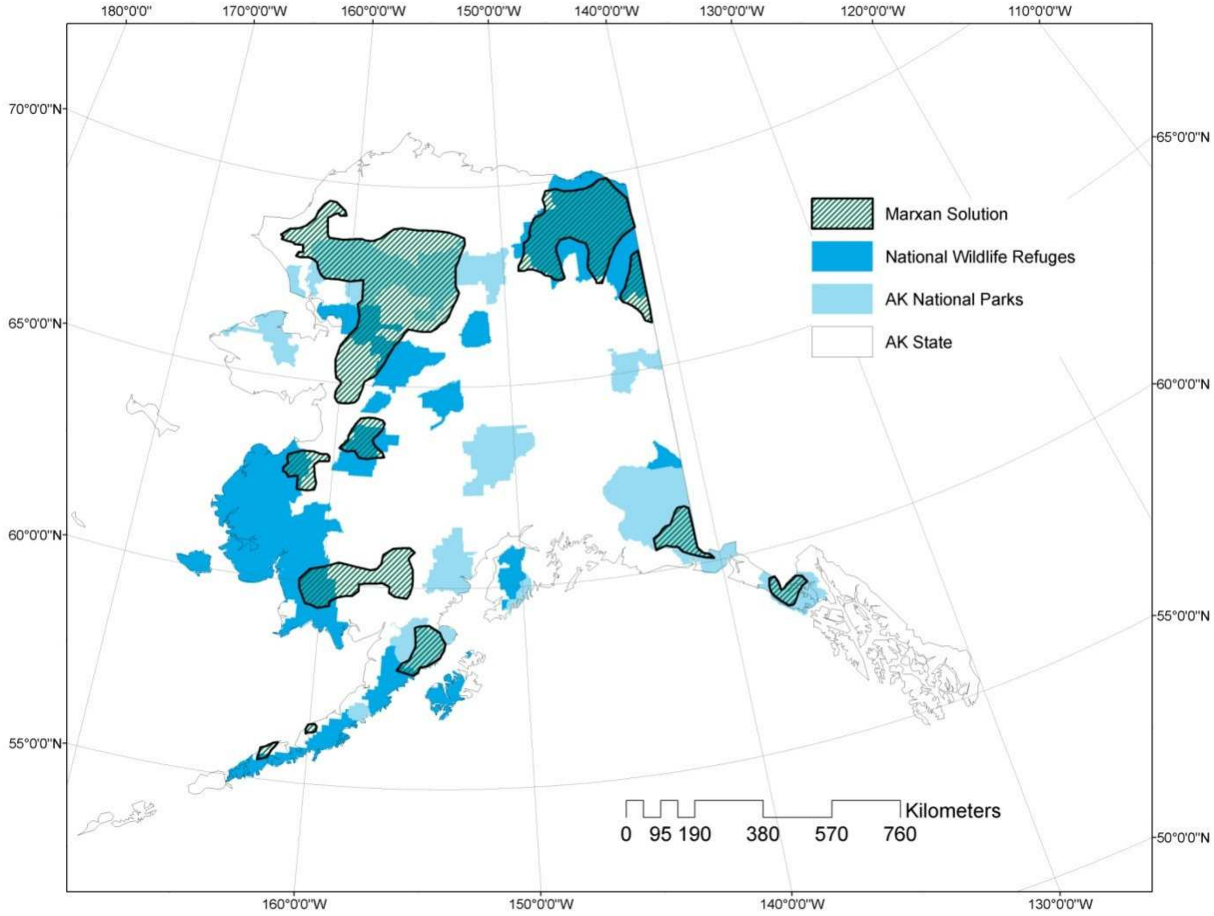


Figure 37: Map of Alaska with Marxan solution 3 for potential protected areas for the predator community. The potential protected areas of Alaska found with Marxan are illustrated by black/ green striped patches, the blue patches are the National Parks and National Wildlife Refuges

As a conclusion the intersection of all three Marxan results are shown in Figure 37. The areas with the highest intersection can be found around the Brooks Range.

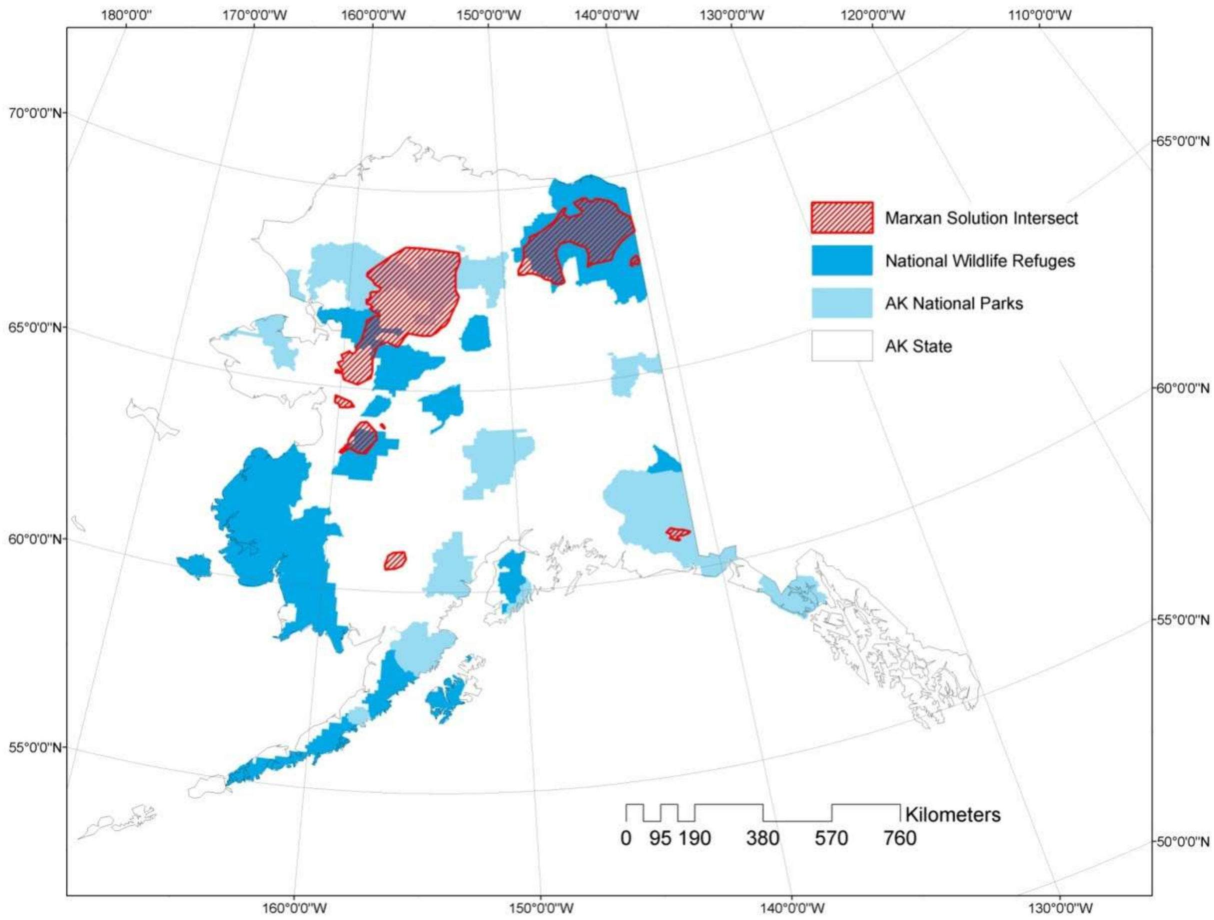


Figure 38: Map of Alaska with the intersection of all three Marxan Approaches for potential protected areas for the predator community. The intersections are red striped, the blue patches are the National Parks and National Wildlife Refuges of Alaska.

Figure 38 shows the intersection of all three Marxan approaches. These areas can be considered as most important for the predator community. Except of two small patches in the South and West of Alaska, the other patches are covered by National Parks or Wildlife Refuges.

4.Discussion

In this study, a new ecological concept of Ecosystems and Predator Ecosystem units was applied. The mega predator community as its own ecosystem unit was developed in order to present the driving spatial factors of predators amongst the mega predators in Alaska and to predict their probable future. Climate variables were taken as a main basis for the prediction, but many other features, also known to increase, have been omitted even. The range layers of the animals were corrected for errors and detectability using Occupancy models. This approach is a robust top- down view (Power 1992) of the predators and gives a clear view of those factors which are influencing the whole predator unit. Factors that influence only one of the species might be overruled by the values of the whole predator community.

In the first TreeNet model the main factors driving the Mega Predator Ecosystem unit were identified. The main influencing variables of this Ecosystem unit are “Distance to railways”, “Distance to the coast”, Distance to airways”, as well as the climate variables of “Temperature in December” and “Precipitation in June”.

The dependence of the variable “Distance to railway” may perhaps not be seen as a human influence but more as an influencing spatial variable because railways are usually located in flat or valley regions etc. The railway is visualized by only one line going from South to North, and only throughout half of Alaska; however it seems to have an important influence on predators. On the one hand it may act as a disturbingly loud mechanical intruder, which is demonstrated by the positive Partial dependence after 250 km distance from the railways. Further, railways can provide carcasses from killed animals for some predators and thus support the population. In Alaska, railways are usally free of snow, being attractive as corridors and for mushers. In Canada, railways have further been identified as bear hotspots and sinks because of leaking grain.

As it can be seen in Figure 18 the innermost temperatures in December have a positive dependence. This may lead to an important change for the predator community since the minimal temperature will rise up to -20° C until 2099 (SNAP 2010). The initial positive dependence changes into a negative dependence, a tipping point (Gladwell 2002), around -19°C, almost excluding the positive dependence for the predator community.

All Partial dependence of the distance to urban influence like roads, cities etc. seems to have a negative value at least in the first 50 km (see Figure 19 and Figure 3, 5, and 8 in Appendix 2). That could indicate that human influence is actually very high, even in regions were the human density is generally low like in Alaska. At least in the ‘western world, it is probably rather difficult to find a large landscape place more pristine and remote than Alaska, and even here we see strong human influences.

On the other hand, direct measurements of human presence, such as the Human Influence Index, show almost no importance in the model. Alaska is claimed to be one of the “last of the wild” Areas (SEDAC 2010), which would testify to the relatively minimal influence of humans in Alaska.

According to this model, most of the ecoregions, NDVI, as well as Slope and Aspect have only marginal influence on the actual predator community.

Variable importance scoring conducted using TreeNet indicated that many factors influence the mega predator community and in a multivariate fashion with interactions. It should be noted that some variables may have stronger influence on individual species than on others, and that even the variables with a smaller score still have an important influence on the predator community Some variables may influence only parts of the ecosystem community positively, with these positive effects being overlapped by the negative effects that they have on the other parts of the predator community. A TreeNet- model of one individual species may lead to different and misleading, spurious scoring of the variables. Ecology means complexity, and a valid analysis and interpretation must take it into account.

4.1 Climatic Model of the Ecosystem Unit “Mega Predators of Alaska”

In order to predict future movements of the predator community a second model was constructed. This model was based on four climate variables (see Table 4). It presented a relatively small error as it can be seen in the ROC curve (Figure 26). The Partial dependence of the four climate variables is comparable with those of the first model. The addition of more variables to this model would have increased the bias further, since other variables e.g. roads, railroads etc. undergo more unpredictable and directly human influenced changes in the future. It is pretty clear that the human footprint will not decline, any time soon.

The habitat that was identified for the predators seems to change extremely within the four described decades. In the decade 2030-2039 the optimal habitat can be found more in the North (Figure 29). During the decade 2060-2069 the habitat seems to decrease in the North and expand in patches throughout Alaska. In the final decade the main habitat can be found towards the “middle – east” of Alaska. Using climate alone, predator habitats seem to change already very fast. The drastic results as shown in Figure 12-17 of the model may not come into effect in the predicted 100 years. This model is only based only on climate data and does not include other variables such as natural succession and human activities. The latter actions are forecasted to have a massive expansion in Alaska, the Arctic and beyond, and thus, predicted effects will show even stronger.

General vegetation may not spread out in the same speed as the predator community could. This leaves the predators some refuge regions in areas without optimal climatic conditions. On the other hand, the predators could have a smaller habitat since the vegetation is not moving with the predators to climate conditions that are favorable for predators and their prey. To avoid the uncertainties, the predictive modeling of vegetation and prey species, and other features, would be necessary. This is not feasible for now because apart from the high expense, a model would be build out of ‘modeled data’ and errors can increase. The bias of such a model would probably be too high to detect conclusions, or simply indescribable. However, it makes for a great start, and platform, to complete such gaps. Model-predicting invasive species makes for a great start already.

Different plant species and also animals may enter with changing climate conditions (USDA 2010). This could lead to different ecosystems that are not suitable for some species. Predators, as the last members in the food chain, may eventually suffer due to lack of prey species and other factors.

It can be safely concluded that the Predator Ecosystem Unit will undergo severe changes in the next 100 years. This will probably result in a trophic cascade (Pace et al. 1999) and may be also accompanied by the disappearance of some predator species and habitat features. As a result, the distribution of some species with small resilience will shrink. This includes for example some traditional wilderness species like the Polar bear, but also the Wolverine and the Black bear. Some other predators like Red foxes and Coyotes may profit from the drawback of the big carnivores. Predators dependent on other predators, like for example the Arctic fox which depends on Polar bear prey carcasses might also decrease (see Chapter 1.8 for species description). It is clear that endemic species will be affected dramatically.

The emergence of pests and diseases may also pose a significant threat to the predator community. A warming climate enlarges the area of distribution of animal diseases and pests (Harwell et al. 2002). Some species, especially ones with a lower resilience compared to endemic species, may suffer from formerly unknown diseases and pests in this region against which they have no natural defenses.

The downscaled underlying predictive SNAP climate data are underestimates. The scenarios are based on IPCC-GCMs from 2007. Due to the ongoing melting of the arctic ice, it can be concluded that the actual climate change will be faster than current estimates suggest it is (Vellinga et al. 2009, Richardson et al. 2009). However these climate predictions are the most precise and reliable data that can be obtained for the Alaska region at present.

4.2 Potential Protected Areas

The first MARXAN model shows a band that encompasses the high predator occurrence in the north as it can be seen in Figure 3.1. This result can be explained as the main factors determining the predator community occurrence are optimal in the Brooks range and Yukon territory. The cost function was build to have minimum costs for implementing a reserve area. In the MARXAN model it was assumed that the costs are minimal where the habitat is optimal for the predator community. No polar bears are found in the South, which makes the solution obvious. However, southern occurrences of Polar bears have been stated in earlier times, e.g. on the Aleutians (Feldhamer et al. 2003; Schliebe et al. 2006).

The main patches of the first presented model are in the Brooks Range of Alaska. This region includes one of the highest predator densities and was never of excessive economic interest, so far.

As Figure 34 shows, National Wildlife Refuges and National Parks are already implemented in the Brooks Range. However, the implemented protected areas do not reach the MARXAN solution in that region. We show that the Brooks Range might well be one of the last wilderness areas in North America, if not in the world, with a more or less complete predator food chain.

The second MARXAN approach (Figure 35) is based on a TreeNet model, that predicted the occurrence of the predator community into the decade 2090-2099. Lesser patches of potential protected areas can be found in the South of Alaska. This MARXAN solution emphasizes again the importance of the Brooks Range and also the importance of the Yukon territory And Kobuk region. The second MARXAN Model has a predication, but is based among others on two predictive models, the TreeNet model, and also the climate model from the SNAP scenarios. Other factors in the cost function are the same as in the first MARXAN approach. The error of this model cannot be determined exactly, the results seem however consistent and should not be ignored.

The third approach of MARXAN shows the preferable protected areas for the most wilderness regions in Alaska. This approach may have two advantages. First, the nature and ecosystem in these regions are lesser influenced, and the implementation of national Parks or preserved areas is less expensive than in other regions near urban settlement. As Figure 36 shows, the main patches of potential protected areas are again in the Brooks Range. Other patches are further South than in the first and second approach of MARXAN. This patches in the South, for example one near Bethel, are not or only marginally covered by the National Wildlife Refuge or National Parks.

In all three approaches, National Parks and Wildlife Refuges in the South and middle of Alaska are often completely without, or only with few patches from MARXAN, indicating a broken food chain lacking relevant predators.

The intersection of all three MARXAN approaches emphasizes the importance of the Brooks Range. Except of two small patches in the South and West of Alaska, the other patches are covered by National Parks or Wildlife Refuges.

All of the MARXAN approaches lead to the conclusion that the current protection of the predator community is not sufficient. The area of protected land seems perhaps to be sufficient, but National Parks and Wildlife Refugees are currently not well sited at locations to guarantee the protection of the predator community.

To advance the efficiency of the protected areas for the predator community, more protected areas are needed in the Brooks Range, especially near the South, and new protected areas should be implemented in the Yukon and Alaska Range territories, and elsewhere. Again, these suggestions are only based on ‘climate’. Including more variables will make the picture more dramatic but realistic.

The approach of using an Ecological Unit “Mega Predator” as a focal conservation goal seems to be promising. This method brings together many different conservation aims composed of such issues as habitat types suitable for many animals, a coherent food chain and the suitability to such a landscape of big predator animals. This conservation attempt might not be as efficient an approach as one based on the protection of an entire ecosystem and biodiversity, but it is infinitely more efficient than opting to concentrate ones focus on only one species (see umbrella and focal species), and as widely done still, and legally implemented.

4.3 Possible Errors of the Models

A potential error might occur because the borders of Alaska are not well defined in the GIS maps. Some of the distribution maps overlapped the coastline of Alaska, though this was not an error of the projection, since all maps were projected in Alaska Albers NAD 1986, but rather an error of the base maps for the distribution maps. This error might be marginal for the developed models but it does mean that the accuracy of the TreeNet model towards the last decades is decreasing with the last two decades showing no more than 50% accuracy. Nevertheless the performance is quite acceptable to see the general trend, and it is recommend to put more effort of obtaining reliable models in the future.

4.4 Wildlife and Human- Influence

It is well known that the occurrence of big predators causes especially big problems with humans (Woodruff 2005). Humans involved in these scenarios reacted mostly with calls for reducing the “disturbers“ by hunting, control and poaching. Bears and wolves were drastically reduced throughout the European continent, as well as in North America. This shows the overlapping habitats of humans and animals. As a consequence this would signify that the habitat preferred by humans is also preferred by predators in the first place, which might be the main reason for this conflict. Most of the mega predators have omnivorous diets like humans do. On the other hand the predators are attracted by the humans and they like to consume human waste and livestock.

To manage the predator community appropriately this conflict has to be understood: before an extension of the human range is made, the existence and the probable attitude of predators have to be reconsidered both within the legal frameworks and within what is actually possible and achievable, e.g governmental funds. After that, only few true options really remain, and these must be prioritized for efficient and realistic measures.

Furthermore it has to be appreciated that within and around human settlements measures dealing with the predators have to be established; building a conscience for waste management is only one example of many. The need for management includes not only the big predators like bears or wolves, but also foxes and marten that profit from the human presence and increase in uncontrollable amounts.

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Appendix 1:

Calculating Human Influence Index

The procedures to calculate the indexes were developed by Sanderson and others (Sanderson 2002). The composite human influence index (HII) was developed out of the combination of the ***Wild/Not Wild*** scores for each of the eight input layers.

Table Appendix 1. 1 Eight input layers for the HII development

Variable category	Influence Score
Influence of Population Density/ sq. km	
0 – 0.5	0
0.6 – 1.5	1
1.6 – 2.5	2
2.6 – 3.5	3
3.6 – 4.5	4
4.6 – 5.5	5
5.6 - 6.5	6
6.6 – 7.5	7
7.6 – 8.5	8
8.6 – 9.5	9

> 9.5	10
Influence Score of Railroads	
Within 2 km of railroads	8
Beyond 2 km of railroads	0
Influence Score of Major Roads	
Within 2 km of roads	8
Within 2 to 15 km of major roads	4
Beyond 15 km of major roads	0
Influence Score of Navigable Rivers	
Within 15 km of navigable rivers	4
Beyond 15 km of navigable rivers	0
Influence Score of Coastlines	
Within 15 km of coastlines	4
Beyond 15 km of coastlines	0

Influence Score of Nighttime Stable Lights Values	
0	0
1-38	3
39 - 88	6
>=89	10
Urban Polygons	
Inside urban polygons	10
Outside urban polygons	0
Land Cover Categories	
Urban areas	10
Irrigated agriculture	8
Rain-fed agriculture	3
Other cover types including forests, tundra, and deserts	0

The Composite Human Influence Index (HII) was calculated by adding influence scores of all eight input variables. Range of HII the values goes from 0 (no human influence) to 64 (maximum human influence possible under the method).

2 Calculating the Human Footprint Score

With the equation below, the Human Footprint (HF) was calculated by normalizing the Human Influence Index across the 15 World Wildlife Fund terrestrial biomes:

$$Z = \frac{(X - X_{min}) * (X_{max} - X_{min})}{(Y_{max} - Y_{min})} + X_{min}$$

where:

Z = Human Footprint value

Xb = Input HII value in a biome

Xbmin = Minimum HII in a biome

Xbmax = Maximum HII value in a biome

Ymin = Minimum HII on Earth (0)

Ymax = Maximum HII on Earth (64)

The normalization assigns zero to minimum HII values and 100 to maximum HII values

Information from: Human influence Index and Human footprint calculated
http://sedac.ciesin.columbia.edu/wildareas/methods.jsp

Ecoregion Mapping

Detailed information at:
http://agdcftp1.wr.usgs.gov/pub/projects/fhm/akecoregions.htm

Description:

“Thirty two units are mapped using a combination of the approaches of Bailey (hierarchical), and Omernick (integrated). The ecoregions are grouped into two higher levels using a "triarchy" based on climate parameters, vegetation response and disturbance processes….The Ecoregion units are arranged in two higher levels along gradients of climate, vegetation and disturbance processes. Thirty two ecoregions fit into eight groups at Level 2, and three regimes at Level 1 (Boreal, Maritime and Polar). Please refer to the tri-archy found on the back of the published map. Written descriptions are located in the section of Overview Description, following the individual ecoregional descriptions." -Metadata from : http://agdcftp1.wr.usgs.gov/pub/projects/fhm/akecoregions.htm(2010)

Level 1	Level 2	Ecoregion
1 Polar (-like)		
	Arctic Tundra	
		Beaufort Coastal Plain
		Brooks Foothills
		Brooks Range
	Bering Tundra	
		Kotzebue Sound Lowlands
		Seward Peninsula
		Bering Sea Islands
2 Boreal (-like)		
	Bering Taiga	
		Nulato Hills
		Yukon-Kuskokwim Delta
		Ahklun Mountains
		Bristol Bay Lowlands
	Intermontane Boreal	
		Kobuk Ridges and Valleys
		Ray Mountains
		Davidson Mountains
		Yukon-Old Crow Basin
		North Ogilvie Mountains
		Yukon-Tanana Uplands
		Tanana-Kuskokwim Lowlands
		Yukon River Lowlands
		Kuskokwim Mountains
	Alaska Range Transition	
		Lime Hills
		Alaska Range
		Cook Inlet Basin
		Copper River Basin
3 Maritime (-like)		
	Aleutian Meadows	

        - Alaska Peninsula
        - Aleutian Islands

    - Coastal Rainforests

        - Alexander Archipelago
        - Boundary Ranges
        - Chugach-St. Elias Mountains
        - Gulf of Alaska Coast
        - Kodiak Island

    - Coast Mountains Transition

        - Wrangell Mountains
        - Kluane Range

Statewide Vegetation/ Land Cover

More Information’s at: http://agdc.usgs.gov/data/projects/fhm/index.html#G

Cell values and Vegetation Class Names:

0	Ocean Water
1	Water
2	Glaciers & Snow
3	Alpine Tundra & Barrens
4	Dwarf Shrub Tundra
5	Tussock Sedge/Dwarf Shrub Tundra
6	Moist Herbaceous/Shrub Tundra
7	Wet Sedge Tundra
8	Low Shrub/Lichen Tundra
9	Low & Dwarf Shrub

10	Tall Shrub
11	Closed Broadleaf & Closed Mixed Forest
12	Closed Mixed Forest
13	Closed Spruce Forest
14	Spruce Woodland/Shrub
15	Open Spruce Forest/Shrub/Bog Mosaic
16	Spruce & Broadleaf Forest
17	Open & Closed Spruce Forest
18	Open Spruce & Closed Mixed Forest Mosaic
19	Closed Spruce & Hemlock Forest
20	1991 Fires
21	1990 Fires & Gravel Bars
22	Canada/Russia
23	Tall & Low Shrub

Appendix 2: Results of the TreeNet Models

File: **Treenet.csv**

Target Variable: **PSIPJ**

Predictor Variables: VEGCLS, AKECORE, HII_N_A, HFP_N_A, ECO2, ECO1, AKASPECT, AKSLOPE, TOWNS, MEANNDVI2K, ROADS, DISTRAI, AIRRWY,

P120009, P6_0009, T120009, T60009, AKDEM30, DISTRIV, DISTOCO, DISTLAK

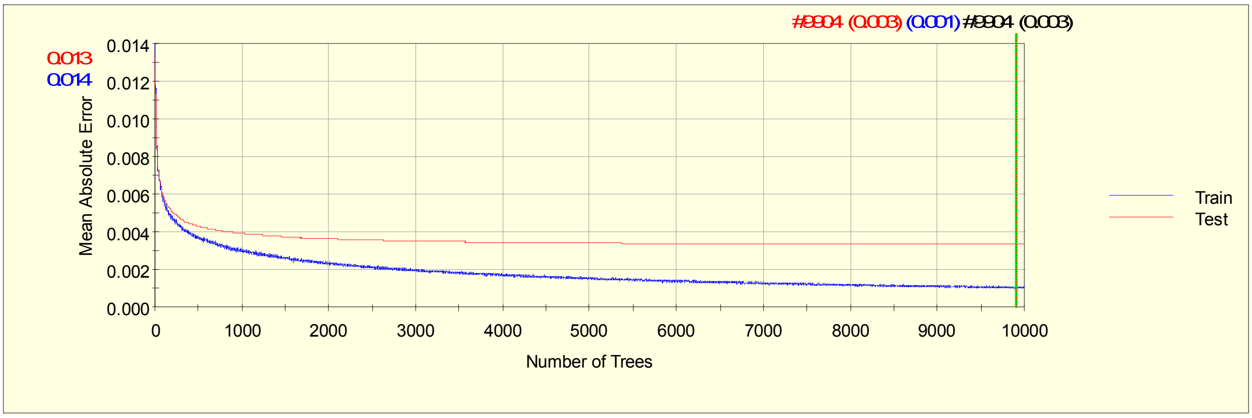

Figure App.2 _ 1: Mean Absolute Error of the TreeNet Model

Bin	Target Bin Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.089	56.63	56.63	11.00	11.00	3,156	5.15	5.15
2	0.028	17.68	74.32	22.00	11.00	3,157	3.38	1.61
3	0.015	9.68	84.00	33.00	11.00	3,156	2.55	0.88
4	0.007	4.05	88.05	43.50	10.50	3,013	2.02	0.39
5	0.007	3.86	91.91	53.50	10.00	2,870	1.72	0.39
6	0.007	3.67	95.58	63.00	9.50	2,726	1.52	0.39
7	0.005	2.77	98.35	72.50	9.50	2,726	1.36	0.29

8	**0.002**	**0.83**	**99.18**	**81.50**	**9.00**	**2,582**	**1.22**	**0.09**
9	**0.001**	**0.65**	**99.83**	**90.55**	**9.05**	**2,596**	**1.10**	**0.07**
10	**0.000**	**0.17**	**100.00**	**100.00**	**9.45**	**2,713**	**1.00**	**0.02**

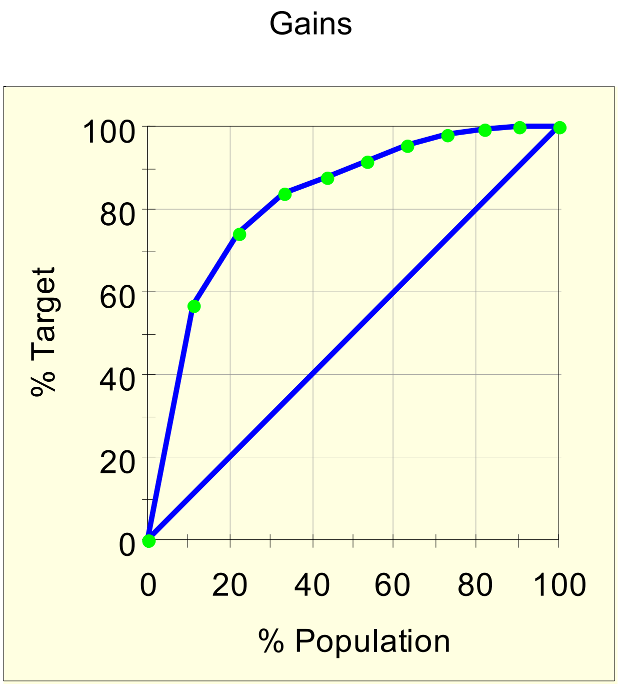

Figure App.2 _ 2: ROC- Curve

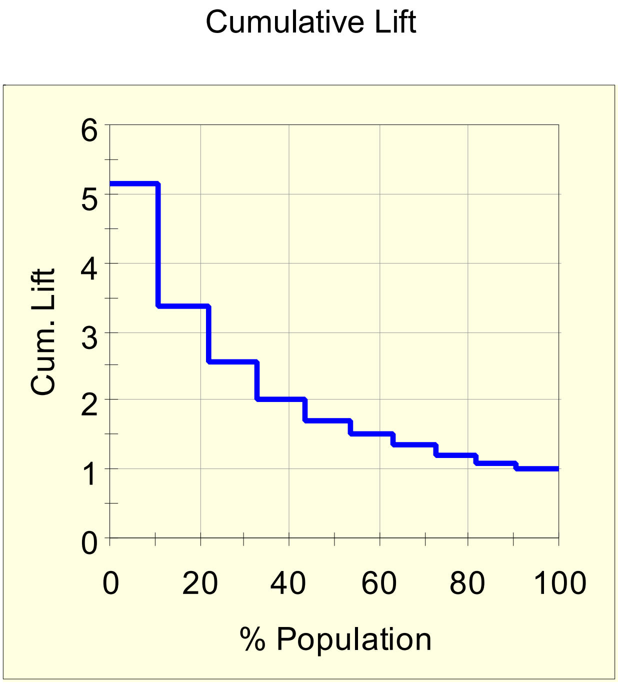

Figure App.2 _ 3: Cumulative Lift of the Data Mining- TreeNet Model

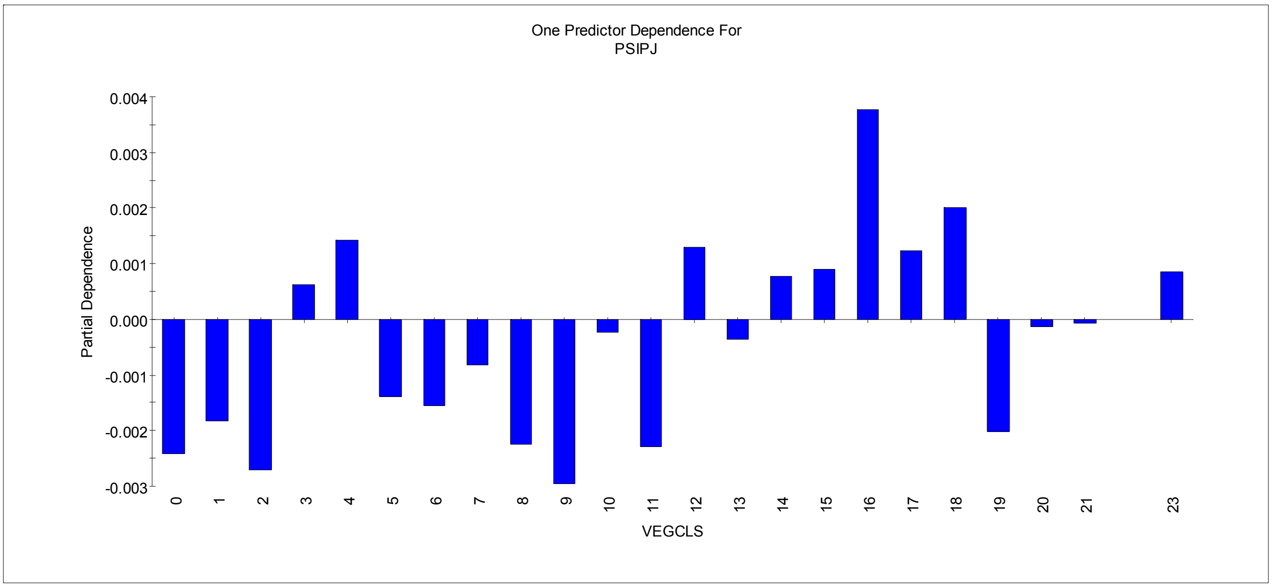

Figure App.2 _ 4: Partial Dependence of the vegetation classes. (See Appendix 1 and Methods for description)

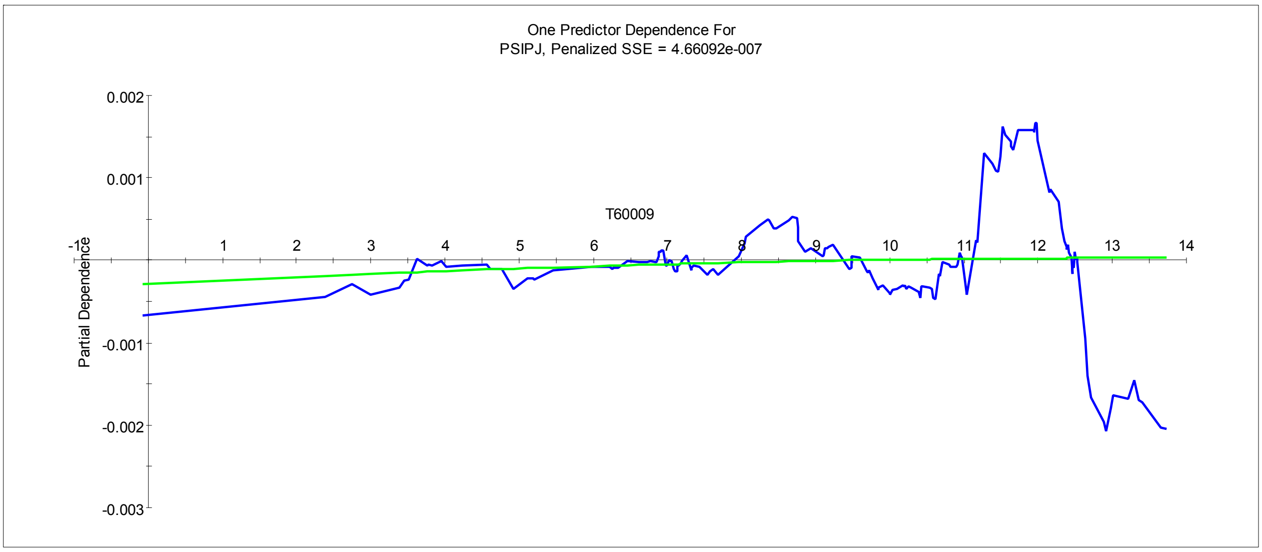

Figure App.2 _ 5: Partial Dependence of the mean temperature in June during the decade 200Partial Dependence of the mean temperature in June during the decade 2000-2009

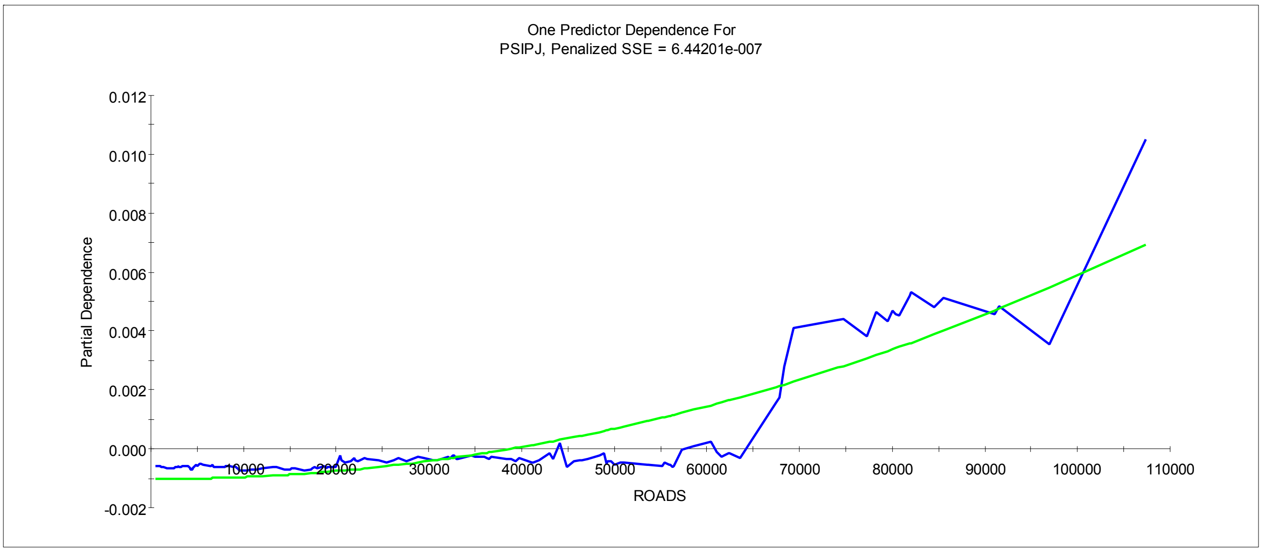

Figure App.2 _ 6: Partial Dependence of the variable “Distance to Roads”

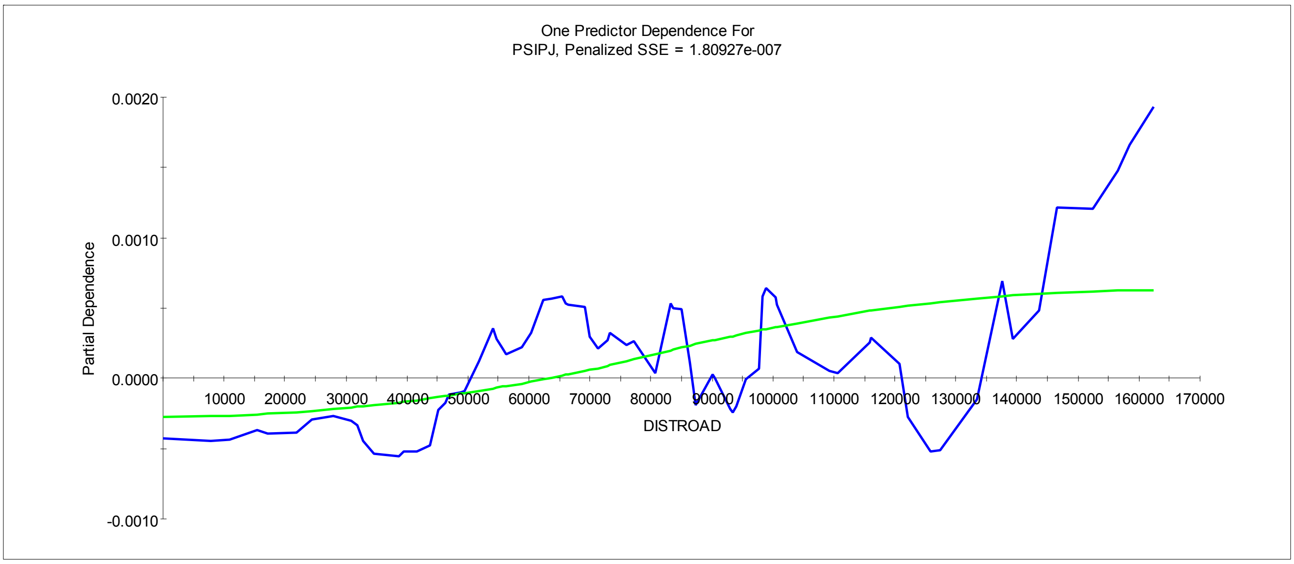

Figure App.2 _ 7: Partial Dependence of the variable “Distance to Towns”

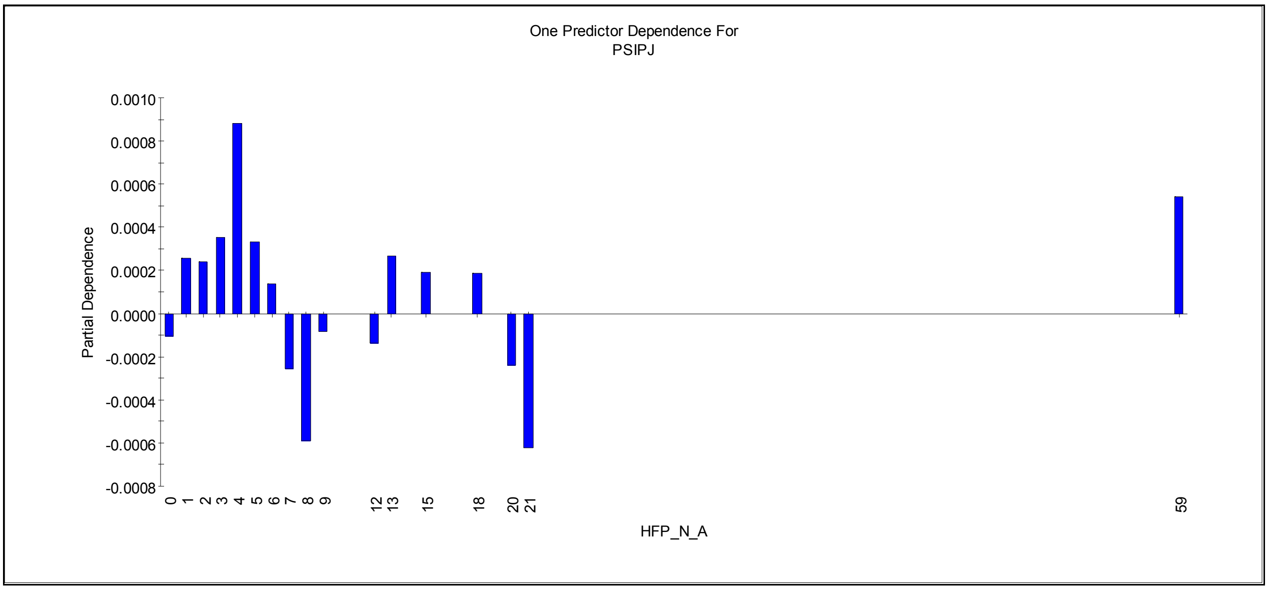

Figure App.2 _ 8: Categorial Partial Dependence of the Human Footprint

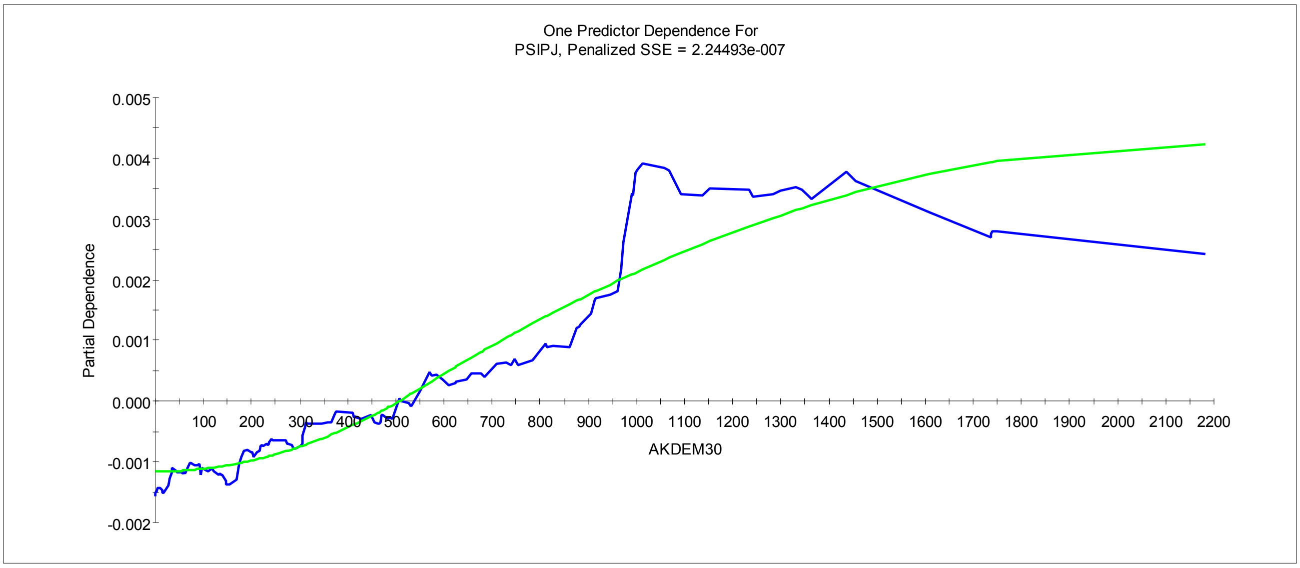

Figure App.2 _ 9:Partial Dependence of the variable “Aspekt”

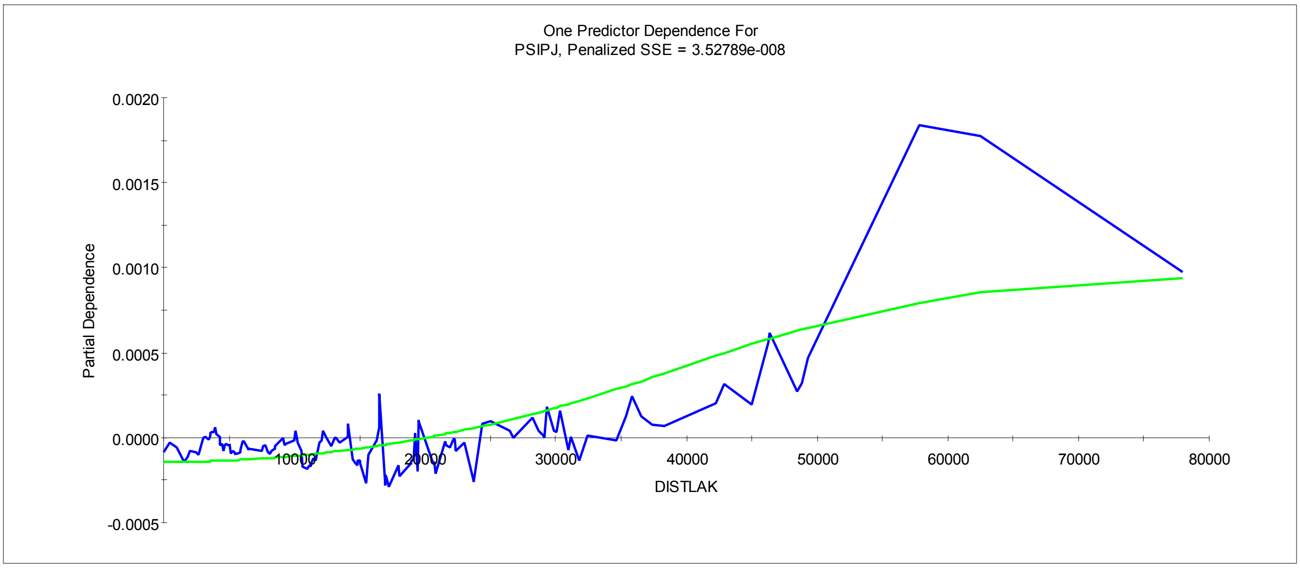

Figure App.2 _ 10: Partial Dependence of the variable” Distance to Lakes”

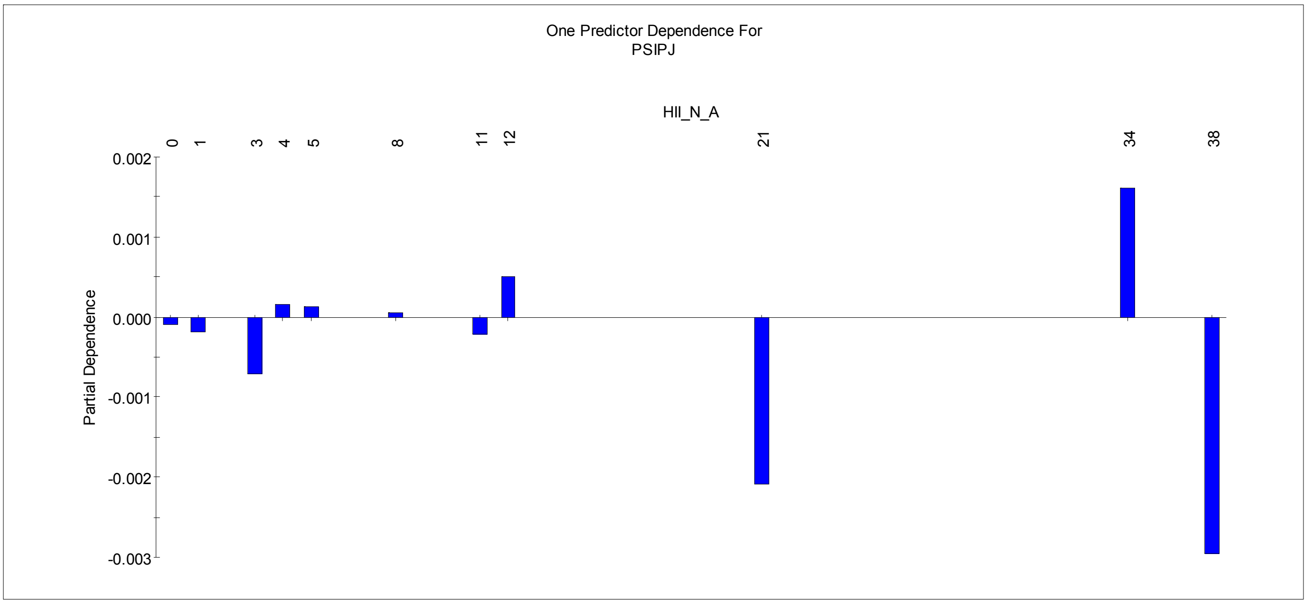

Figure App.2 _ 11: Categorial Partial Dependence of the variable “Human influence Index”

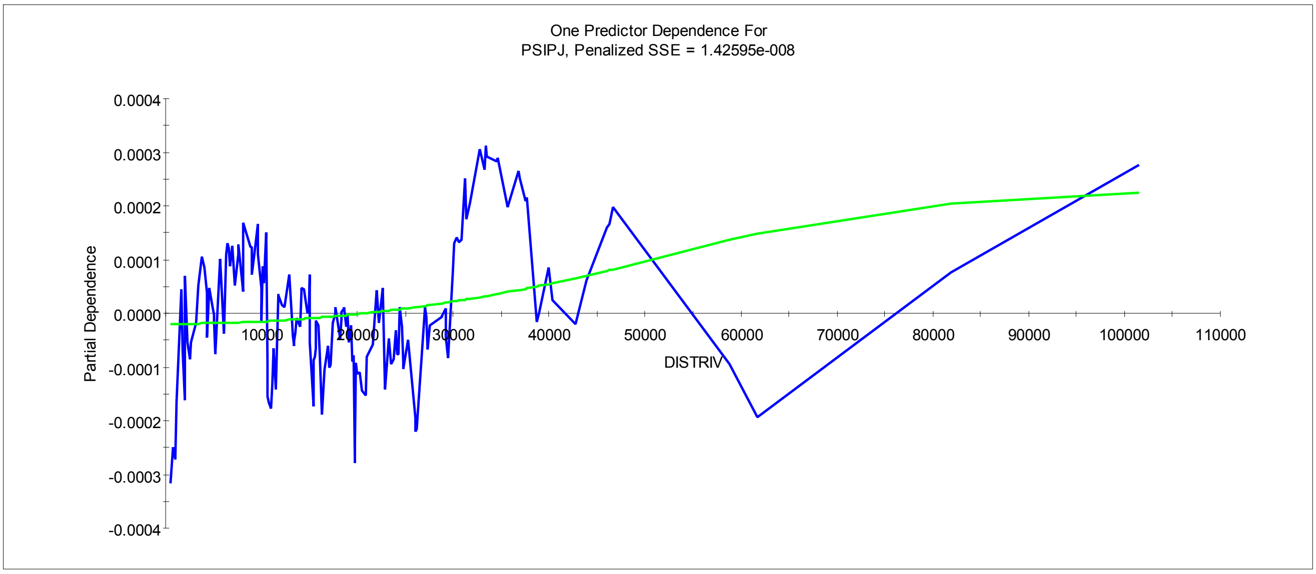

Figure App.2 _ 12: Partial Dependence of the variable “Distance to Rivers”

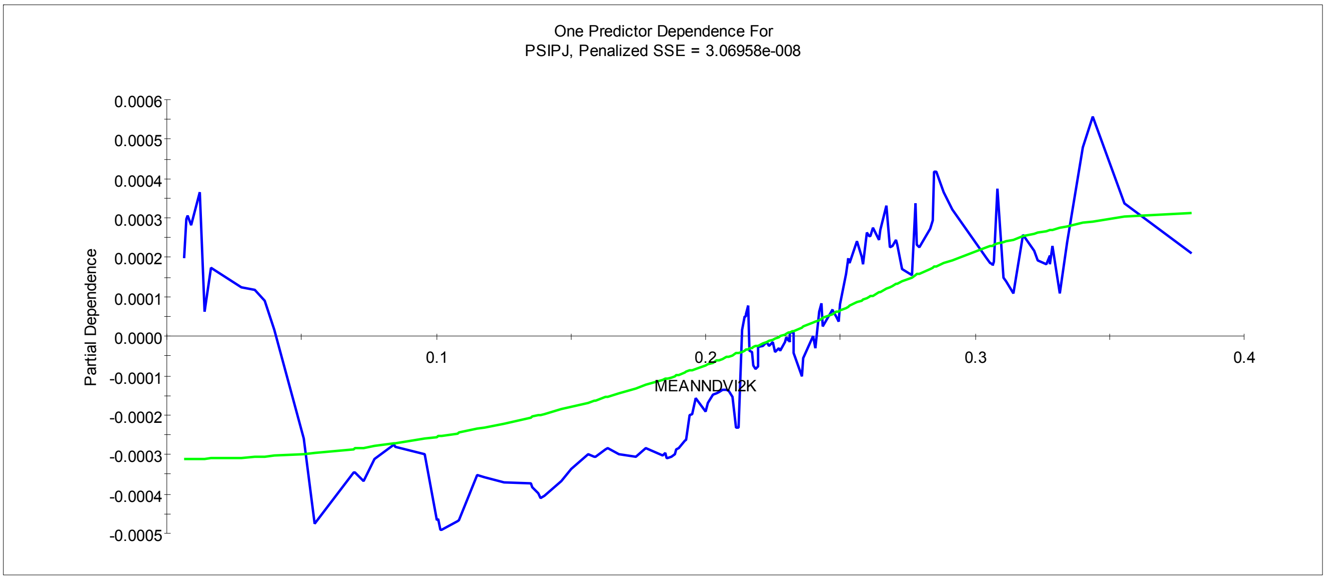

Figure App.2 _ 13: Partial Dependence of the variable " Mean NDVI of 2000"

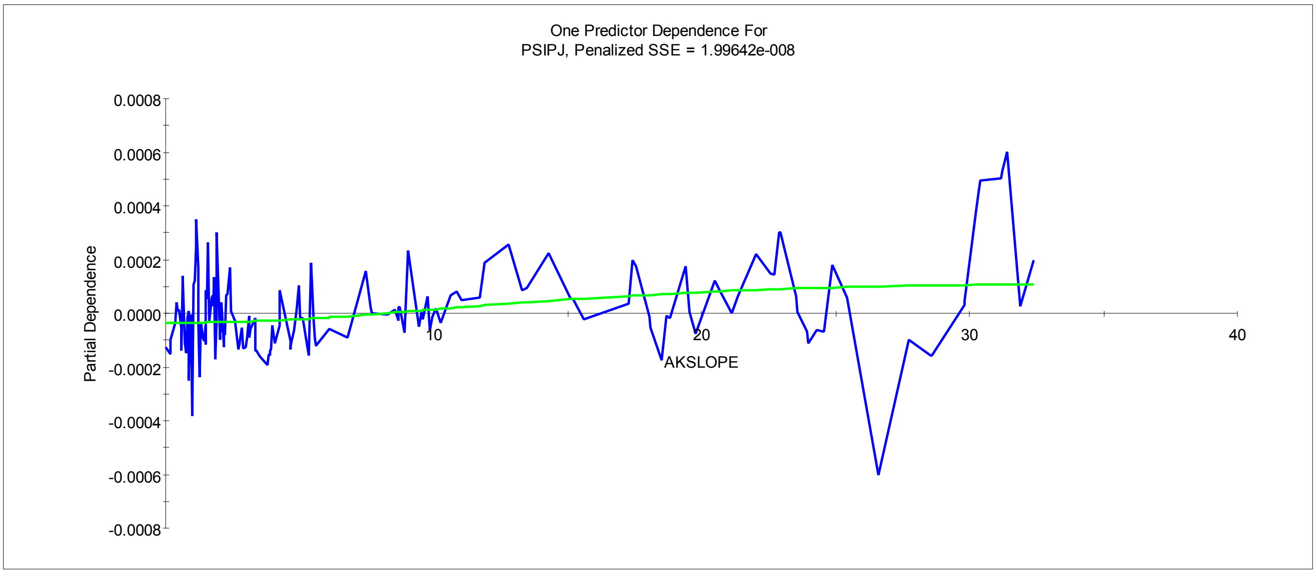

Figure App.2 _ 14: Partial Dependence of the variable "Slope"

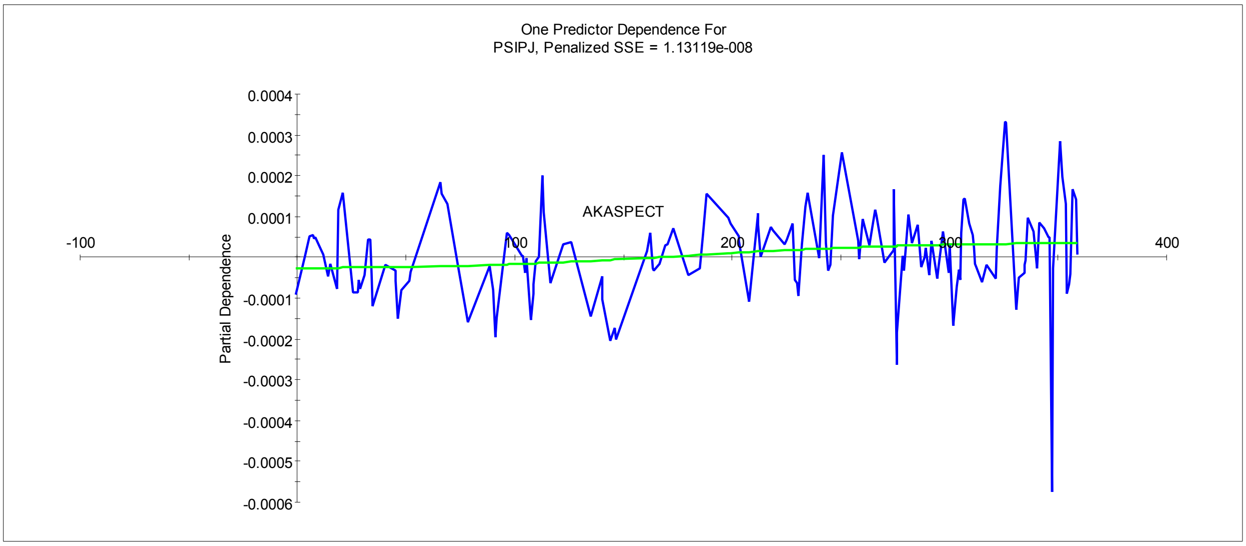

Figure App.2 _ 15: Partial Dependence of the variable " Aspect"

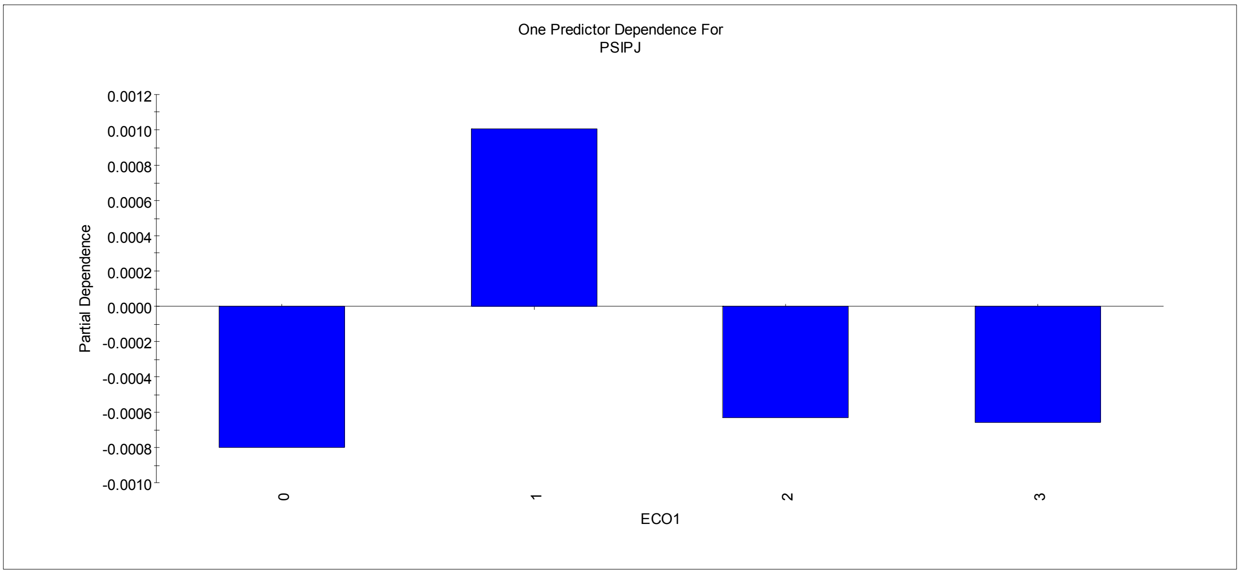

Figure App.2 _ 16: Categorial Partial Dependence of the Variable " Ecoregions category 1" see Ecoregion Mapping for explanations

Prediction Model

Mean Squared Error

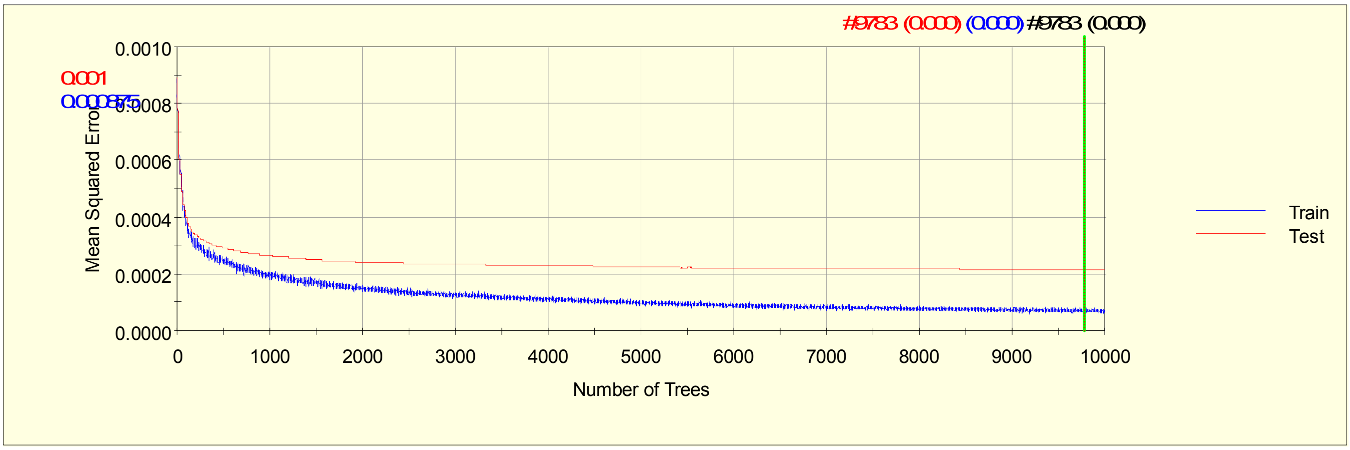

Figure App.2 _ 17: Mean squared Error of the Prediction Model

Table App.2_ 1: Table of the TreeNet Gains Data of the prediction model

Bin	Target Bin Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.085	55.80	55.80	11.00	11.00	2,521	5.07	5.07
2	0.028	18.25	74.05	22.00	11.00	2,521	3.37	1.66
3	0.014	9.13	83.18	33.00	11.00	2,521	2.52	0.83
4	0.007	4.23	87.41	43.50	10.50	2,407	2.01	0.40
5	0.007	3.97	91.38	53.50	10.00	2,292	1.71	0.40
6	0.007	3.73	95.11	63.00	9.50	2,177	1.51	0.39
7	0.005	2.99	98.10	72.50	9.50	2,177	1.35	0.32
8	0.002	0.88	98.98	81.50	9.00	2,063	1.21	0.10
9	0.001	0.64	99.62	90.52	9.02	2,067	1.10	0.07
10	0.001	0.38	100.00	100.00	9.48	2,173	1.00	0.04

Table App.2_ 2: Table of the TreeNet Gains Data of the scored Data from the decade 2000-2009

Bin	Target Bin Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.083	53.67	53.67	11.00	11.00	6,307.00	4.88	4.88
2	0.028	17.82	71.49	22.00	11.00	6,308.00	3.25	1.62
3	0.016	10.57	82.06	33.00	11.00	6,307.00	2.49	0.96
4	0.007	4.48	86.54	43.50	10.50	6,021.00	1.99	0.43
5	0.007	3.92	90.46	53.50	10.00	5,734.00	1.69	0.39
6	0.007	3.71	94.17	63.00	9.50	5,447.00	1.49	0.39
7	0.006	3.06	97.22	72.50	9.50	5,448.00	1.34	0.32
8	0.002	1.25	98.47	81.50	9.00	5,160.00	1.21	0.14
9	0.001	0.79	99.26	90.65	9.15	5,245.00	1.10	0.09
10	0.001	0.74	100.00	100.00	9.35	5,363.00	1.00	0.08

Table App.2_ 3: Table of the TreeNet Gains Data of the scored Data from the decade 2030-2039

Bin	Target Bi:n Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.041	26.68	26.68	10.99	10.99	6,303.00	2.43	2.43
2	0.030	18.15	44.83	21.50	10.51	6,026.00	2.08	1.73
3	0.023	13.85	58.68	32.00	10.50	6,021.00	1.83	1.32
4	0.020	13.08	71.76	43.00	11.00	6,306.00	1.67	1.19
5	0.013	8.00	79.76	53.50	10.50	6,021.00	1.49	0.76
6	0.010	5.95	85.71	63.50	10.00	5,734.00	1.35	0.60
7	0.009	5.21	90.92	73.00	9.50	5,449.00	1.25	0.55
8	0.008	4.04	94.97	82.00	8.99	5,156.00	1.16	0.45
9	0.005	2.56	97.52	91.01	9.01	5,167.00	1.07	0.28
10	0.005	2.48	100.00	100.00	8.99	5,157.00	1.00	0.28

Table App.2_ 4: Table of the TreeNet Gains Data of the scored Data from the decade 2060-2069

Bin	Target Bin Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.026	16.70	16.70	11.00	11.00	6,307.00	1.52	1.52
2	0.018	11.34	28.04	21.50	10.50	6,022.00	1.30	1.08
3	0.017	10.68	38.72	32.50	11.00	6,306.00	1.19	0.97
4	0.015	8.97	47.70	43.00	10.50	6,021.00	1.11	0.85
5	0.015	8.90	56.60	53.00	10.00	5,735.00	1.07	0.89
6	0.017	9.99	66.59	63.00	10.00	5,733.00	1.06	1.00
7	0.015	8.18	74.77	72.50	9.50	5,448.00	1.03	0.86
8	0.012	6.23	81.00	81.50	9.00	5,161.00	0.99	0.69
9	0.018	9.40	90.40	90.50	8.99	5,157.00	1.00	1.05
10	0.017	9.60	100.00	100.00	9.50	5,450.00	1.00	1.01

Table App.2_ 5: Table of the TreeNet Gains Data of the scored Data from the decade 2090-2099

Bin	Target Bin Avg.	% Target in Bin	Cum % Target in Bin	Cum % Pop	% Pop	Cases in Bin	Cum lift	Lift Pop
1	0.029	18.47	18.47	10.99	10.99	6,301.00	1.68	1.68
2	0.019	11.69	30.15	21.50	10.51	6,027.00	1.40	1.11
3	0.014	8.93	39.09	32.50	11.00	6,308.00	1.20	0.81
4	0.017	10.59	49.67	43.00	10.50	6,022.00	1.16	1.01
5	0.020	12.25	61.92	53.50	10.50	6,019.00	1.16	1.17
6	0.017	10.00	71.93	63.50	10.00	5,734.00	1.13	1.00
7	0.016	8.77	80.69	73.00	9.50	5,450.00	1.11	0.92
8	0.012	6.11	86.80	82.00	9.00	5,160.00	1.06	0.68

9	0.013	6.74	93.54	91.01	9.01	5,164.00	1.03	0.75
10	0.012	6.46	100.00	100.00	8.99	5,155.00	1.00	0.72

3 Appendix 3: Brief Metadata

Name of The Variable	**Format and Source**
Elevation	ArcView Image File (USGS 2009 http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz
Aspect	ArcView Image File (USGS 2009) http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz
Slope	ArcView Image File (USGS 2009 http://agdcftp1.wr.usgs.gov/pub/projects/dem/300m/akdem300m.tar.gz)
Towns	Tom Paragi, AK Fish & Game Dept Shapefile http://dnr.alaska.gov/SpatialUtility
Roads	Shapefile http://dnr.alaska.gov/SpatialUtility
Railways	Shapefile http://dnr.alaska.gov/SpatialUtility
Coast	Shapefile http://dnr.alaska.gov/SpatialUtility
Airways	Shapefile http://dnr.alaska.gov/mlw/index.htm
Ecoregions 1 and 2	Shapefile (http://agdc.usgs.gov/data/usgs/erosafo/ecoreg/index.html)
Mean NDVI from 2000	Shapefile D. C. Douglas US GS Alaska Science Center, Biology & Geography Sciences, Juneau Office download at: (http://glcf.umiacs.umd.edu/data/)

Vegetationclasses	Shapefile http://agdc.usgs.gov/data/projects/fhm/index.html#G
Rivers	Shapefile http://dnr.alaska.gov/mlw/index.htm
Temperature	ASCII (SNAP 2009) http://www.snap.uaf.edu/
Percipitation	ASCII (SNAP 2009) http://www.snap.uaf.edu/
Human Footprint	Shapefile (CIESIN 2009) http://sedac.ciesin.columbia.edu/wildareas/
Human Influence Index	Shapefile (CIESIN 2009) http://sedac.ciesin.columbia.edu/wildareas/
Alaska National Park	Shapefile http://www.nps.gov/gis/data_info
Alaska Wildlife Refuge	Shapefile http://www.nps.gov/gis/data_info

Declaration of Honor

I hereby declare in accordance with § 26 clause 6 of the Bachelor and Master examination regulation from August 27th 2002, that I conducted the submitted thesis on my own and did not use any other references and resources than cited.

Göttingen, ______________________