Seasonal Moose Habitat Selection in Minnesota

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Abstract

The moose is Minnesota's largest wild animal. In December 2012 moose were proposed as a species of special concern under Minnesota law due to their population decline (Baker, 2012). Time series analysis of the northeast Minnesota moose population estimates conducted by Lenarz (2012) found a significant decline between 2005 and 2012. Moose habitat lacks highly specific requirements, depending mostly on food availability, elevation, and climate factors. Moose have been found to live in different locations depending on the season of the year, leading researchers to question what impact long-term climate change could have on moose survival (Minnesota Department of Natural Resources, 2011). In this paper, seasonal moose habitats in Minnesota were identified using the following data: elevation, aspect, land use, tree canopy, lake and river distribution, snow depth, wetland location, and floodway location. Separate winter/spring and summer/fall habitats for moose were delineated to accommodate seasonal factors, feeding, and thermal cover requirements. Moose harvest locations were then compared to the habitat suitability results.

Introduction

Moose (*Alces alces*) are the largest members of the deer family. Their average weight is between 950 and 1,000 pounds, and they can weigh up to 1,200 pounds (Silliker, 2005). Their long legs and splayed hooves allow them to move easily in marshy areas and along streams and lakes (Hemstock, 1999). Moose are also powerful swimmers and will dive to obtain food from lake bottoms. Moose communicate by making sounds and they depend on their sense of hearing and smell more than vision (Silliker, 2005).

Moose activities are impacted by climate change, land use change, hunting and other human activities, and animal predators, such as wolves and bears. Moreover, deer *(Odocoileus virginianus)* often share moose habitat and can expose moose to brainworm infection (*Parelaphostrongylus tenuis*), which is generally fatal to moose but seldom affects deer (Peterson, 1997).

Most moose live in the forests that stretch across Canada and the northern United States. Forests not only provide moose with food and cover from predators, but also provide partial shelter from snow during the winter and heat during the summer (Silliker, 2005). Moose prefer to live near forested areas that have been cleared by fires, floods, or people, as young trees and shrubs are good sources of food. They also choose to live in wooded areas near streams, ponds, and lakes, where they can escape warm weather and find food.

In North America, moose tend to have a home-range of between 5 and 40 km^2 (Sattler, 2013). They often concentrate their time in small areas and use other areas within their range as corridors.

Moose have been found in various habitat types including wetlands, shrublands, and conifer/hardwood forests (Telfer, 1984). Based on past studies, moose choose different habitats and food depending on the season, classified as winter/spring and summer/fall. During the winter, moose feed primarily on forage plants found in open areas. Winter food includes willows (*Salix spp*.), falsebox (*Pachistima spp*.), highbush - cranberry (*Viburnum edule*), saskatoon (*Amelanchier alnifolia*), aspen (*Populus tremuloides*), and sitka mountain ash (*Sorbus sitchensis*) (Forbes and Theberge, 1993).

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During the summer, thermal cover has been reported by many researchers to be an important habitat feature for moose (Schwab, 1985; Renecker and Hudson, 1986; Demarchi and Bunnell, 1993). Wetland areas, such as lakes, rivers, and ponds, provide respite on hot days, and forests with canopy cover provide shade (Ardea Biological Consulting, 2004). This time of year, willow and herbaceous plants continue to comprise the moose diet as well as aquatic plants in the early part of the summer (Ardea Biological Consulting, 2004).

The moose is an important species to Minnesota. Historically, moose have occupied the northwest and northeast portions of Minnesota. Recently they are primarily found in the northeast. In 1985, there were almost 4.000 moose that called Minnesota home. Now there are approximately 200 left (Smith, 2007). The 2013 moose harvest season was cancelled due to their population decline (Minnesota Department of Natural Resources, 2012).

In this research, seasonal moose habitats in Minnesota were mapped. This research can help to understand moose habitat requirements and identify potential locations to protect. Identifying the seasonal habitats will hopefully assist in efforts to stop the population decline and restore moose populations in Minnesota.

Methods

Study Area

For this research, the study area was the northern portion of Minnesota, which includes the following counties: Becker, Beltrami, Cass, Clay, Clearwater, Cook, Hubbard, Itasca, Kittson, Koochiching, Lake of the Woods, Lake, Mahnomen, Marshall, Pennington, Polk, Red Lake, Roseau, and St. Louis. These areas were included because they were thought to likely contain areas with suitable land cover, canopy cover, food, and weather for moose habitat (Figure 1).

Data Collection

The data that were used in this paper included: Minnesota digital elevation model (tiled 30 m resolution), Federal Emergency Management Agency (FEMA) Q3 floodway, Minnesota Department of Natural Resources (MNDNR) 100K lakes

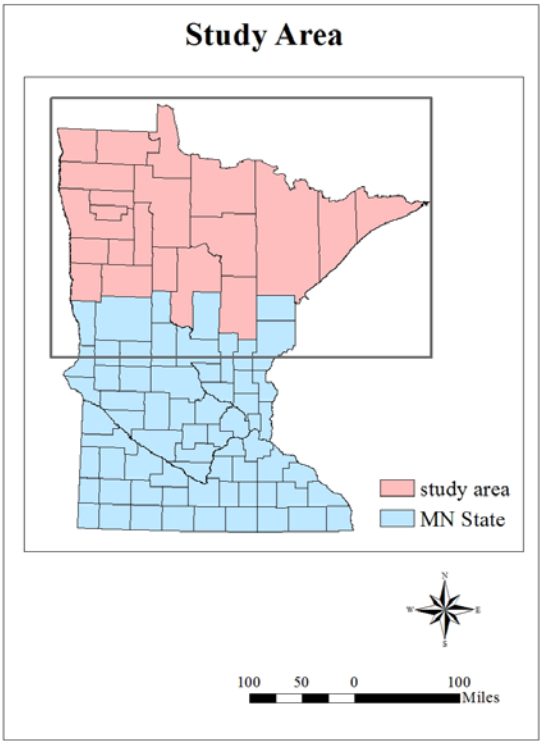

Figure 1. Twenty counties of northern Minnesota (pink) included in the project study area.

and rivers, county boundaries of Minnesota, Minnesota moose harvest data from 2006 to 2009, and wetlands of Minnesota. These data were obtained from the Minnesota Department of Natural Resources Data Deli. Average annual precipitation data from 1981 to 2010 was obtained from the Minnesota Climatology Working Group. Gap Analysis Project (GAP) land cover (tiled raster) and tree canopy datasets from the National Land Cover Dataset of 2001 were obtained from the United States Department of Agriculture. Esri's ArcGIS software was used in this research. All analysis was conducted using the North American Datum of 1983 Universal Transverse Mercator Zone 15 North coordinate system. Elevation and aspect data were extracted from the Minnesota digital elevation model. GAP land cover data

were classified by type of forest. The tree canopy dataset was classified by percentage of canopy. Lake, floodway, and wetland vector polygons were converted to raster data. Each dataset was used to classify moose habitats as good, moderate, or poor as described in the following section.

Habitat Selection

In order for habitat to be suitable for moose, it must meet both feeding habitat and thermal cover habitat requirements. Requirements vary significantly from winter to summer, which results in different habitat variables and criteria for each season's model (Ardea Biological Consulting, 2004).

Separate moose habitat models were developed for winter/spring and summer/fall. Each dataset was used to classify moose habitat as good, moderate, or poor as described in the following section. Good, moderate, and poor areas, according to each criterion, were assigned scores of three, two, and one, respectively.

Winter/Spring Habitat Selection

During winter months moose usually become less active in order to conserve energy. Finding suitable forage is very important in winter to help moose stay warm. During this time, moose habitat is limited by snow depth, elevation, aspect, forest type, and canopy cover. The following criteria were used for winter/spring habitat selection (Table 1, Appendix 1).

Elevation

Moose are often migratory, moving between low elevations in the winter and high elevations in the summer. Generally, moose can live between 400 and 1,500 ft elevation. Moose do not typically use elevations above 900 ft and elevations above 1,200 ft are considered to have too much snow for moose to live (Silliker, 2005). The Minnesota digital elevation data was used to classify areas less than 900 ft as good suitability, 900 to 1,200 ft as moderate suitability, and greater than 1,200 ft as poor suitability.

Snow Depth

During the winter, snow depth is the main limitation for the mobility of moose. Generally, "moose have low mobility in deep snow and high mobility in shallow snow" (Ardea Biological Consulting, 2004). Due to this reduction of mobility in deep snow, moose predation by wolves may increase in winters with greater snow depth (Innes, 2010). Generally, more than 28 inches (moose chest height) will make movement more difficult, with 35 inches of snow significantly impairing movement (Innes, 2010). These values were applied to the snow depth dataset to classify areas less than 28 inches as good suitability, between 28 and 35 inches as moderately suitable, and locations with greater than 35 inches as poor.

Aspect

North facing slopes will retain more snow for a longer time than warmer south facing slopes (Ardea Biological Consulting, 2004). For this reason, the suitability of south facing aspects (112.5° to 292.5°) was considered good and north facing aspects (0° to 112.5°, 292.5° to 360°) were considered poor. Flat ground was considered moderately suitable.

Forest Type

Forest type is also a consideration for snow depth. Usually, forests with high canopy closure result in greater snow depth (D'Eon, 2004). Food supply and thermal cover depend on forest type as well. In winter, shrub species and small trees are the main food source (Doerr, 1983). The land cover dataset classified areas as either coniferous, mixed, deciduous, or non-forested. Coniferous and mixed forest types were considered the most suitable due to their ability to provide thermal cover (Ardea Biological Consulting, 2004).

Tree Canopy

Canopy cover provides shade on warm days and protection from wind chill on cold days (Ardea Biological Consulting, 2004). Canopy cover can be classified as no canopy (0%), low canopy (0 – 50%), moderate canopy (50 – 75%), and high canopy (75 –100%) (MacCraken, van Ballenberghe, and Peek, 1997). Areas with canopy closure between 50% and 75% were considered good. Canopy closure less than 50% was considered moderately suitable, because it provides less thermal cover. Canopy closure greater than 75% was considered poor, because it would reduce snow melt.

Table 1: Criteria and rating of winter/spring habitat selection.

Criteria	Good (3)	Moderate (2)	Poor (1)
Elevation	< 900 ft	900 – 1,200 ft	>1,200 ft
Snow Depth	< 28 in	> 28, < 35 in	>35 in
Aspect	Warm (112.5°to 292.5°)	Flat (sites that have slopes less than -1°)	Cool (0°to 112.5°, 292.5 to 360)
Forest Type	Coniferous and mixed	Deciduous and non-forested	Others
Tree Canopy	50% - 75%	0 - 50%	75% - 100%

Summer/Fall Habitat Selection

During summer, the habitat options for moose expand. They are good swimmers and can dive underwater to feed on aquatic plants. As such, moose often live near wetlands, lakes, and rivers which can also help avoid overheating. The following criteria were used for summer/fall habitat selection (Table 2, Appendix 2).

Elevation

During summer, moose can move to elevations around 1,200 ft in search of cooler cover (Ardea Biological Consulting, 2004; Silliker, 2005).

Table 2: Criteria and rating of summer/fall habitat selection.

Criteria	Good (3)	Moderate (2)	Poor (1)
Elevation	900 – 1,200 ft	< 900 ft, 1,200 ft – 1,500 ft	>1,500 ft
Aspect	Cool (0° to 112.5°, 292.5° - 360°)	Flat (sites that have slopes less than -1°)	Warm (112.5° to 292.5°)
Forest type	Coniferous and deciduous	Mixed, non-forested, and non-vegetated	Others
Tree canopy	75% - 100%	50% - 75%	0 - 50%
Water Access	Lakes and rivers, wetlands and floodways		

Aspect

To avoid overheating, moose usually choose north-facing slopes in summer (Parker and Gillingham, 2007); therefore, locations with a north aspect were classified as good suitability. Flat sites were considered moderately suitable, and south facing warm slopes were considered poor.

Forest Type

Suitable forest types included coniferous, mixed forest, deciduous, non-vegetated,

and non-forested (Ardea Biological Consulting, 2004). Thermal cover and food provided by coniferous and deciduous forests make them especially suitable in the summer (Dungan, n.d.). Coniferous and deciduous forests were classified as good. Mixed forested, non-forested, and non-vegetated areas were considered moderately suitable, and remaining forest types were considered poor.

Canopy Closure

Avoiding overheating is a greater consideration during summer than in winter. In summer, thermal habitat is a function of canopy closure. Canopy closure between 75% and 100% is the most suitable because of the shade it can offer. Canopy closure between 50% and 75% was considered moderately suitable (Demarchi and Bunnell, 1993). Less than 50% was ranked as poor suitability.

Proximity to Water

Access to water is also important as moose can find both food and thermal cover near lakes, rivers, wetlands, and floodways (Minnesota Department of Natural Resources, 2011). Minnesota often experiences flooding in early summer. Moose prefer flooded areas during the summer where high levels of nutrients/minerals enter the soil and grow nutrient-rich aquatic vegetation (Adair, Jordan, and Tillma, 1991)

In this paper, locations within 3.6 km of lakes and rivers, wetlands, and floodway areas were selected separately. Since the size of moose habitat is usually 4 – 40 km^2, a 3.6 km buffer was chosen to approximate this size. Lakes and rivers were divided into two categories: those larger than 245 acres (Lake Area 1) and lakes and rivers between 25 and 245 acres (Lake Area 2) (Hemstock, 1999).

Comparing Model Results to Harvest Locations

In order to test the results of the moose habitat models, moose harvest locations from 2006 through 2008 were plotted on predicted moose habitat. In northeastern Minnesota, there were 160, 111, 110, and 103 moose harvested in 2006, 2007, 2008 and 2009, respectively (Figure 2).

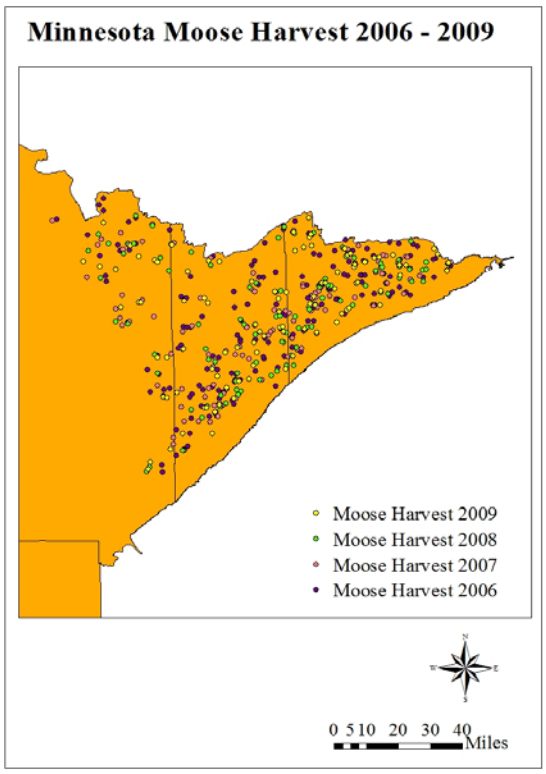

Figure 2. The purple, pink, green, and yellow points represent the Minnesota moose harvest locations in 2006, 2007, 2008, and 2009. Each point presents a single moose harvested.

Results

Based on the requirements for seasonal moose habitat, each location was ranked as good, moderate, or poor suitability for each criterion. Criteria were then combined to determine overall habitat suitability. Locations were rated good if the majority of the criteria at the location were classified as good. If the majority of the criteria in the selected areas were poorly suitable, then the overall habitat was considered as poor. The remaining areas were considered moderately suitable.

For winter habitat, 320.61 km^2 of good habitat, 8,409.27 km^2 of moderate habitat, and 78,285.08 km^2 of poor habitat

were identified (Figure 3). As the result shows, during winter, the north central and northeastern parts of the study area have the most suitable habitat. These also represent the areas where the majority of moose harvest occurred.

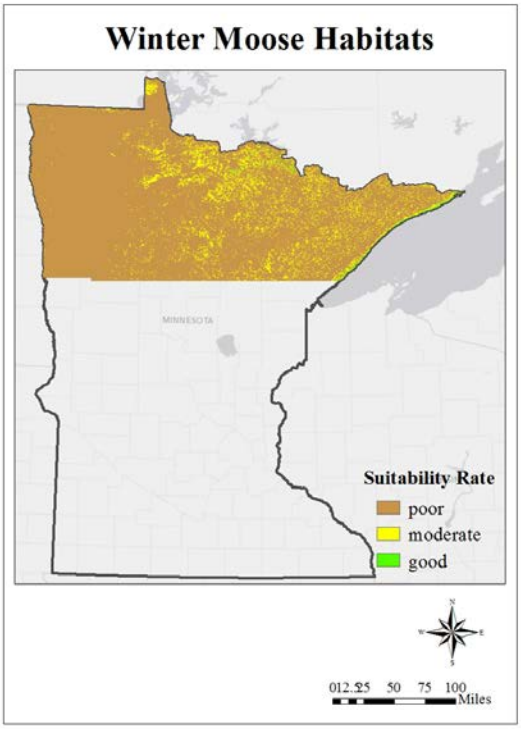

Figure 3. Winter habitat for moose in northern Minnesota.

For summer habitat in wetland areas, 5,113.2 km^2 of good habitat was noted, 8,716.6 km^2 of moderate habitat, and 112.45 km^2 of poor habitat were identified (Figure 4). As figure 4 illustrates, the most suitable habitats were located in the central north part of the study area, which has large wetlands. The moderate habitats are located in both the north central and northeastern part of the study area.

Summer habitat was also classified in floodways. Most floodways were located in the northwest and northeastern regions of the study area. In the floodway areas, 600.9 km^2 of good habitat, 4,342.7 km^2 of moderate habitat and 548.01 km^2 of poor habitat were identified (Figure 5). As shown in the figure 5, there are areas of good floodway habitat located in the

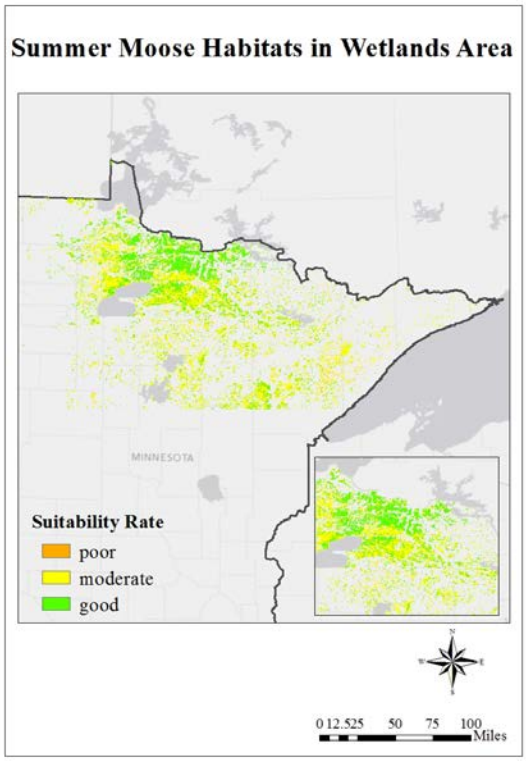

Figure 4. Summer habitat in wetland areas for moose in northern Minnesota.

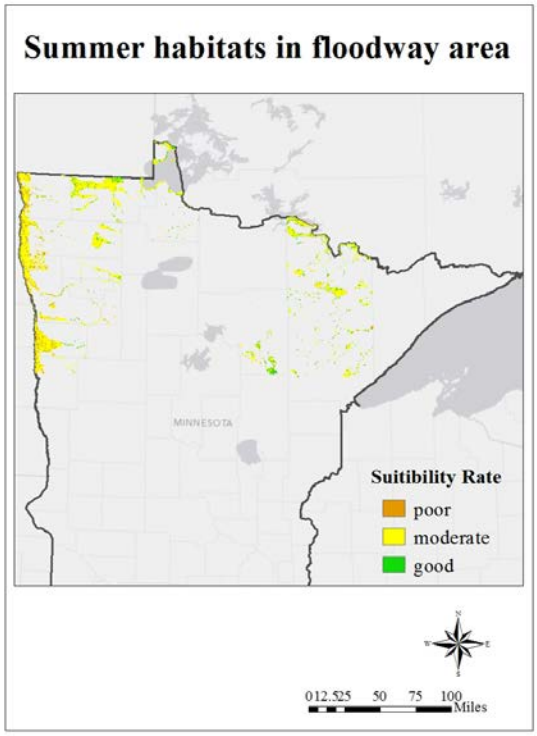

Figure 5. Summer habitat in floodway areas for moose in northern Minnesota.

north and central parts of the study area and central north region. Most of floodway locations were rated as moderate.

In Lake Area 1, the size of the lakes and rivers were larger than 245 acres. 3,621.7 km^2 of good habitat, 8,043.9 km^2 of moderate habitat, and 231.7 km^2 of poor habitat were identified (Figure 6). Most of the habitat rated as good was located in the north region of the study area.

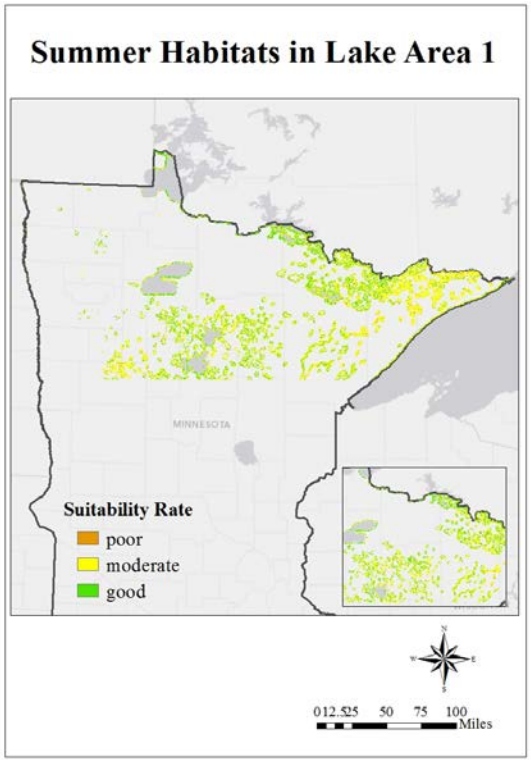

Figure 6. Summer habitat near lakes and rivers that are larger than 245 acres in northern Minnesota.

In Lake Area 2, areas surrounding lakes between 25 and 245 acres were classified. Good habitat included 2,258.41 km^2. Moderately suitable and poorly suitable habitat included 6,516.33 km^2 and 3,040.64 km^2 respectively (Figure 7). As figure 7 shows, the habitat rated as good was located in the north central region of the study area and the habitat rated as moderate was found primarily in the eastern part of the study area.

Due to the moose harvest in October, which occurs between the fall and winter seasons, the harvest locations were compared to both the summer/fall habitat and winter/spring habitat model results. Comparing the harvest locations to the winter/spring habitat results, 16.7% of points were within good and moderate habitat, 49.3% of points were within 200 ft of good and moderate habitat, and 34% of points were between 200 ft and 500 ft of good and moderate habitat. Using the summer/fall habitat results, 53.1% of points were within good and moderate habitat, 7% of points were within 200 ft of good and moderate habitat, and 5% of points were between 200 ft and 500 ft of good and moderate habitat. The remaining 34.9% of points were between 500 ft and 1500 ft of good and moderate habitat.

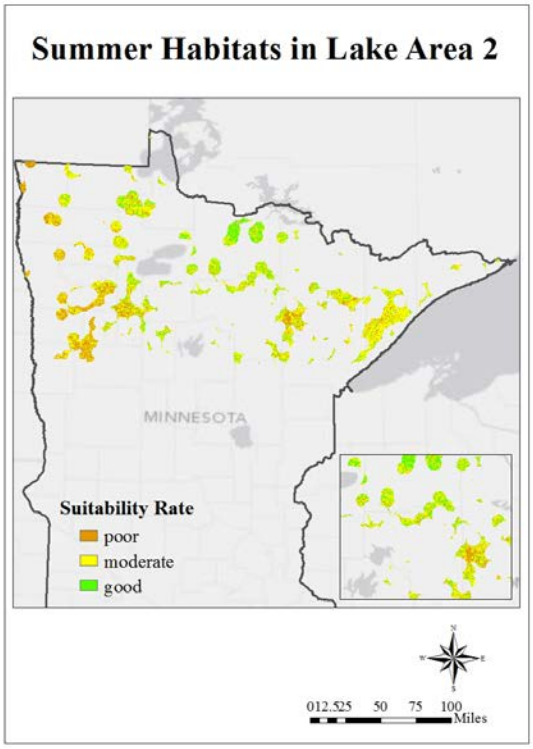

Figure 7. Summer habitat near lakes and rivers that are between 25 and 245 acres in northern Minnesota.

Discussion

In this paper, the major requirements for seasonal moose habitats were identified and analyzed. However, additional information such as locations of deer and bear populations would make the results more reliable. As the results show, by

using moose harvest data, not every known moose harvest location was located in an area that the model deemed suitable. There were also areas the model found suitable where no moose were harvested. This could be due to a variety of factors. First, moose harvest occurred only in certain areas according to state regulation. Second, the points of moose harvest only represent the place moose were killed, it does not mean moose lived there all the time.

Based on land cover type, elevation, tree canopy, and aspect, northwestern Minnesota is considered a good habitat for moose. According to federal research, increase in temperature is the main reason why moose have disappeared in northwestern Minnesota (Smith, 2007). For future studies, the effect of climate change on moose should be considered.

Conclusion

Moose have been an icon of North America, but now moose habitat has been affected by various influences such as global warming, land cover change, and human activity (Smith, 2007). In 1995, federal officials launched a five-year study in northwestern Minnesota where 4,000 moose were supposed to roam in the sparsely populated woods and grasslands. By 2003, the number had decreased to 237 (Smith, 2007). The exact reason why the number of moose declined is not clear.

Minnesota is one of the few states that has a large number of moose with a good combination of suitable forests, elevation, and weather. In this research, GIS analysis was used to identify suitable seasonal habitats for moose in northern Minnesota. 320.61 km^2 of good winter habitat, 8,409.27 km^2 of moderate winter habitat, and 78,285.08 km^2 of poor winter habitat were identified; 11,594.21 km^2 of good summer habitat, 27,619.53 km^2 of moderate summer habitat, and 3,932.8 km^2 of poor summer habitat were also identified. Most of the suitable winter habitat was found in the central and eastern part of northern Minnesota. The majority of the suitable summer habitat was located in the central northern portion of the study area. More suitable summer habitat was found than winter habitat.

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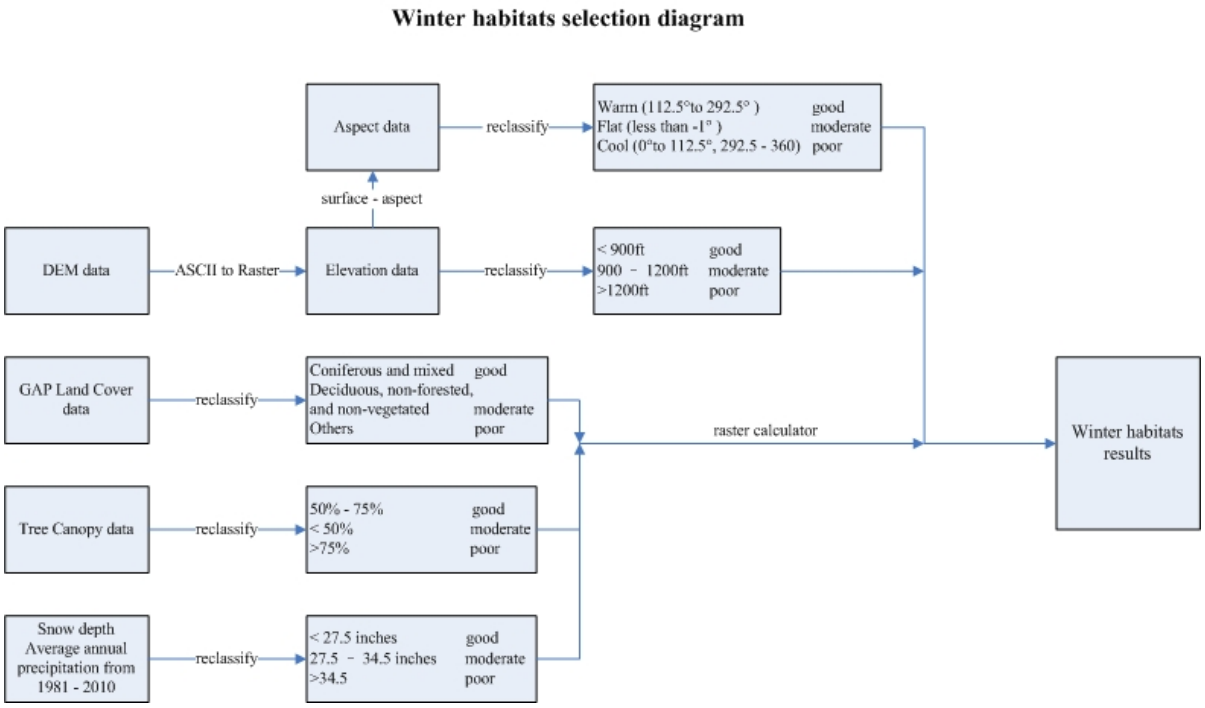
Appendix 1. This flow chart indicates the data, tools, and criteria used for the winter habitat analysis. The first column shows the data used, the arrows show the tools that were used for processing. The second column is the criteria used for analyzing habitat suitability.



Appendix 2. This flow chart indicates the data, tools and criteria used for the summer habitat analysis. The first column indicates the data used, the arrows show the tools used for processing. The second column contains the criteria were used for analyzing for habitat suitability.