Factors Influencing Spruce Tree Susceptibility to Spruce Bark Beetle (*Dendroctonus rufipennis*) Attack in the Copper River Basin, Southeast Alaska

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Abstract

Spruce bark beetles (*Dendroctonus rufipennis*) have caused widespread damage in Alaska, more specifically in the Copper River Basin of southeast Alaska. The most damage occurred between 1990 and 2000. These beetles have caused up to 275,000 hectares of spruce mortality in the Copper River Basin. Climate change seems to be exacerbating the outbreaks by creating warmer, drier conditions. A geographic information system (GIS) was used to identify areas of spruce forests that were most susceptible to spruce bark beetle attack during the late 1990s and the late 2000s. The Copper River Basin was selected as the study area because it had such a large area infested by spruce bark beetles. Five factors were used in the susceptibility model to identify areas at risk. Climate data was also used to determine temperature and precipitation ranges that corresponded with beetle attack. Of the 335,505 hectares of spruce trees in the study area, 67,791 hectares and 28,166 hectares were most susceptible in the 1990s and the 2000s, respectively. According to the climate analysis, average summer temperatures that seemed to be most preferred ranged from 9.9°C to 14.2°C, while precipitation ranged from 38 mm to 308 mm.

Introduction

Spruce bark beetles (SPB) have been a growing cause of tree mortality in North America. The most extensive spruce tree damage has occurred in Alaska, more specifically on the Kenai Peninsula and in the Copper River Basin (CRB). One of the largest outbreaks occurred throughout Alaska began in 1989 and peaked in 1996 (Werner, Holsten, Matsuoka, and Burnside, 2006). Between 1990 and 2000, an estimated 1,192,000 hectares of spruce forest in Alaska were infested by bark beetles; approximately 275,000 of those hectares were within the CRB (Bentz, Regniere, Fettig, Hansen, Hayes, Hicke, Kelsey, Negron, and Seybold, 2010). Figure 1 displays the total damage caused by spruce bark beetles between 1990 and 2011.

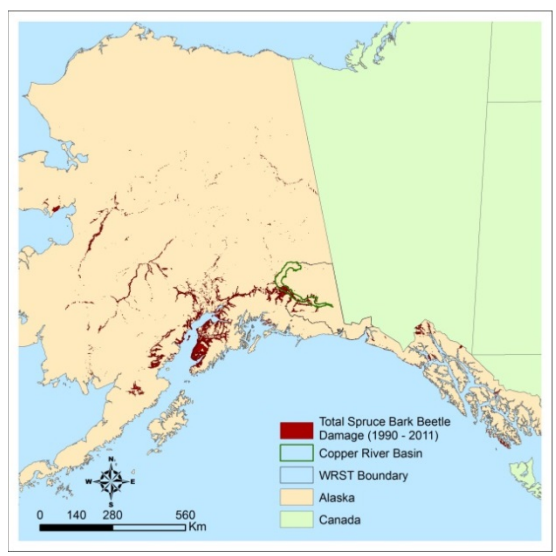

Figure 1. Total spruce bark beetle damage between 1990 and 2011 for the state of Alaska.

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Spruce bark beetle outbreaks have seemingly become more severe in the last two decades, which is thought to have been exacerbated by a 20-year drought throughout Alaska and changes in annual temperature and precipitation (Bentz *et al*., 2010).

Spruce Bark Beetle

The spruce bark beetle is a small boring beetle (approximately ¼ inch long) that lives in the phloem layer of spruce trees (Alaska Department of Natural Resources [ADNR] Division of Forestry [DOF], 2013). Spruce bark beetles have a geographic range spreading across Canada and the Northern United States (Holsten, Thier, Munson, and Gibson, 2000), but evidence of them has been observed as far south as Arizona (Werner *et al*., 2006). Generally, two to three females mate with one male beetle. Each female lays her eggs in the phloem, in a web-like tunnel called a gallery system. On average, one gallery holds 80 eggs, but can hold up to 150 eggs (ADNR DOF, 2013). The eggs grow into larvae, which feed on the phloem tissue. This process is one of the main causes of host mortality (Wermelinger, 2004). Under normal conditions, spruce bark beetles infest downed trees; however, if trees become too dry or the beetle population outgrows this food source, they will disperse to living tree hosts (ADNR DOF, 2013). The spruce bark beetle is one of the one percent of bark beetles considered to be aggressive, which means this species is capable of successfully attacking live trees (Bentz *et al*., 2010).

Climate Change Concerns

There is growing concern climate change will continue to create more favorable conditions for spruce bark beetles. Climate models predict change will be greatest at higher latitudes, such as in Alaska (National Park Service [NPS], 2011). In the Wrangell-Saint Elias National Park and Preserve (WRST) Copper River Basin (CRB) region, temperatures are projected to increase approximately 0.6°C (1°F) per decade over the next century (Scenarios Network for Alaska and Arctic Planning [SNAP], The Wilderness Society [TWS], and NPS, 2009). Figure 2 displays climate projections for the study area. Warmer, drier climate creates an added stress to spruce stands, making them more susceptible to beetle attack.

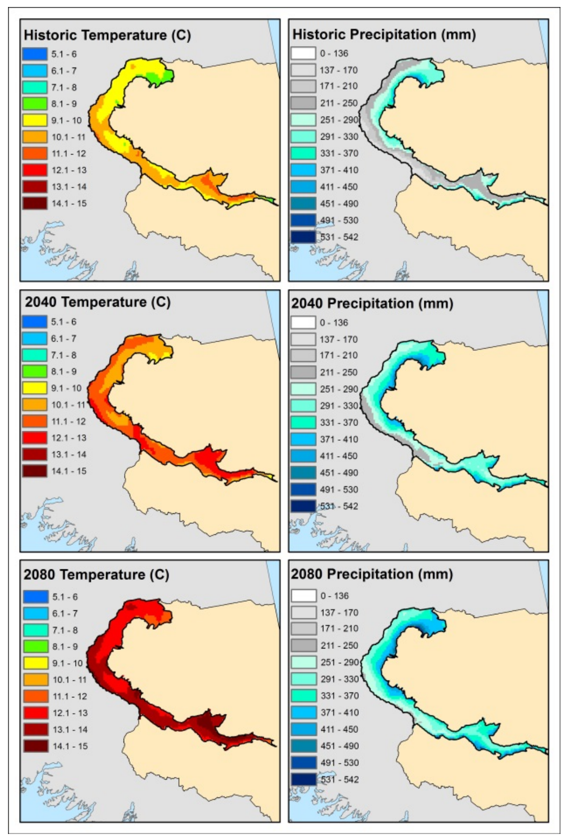

Figure 2. The climate projections including average summer temperature (°C) and total summer precipitation (mm) (SNAP *et al*., 2009). A 30-year historic average (1961 – 1990) was used for the historic climate projections.

Precipitation is predicted to increase by nine percent, but evapotranspiration is also projected to increase due to warmer temperatures. This increase in evapotranspiration coupled with a longer growing season will likely lead to an overall drier climate (SNAP *et al*., 2009).

A study by Wheeler (2006) suggests certain tree species have shifted their range to higher elevations in an attempt to adapt to climate change and insect outbreaks; however, the beetles have a fast reproductive cycle that has become shorter due to climate change. This adaptation could allow the population to follow the tree shift to higher elevations and cooler temperatures (Wheeler, 2006), thus making a spruce distribution shift ineffective.

Study Definition

The Copper River Basin (CRB) is located in southeast Alaska. The majority of the basin expands past the north and west border of WRST. The portion of the basin located within the park boundary was chosen as the study area. The CRB was chosen because of the large areas of spruce forests impacted by SPB outbreaks. The study area covers approximately 647,751 hectares. The CRB is just south of the Wrangell Mountains and occurs at a lower elevation of 137 meters to 1,289 meters above sea level. Figure 3 displays the study area in comparison to WRST.

The purpose of this project was to identify spruce forests in the CRB that were susceptible to spruce bark beetle attack in the 1990s and 2000s. Susceptibility to spruce bark beetles in the 1990s was compared to the susceptibility to spruce bark beetles in the 2000s. The susceptibility maps were then compared to the areas of damage within the study area. Temperature and precipitation in the study area were also compared to that of the actual damaged areas. This project could help managers identify susceptible areas by present stress factors, prioritize areas of high susceptibility, and determine correlations in historic climate to increased susceptibility.

Figure 3. The Copper River Basin (study area) located on the western border of WRST.

Five factors were used to determine areas of susceptibility: host species locations, rivers/floodplains (areas void of most trees and with higher water availability), proximity to previous attack, aspect, and fire history. White spruce (*Picea glauca*) is the primary host species for spruce bark beetles; however, these beetles have been known to attack all spruce in Alaska, including black spruce (*P. mariana*), sitka spruce (*P. sitchensis*), and lutz spruce (*P. lutzii*) (Wheeler, 2006). White spruce and black spruce are the only species found in the CRB. A close proximity (100 meters) to previously attacked tree stands causes increased susceptibility to future beetle attacks (Wermelinger, 2004). Beetles have been known to fly as far as 500 meters from their overwinter spot, and beetles can attack more than one host in a summer (Wermelinger, 2004). Water availability and sunlight also influences spruce tree susceptibility. In the northern hemisphere, southern aspects tend to be warmer and drier because the sunlight strikes those aspects in the afternoon when the temperature is warmer (Forest Service National Avalanche Center, 2013). Warmer and drier conditions can cause tree stress, making successful attacks more likely. Other ecological processes, mainly fire, can also cause increased stress on spruce trees, since they are not adapted to survive fire (Trowbridge, 2012). Summer temperature and precipitation were observed for each year of beetle infestation to find trends in climate over this 22 year study period. An average summer temperature greater than or equal to 10.3°C found to have a 50 percent probability of spruce beetle outbreaks (Berg, Henry, Fastie, De Volder, and Matsuoka, 2006).

Methods

Data

There were several datasets used in this research. The 2001 National Land Cover Dataset (NLCD) was the largest dataset used. The NLCD was created by The Department of the Interior and United States Geological Survey (USGS). It contained vegetation coverage for the study area at a 100 meter cell size and was used to query locations of host species.

To locate recent spruce bark beetle outbreaks and the area impacted, yearly coverages of infested areas by insects and diseases from 1990 to 2011 were used. These yearly coverages were created by the State and Private Forestry, Forest Health and Protection, and the Alaska Department of Natural Resources.

Other datasets included shapefiles of the Wrangell-St. Elias National Park and Preserve (WRST) boundary, WRST ecological subunits, and Alaska rivers and streams polylines. A fire history dataset was used, which contained historical wildland fire perimeters recorded in Alaska between 1942 and 2009. A 30 meter digital elevation model (DEM) was also used to create a hillshade and aspect to visually show topography and determine southern aspects within the study area.

Climate data included the following sets of data: Climate Research Unit (CRU) time series datasets for Alaska between 1990 and 2009, Scenarios Network for Alaska and Arctic Planning (SNAP) climate projections, and Global Historical Climatology Network (GHCN) daily climate data. CRU data was used to determine average summer temperatures and total summer precipitation for the study area. SNAP data were used to display the change in climate over several decades.

These data were collected from two sources. The yearly coverages of infested areas were obtained from the Forest Health Monitoring Clearinghouse, which is maintained by the USGS. The remaining spatial data were obtained through NPS Theme Manager, which permits users to download GIS shapefiles and rasters created by NPS.

Data Processing

Several datasets needed to be processed before analysis. The CRB and river floodplain boundaries were queried from the WRST ecological subunits shapefile and were converted into separate shapefiles. The 30 meter DEM was used to create an aspect dataset for WRST and CRB. The southern aspects were extracted from the aspect raster and converted to shapefile for additional analysis.

Each year with reported spruce bark beetle damage was queried from the insect and disease coverage dataset. SPB damage shapefiles were combined into total damage areas for four time periods: 1990 – 1995, 1996 – 2000, 2001 – 2006, and 2007 – 2011. The aggregations of 1990-1995 and 2001 - 2006 were used to predict susceptibility in the latter half of each decade. The aggregations of 1996 – 2000 and 2007 – 2011 were used to display areas of actual damage in comparison to the susceptibility model.

A multiple ring buffer was then created from the two sets of SPB damage data from the early part of each decade (1990 – 1995, 2001 - 2006). The distances used for this layer consisted of 100 meters, 500 meters, 1000 meters, and 2000 meters. Distances were determined by using beetle flight distances suggested in the literature. The multiple ring buffer was used to display beetle flight capability of five years. The shorter the distance of the buffer, the more susceptible stands of trees become. Fire history data was only aggregated into two time periods (1990 – 1995, 2001 – 2006). Fire history was split into these two aggregations for predicting susceptibility in the latter half of each decade.

The NLCD dataset was used to extract white spruce, black spruce, and mixed spruce classes into three classes (white spruce, black spruce, mixed spruce).

Data Analysis

This analysis required five spatial layers to be created representing five factors influencing spruce tree susceptibility to spruce bark beetle attack. The five layers were host species, river constraint, southern aspects, proximity to previous infestation, and fire damage. Two of the five spatial layers were unioned together. The “host species” spatial layer combined the three host species shapefiles (white spruce, black spruce, and mixed spruce). The “river constraint” layer combined the WRST river shapefile, a 5 meter river buffer, and the Copper River floodplain. The “aspect”, “proximity”, and “fire damage” spatial layers reflected the reclassified southern aspect shapefile, the 1990 – 1995 SPB damage multiple ring buffer, and 1990 – 1995 fire damage shapefile, respectively.

Next a “value” field was added to each spatial layer. Values from -999 to 5 were assigned to represent a level of susceptibility; -999 was the value that represented restricted or not susceptible, while five represented the most susceptibility. A different value was given to each category within each spatial layer with the exception of the fire damage layer. The fire damage layer only contained one category (all damage). Table 1 displays the values given for each spatial layer.

Table 1. The values assigned to each attribute within each of the five spatial layers.

Spatial Layer	Category	Value
Host Species	White Spruce	3
	Mixed Spruce	2
	Black Spruce	1
River Constraint	Rivers	-999
	Rivers buffer	-1
	Floodplain	-1
Proximity	100 meters	4
	500 meters	3
	1000 meters	2
	2000 meters	1
Aspect	Southern Aspects	1
	Other Aspects	-1
Fire Damage	All damage	1

An overall weight was then formulated for each spatial layer. The spatial layers were given a Critical Importance Rating (CIR) from one (least important) to five (most important). Those rankings were fire damage (1), aspect (2), proximity to previous infestation (3), river constraint (4), and host species (5). Rankings were chosen by determining which of the factors had most influence over susceptibility. Tree host was the most important because beetles need a host to survive. Rivers and floodplains were ranked as second most critical because spruce cannot grow in the river, and the floodplain may provide water availability thus reducing susceptibility. Next, proximity to previous infestation does not always lead to infestation; however, it does increase susceptibility. Aspect was then chosen because there was little variation in slope in the study area, so aspect was not predicted to impact the area as much as host and proximity. Fire damage was ranked last because fire damage does not always result in infestation. The impact of fire damage depends on severity, because a low severity fire may weaken tree defenses, but a severe fire event may cause so much damage that it becomes uninhabitable.

A "total value" field was created. Values for each layer were summed to provide a numerical susceptibility value for mapping. Next, a weight field was calculated using the product of the total value field and the CIR field.

After the weight fields were calculated, all five spatial layers were aggregated with a union. Next, a potential cost surface (PCS) field was added to the final combined spatial layer and calculated using the sum of the five weight fields. The final combined spatial layer was then clipped to the CRB boundary and classified using the PCS value. Table 2 displays the range and label given to each class. The same procedure was used with 2001-2006 SPB damage data and fire history data to determine susceptibility for the 2000s.

Table 2. The ranges of PCS values and the associated susceptibility label.

Range	Label
-999	Not Susceptible
-998 – 5	Least Susceptible
6 – 12	Less Susceptible
13 – 18	Susceptible
19 - 25	Most Susceptible

Climate Analysis

Climate data was used as a supplement to the analysis on spruce tree susceptibility. The CRU and GHCN datasets were used with the analysis to display any possible trends in summer temperature and precipitation over the study period in comparison to actual spruce bark beetle damage.

Results

Spruce Coverage

Spruce forests cover approximately 51 percent of the study area with 335,505 hectares (Figure 4). There were three types of spruce forest stands classified: white spruce, mixed spruce, and black spruce.

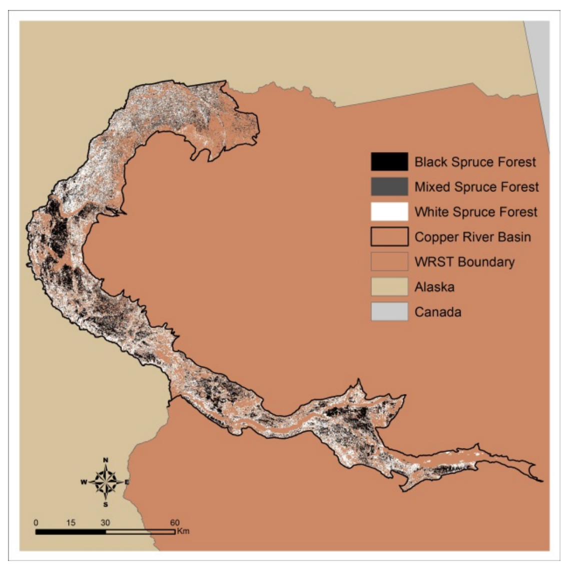

Figure 4. Spruce forests including white, black, and mixed spruce stands in the Copper River Basin (CRB).

White spruce stands covered most of that area (202,790 ha), while mixed spruce stands covered the least amount of area (43,699 ha). Black spruce stands covered a little less than half the area that white spruce forest covered (108,152 ha).

Spruce Bark Beetle Damage

Spruce bark beetle damages were recorded for the Copper River Basin between 1990 and 2011. There were 18 years of beetle damage documented; four years of damage were not documented due to the lack of spruce beetle damage during those years (Appendix A).

Spruce bark beetle damage affected approximately 30 percent of the study area throughout the 22 year study period. Damage within the study area accounted for 87 percent of the beetle damage that occurred in WRST. Total damage within the park amounted to 226,082 hectares, while 197,065 of those hectares occurred in the study area.

Spruce beetle damage in the CRB was first documented in 1991 with a total damaged area of 9,752 ha. With an exception of 1992 (5,119 ha) and 1994 (9,768 ha), the outbreak seemed to be spreading until 1996. The outbreak peaked in 1996 with 55,985 hectares damaged. In 1997, damages were considerably lower than those of the previous two years. By 1999, yearly damage was approximately 16,240 hectares. At the start of the 2000s, spruce bark beetle damage was approximately a third this size of what it was at the beginning of the 1990s. Damages did not exceed 5,000 hectares for any one year's worth of data during the 2000s. By 2010 and 2011, damaged areas resulted in 686 hectares and 317 hectares, respectively. Figure 5 and Figure 6 display total spruce bark beetle damage between 1990 and 2011; damages were divided into two 11-year periods (1990-2000 and 2001-2011).

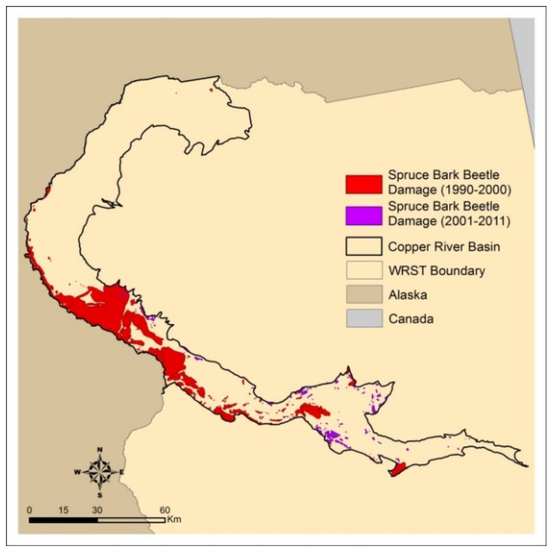

Figure 5. Spruce bark beetle damage occurring between 1990 and 2011 in the study area.

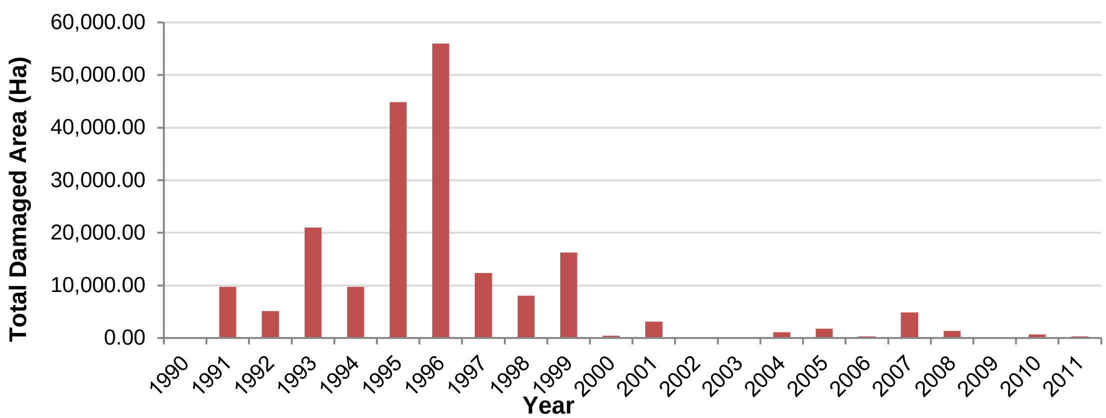

Figure 6. Total spruce bark beetle induced damage in the study area between 1990 and 2011.

Fire Damage

Fire damage did not occur as often as bark beetle damage. The only years that had recorded fire damages were 1990, 1993, 1995, and 2009. The largest fire event occurred in 2009; it impacted an estimated 56,413 hectares. Smaller fire events impacted 156 hectares, 66 hectares, and 418 hectares in 1990, 1993, and 1995, respectively. All recorded fires were said to be caused by lightening (USGS, 2010). Figure 7 displays fire damage that occurred between 1990 and 2000, and between 2001 and 2009.

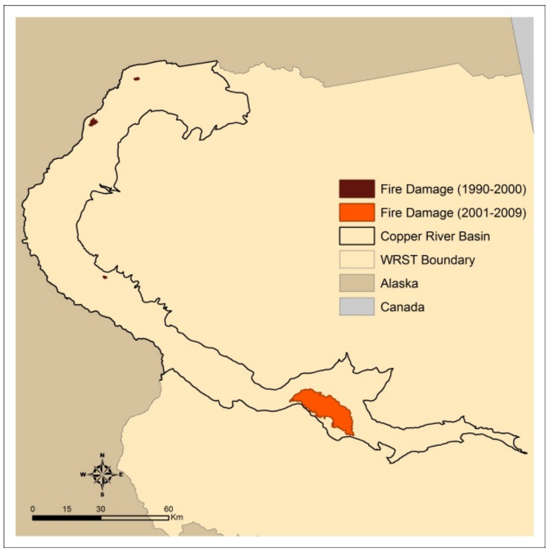

Figure 5. The total fire damage that occurred between 1990 and 2009 in the study area.

Susceptibility Analysis

The area classified as “most susceptible” in the 1990s analysis covered 67,791 hectares. There was a larger area (160,525 ha) of “susceptible” spruce forests. Analysis determined 226,942 hectares of the 335,505 hectares of spruce forest were considered “least susceptible” to beetle attack. Table 3 displays susceptibility classifications, sizes of those areas, and percent of actual damage within the predicted susceptibility classification. Figure 8 and Figure 9 display spruce tree susceptibility in the Copper River Basin for the 1990s and 2000s, respectively.

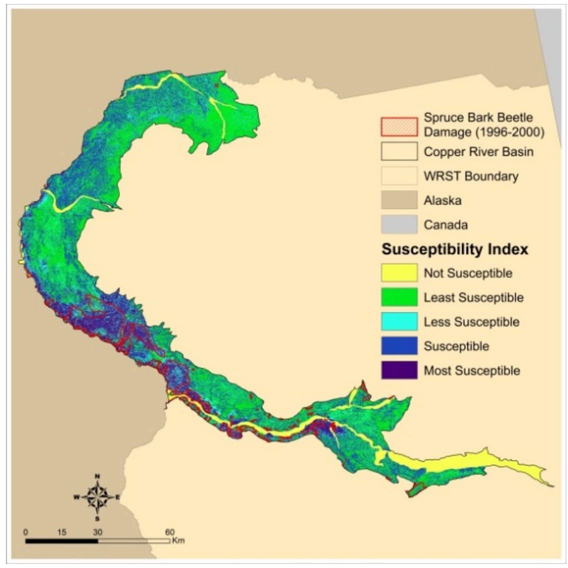

Figure 6. Spruce tree susceptibility including areas of spruce that area most susceptible, susceptible, less susceptible, least susceptible, and not susceptible from 1990 to 2000.

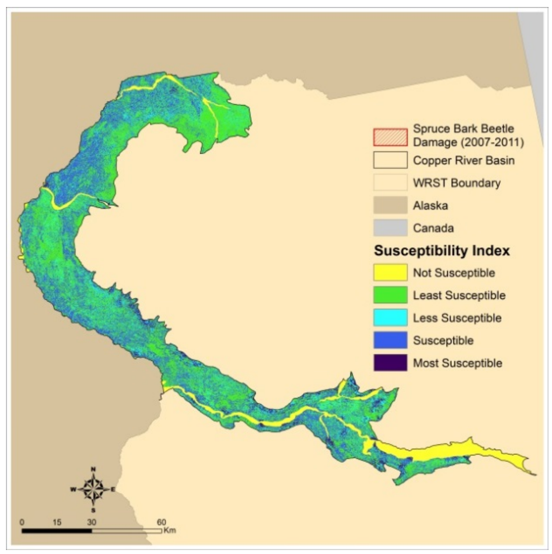

Figure 7. Spruce tree susceptibility including areas of spruce that area most susceptible, susceptible, less susceptible, least susceptible, and not susceptible from 2001 to 2011.

Table 3. Classifications of spruce tree susceptibility and the size of the area (ha) with the associated susceptibility for the 1990s (left) and 2000s (right) analyses.

Classification	Area (ha) - 1990s (Percent Actually Damaged [%])	Area (ha) - 2000s (Percent Actually Damaged [%])
Most Susceptible	67,791 (62%)	28,166 (11%)
Susceptible	160,525 (17%)	174,154 (3%)
Less Susceptible	90,433 (33%)	73,211 (8%)
Least Susceptible	266,942 (40%)	309,787 (25%)
Not Susceptible	61,932 (23%)	61,392 (19%)

There was a considerable decrease in area classified as "most susceptible" and "susceptible" in the 2000s analysis. The "most susceptible" area covered 28,166 hectares. There was a larger area (174,154 ha) of "susceptible" spruce forests. The analysis determined 309,787 hectares of the 335,505 hectares of spruce forest were considered "least susceptible" to beetle attack. For the area the 1990s model classified as most susceptible, 62 percent was actually damaged. Only 11 percent of the area the 2000s model considered most susceptible was actually damaged.

Climate

CRU climate data was documented for 20 years between 1990 and 2009. Ranges in summer precipitation and temperature were used to compare the climate of damaged areas and the climate of the entire study area.

Total summer precipitation was higher in the study area than those of the damaged areas. Differences in precipitation range were smaller in the damaged areas than the study area. Total summer precipitation dropped as low as 36 mm in some areas and as high as 558 mm in other areas in the study area. Total summer precipitation in the damaged areas had a low of 38 mm and a high of 308 mm. Figure 10 displays differences in precipitation between damaged areas and the study area.

Average summer temperatures in the damaged areas were higher than those of the study area. Differences in range were smaller in the damaged areas than in the study area. Average summer temperatures dropped as low as 7.2°C in some areas and up to 14.4°C in the Copper River Basin, but average temperatures only dropped as low as 9.97°C and as high as 14.2°C in the damaged areas. Figure 11 displays differences in temperature range between damaged areas and the study area.

Appendix A displays all total summer precipitation ranges and average temperature ranges from 1990 to 2009. Twelve of 16 years had average temperatures that were above 10.3°C. Temperature averages that are equal to or greater than 10.3°C were found to have a 50 percent probability of beetle outbreaks in a previous study (Berg *et al.*, 2006).

Discussion

Determining the factors influencing spruce tree susceptibility to spruce bark beetle attack is very important to the future health of spruce forests and their associated ecological communities. There are many factors influencing susceptibility. The 1990s susceptibility map suggests the 1990-1995 data seemed helpful in predicting forest areas that were most susceptible during the 1996-2000 time period. The 2000s susceptibility map displayed predicted forest areas that were most susceptible using the 2001-2006 data

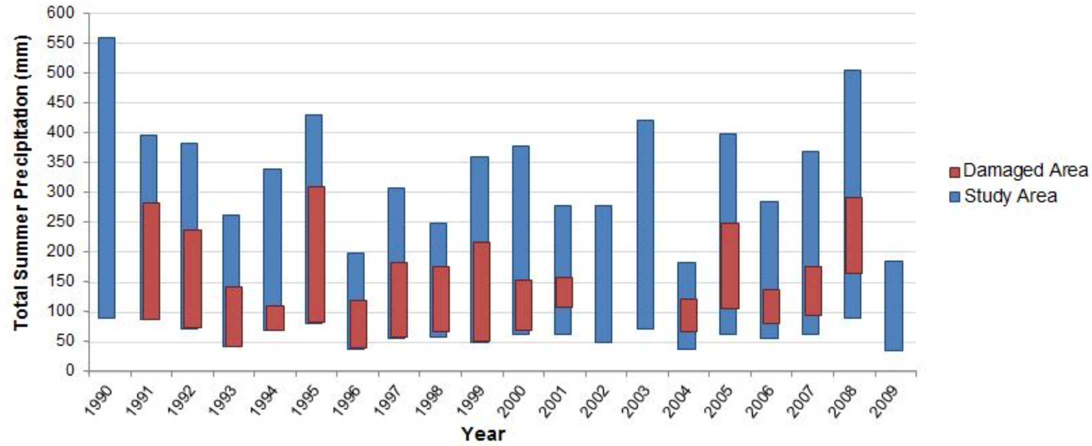

Figure 8. Total summer precipitation ranges in damaged areas and the study area between 1990 and 2009.

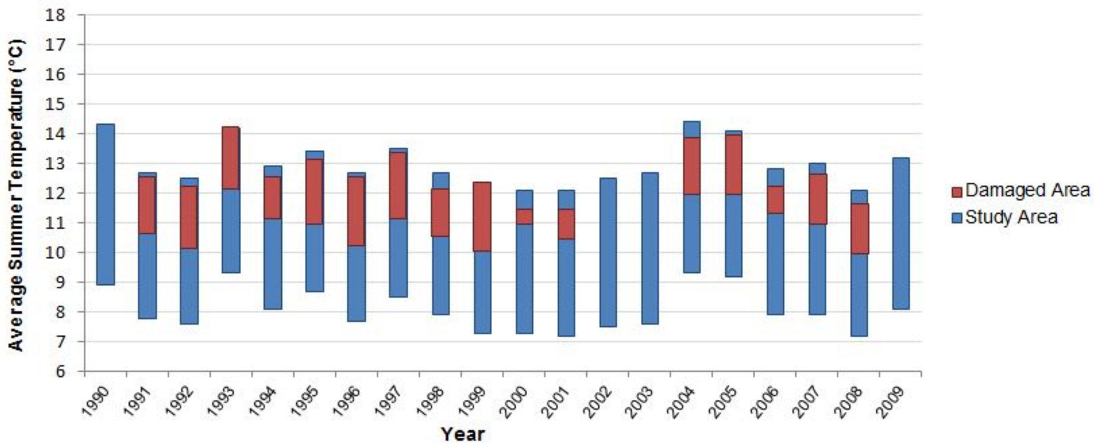

Figure 9. Average summer temperature ranges in damaged areas and the study area between 1990 and 2009.

to predict susceptibility for the 2007-2011 time period.

The areas of susceptibility to spruce bark beetle in the 1990s were considerably different than those in the 2000s. The bark beetle outbreak in the early half of 1990 was one of the largest outbreaks to affect the CRB, which caused the area of susceptibility during the latter half of the 1990s to be much larger than in the 2000s. In the 1990s and 2000s, the area most susceptible totaled 67,791 hectares and 28,166 hectares, respectively.

Susceptibility maps displayed similar amounts of damage (hectares) to those areas with actual damage; however, not all of the areas that were classified as most susceptible and susceptible were located in the same locations as damage was found. The susceptibility map predicted susceptibility throughout the study area due to available tree hosts. The actual damaged areas seemed to be in a more compact area, and a majority of the damage occurred in the southwestern portion of the study area. This could be due to the climate variations in the study area. According to the climate data, the northern portion of the study area seems to be cooler and receive more precipitation than the southwest portion of the study area.

The climate data was helpful in understanding the importance of average summer temperatures and total precipitation in influencing bark beetle success and tree stress. Climate comparison between damaged areas and the study area may be helpful in showing preferred average summer temperature and precipitation ranges. The temperature ranges in the damaged areas had a smaller difference and were warmer on average. The precipitation range within damaged areas were lower than the overall study area. This suggests outbreaks occurred in warmer, drier areas of the CRB.

A few datasets would have made the analysis more accurate. The NLCD dataset used to make the spruce tree coverages was from 2001. It was the only dataset available. A land cover dataset from the early 1990s would have shown the extent of the spruce forests before the initial outbreak in 1990.

Factors used in this analysis were helpful; however, dynamics of beetle attacks and host tree susceptibility are very complex. Other datasets and attributes that would provide a more thorough susceptibility analysis include density of tree stands, individual tree diameter, tree age, long term drought data, and long-term weather stations with consecutive precipitation and temperature data.

There was substantial data processing contributing to this analysis. There is a possibility that error occurred during the processing, which may have increased threats to internal validity of the data. When extracting spruce attributes from the NLCD dataset, some records could have been missed or accidentally deleted. Missing records may not have been visible during this analysis due to the large study area.

Recommendations for future work would include a study on the factors that influence bark beetle populations, such as population size of beetle predators and location of beetle predators. This study could also be repeated with a smaller section of the study area and with well-distributed weather stations that more accurately represent that location. The size of the CRB and large range in annual precipitation and temperature observed make it impossible for any single weather station to represent the entire study area.

Further analysis could include daily climate data from several stations to determine if there are is a daily minimum summer temperature that could deter beetle flight and attack.

Conclusion

There are many factors influencing tree susceptibility to beetle attacks. The purpose of this study was to determine factors that influence spruce tree susceptibility to spruce bark beetle attacks. Location/availability of host species, proximity to previous attack, aspect, fire events, and seasonal climate patterns were five factors used in this analysis. The results appeared to provide a good initial indication of spruce bark beetle susceptibility, which could further be used as a foundation for future studies.

Acknowledgements

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Appendix A. Total spruce bark beetle damage, total summer precipitation (mm), and average summer temperatures (°C) between 1990 and 2011. Precipitation and temperatures for damaged area were compared with those of the study area (CRU, 2010). Highlighted records did not meet the average temperature standard (10.3°C) correlated with 50 percent probability of spruce beetle outbreak (Berg *et al.*, 2006).

	Spruce Beetle	Total Summer Precipitation (mm)		Average Summer Temperature (°C)	
Year	**Damage (ha)**	**Damaged Area**	**Study Area**	**Damaged Area**	**Study Area**
1990	--	--	91 - 558	--	8.9 - 14.3
1991	9,752	87 - 282	87 - 396	10.6 - 12.5	7.8 - 12.7
1992	5,119	73 - 237	73 - 383	10.1 - 12.2	7.6 - 12.5
1993	21,024	42 - 141	42 - 262	12.1 - 14.2	9.3 - 14.2
1994	9,768	69 - 109	69 - 339	11.1 - 12.5	8.1 - 12.9
1995	44,820	81 - 308	81 - 429	10.9 - 13.1	8.7 - 13.4
1996	55,985	38 - 119	38 - 199	10.2 - 12.5	7.7 - 12.7
1997	12,352	56 - 181	56 - 308	11.1 - 13.3	8.5 - 13.5
1998	8,044	66 - 175	58 - 248	10.5 - 12.1	7.9 - 12.7
1999	16,240	50 - 215	50 - 360	10.0 - 12.3	7.3 - 12.3
2000	433	69 - 152	62 - 377	10.9 - 11.4	7.3 - 12.1
2001	3,132	106 - 156	64 - 278	10.4 - 11.4	7.2 - 12.1
2002	--	--	49 - 278	--	7.5 - 12.5
2003	--	--	71 - 420	--	7.6 - 12.7
2004	1,084	65 - 120	39 - 184	11.9 - 13.8	9.3 - 14.4
2005	1,765	104 - 247	64 - 397	11.9 - 13.9	9.2 - 14.1
2006	323	79 - 136	57 - 286	11.3 - 12.2	7.9 - 12.8
2007	4,873	94 - 175	63 - 368	10.9 - 12.6	7.9 - 13.0
2008	1,348	163 - 291	91 - 504	9.9 - 11.6	7.2 - 12.1
2009	--	--	36 - 186	--	8.1 - 13.2
2010	686	--	--	--	--
2011	317	--	--	--	--