Spruce mortality by Spruce Beetle Outbreaks on the Kenai Peninsula, Alaska, 1990-2010.

Alicia K. Abrego, Cheyenna Burrows, Alfonso Herrera, Jason Sikorski

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Abstract

A global increase in temperature, publicly recognized as climate change, is creating havoc in many ways. When most consider the effects of climate change, they often think of instantaneous natural disasters but too few are considering how small increments of temperature changes are affecting populations of insects. According to Erik E. Stange of Norwegian Institute for Nature Research, warmer temperatures associated with climate changes will tend to influence and frequently amplify insect species' population dynamics directly through effects on survival, generation time, fecundity, and dispersal. The *Dendroctonus rufipennis,* or commonly known as the spruce bark beetle, has proven to be a species of insect that has been highly affected due to the increase in temperatures, fire suppression, and droughts. With some research, we discovered that vast portions of spruce trees are dying in the western region of North America. Some experts claim that between 2 to 3 million acres of trees have been infected in the past ten years, in southcentral Alaska, alone. With this outstanding amount of damages, we decided to narrow our analysis to the Kenai Peninsula of Alaska and try to map how certain components of the area have allowed the spruce beetle to thrive over the years.

Introduction

Spruce beetles and Alaskan forests have had a long standing relationship, but due to our climate rapidly warming and devastating recent outbreaks the topic has become more relevant (See Figure 1, Locator Map of Kenai Peninsula). The Kenai Peninsula has been experiencing spruce beetle outbreaks over the last couple centuries but historically the trees are thinned by the beetles and eventually recover. These outbreaks have a mean return interval of 52 years. This return interval was disrupted in the early 1990s when a massive outbreak hit the Alaskan forests. According to a study published in *Forest Ecology and Management* conducted by Edward Berg and J. David Henry, there was a massive spruce beetle outbreak in the 1990s on the Kenai Peninsula that was thought to be connected to the unusually high summer temperatures. The study also showed a positive correlation between higher temperatures and higher spruce beetle populations with an "increased overwinter survival, a doubling of the maturation rate from 2 years to 1 year, and regional drought-induced stress of mature host trees." (Berg and Henry). Along with this research there has been extensive research conducted by the U.S. Forest Service, Pacific Northwest Research Station, and Forest Inventory and Analysis Program in response to these major outbreaks. Our goal is to map out the areas of The Kenai Peninsula that were affected by these large outbreak years and potentially allow for further management and research into preserving these Spruce forests in the Alaska region. We are using National data sets in order to determine the percentage of vegetation loss in Kenai Peninsula area of Alaska We are focusing specifically on spruce forests including, Sitka spruce (*Picea sitchensis)*, White spruce (*Picea glauca*), and Lutz spruce (*Picea lutzii*) in direct correlation to the overpopulation of spruce beetles (*Dendroctonus rufipennis*) due to temperature change. The Lutz spruce is the hybrid of the Sitka and White spruce. We are looking at a 20-year time spread from 1990 to 2010 with 5 year intervals excluding 1995 due to lack of data. With Alaska warming at a rate of 3 degrees Fahrenheit per century this caused some alarm at seeing more outbreaks, like the ones we have seen, in the past century. We are hoping to use our research as a means of tracking and analyzing forest and ecosystem health in order to better manage the forests and control the spruce beetle populations and ensure the future health of Alaska forests.

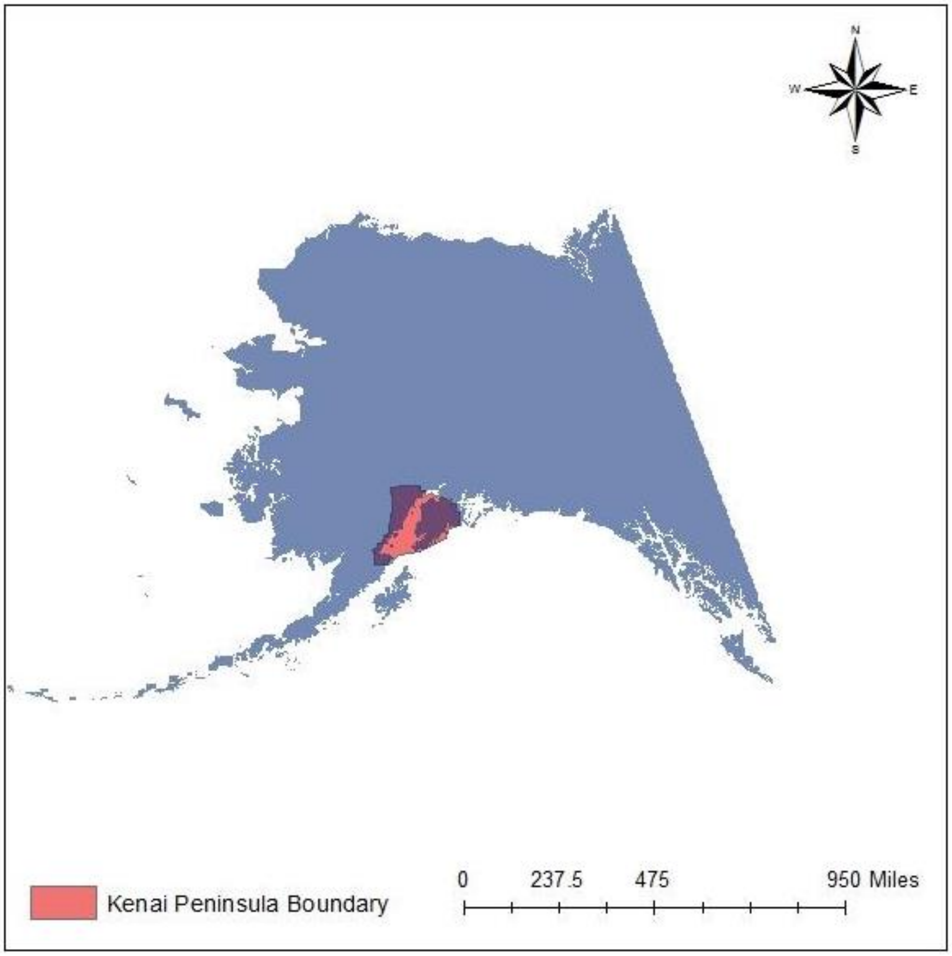

Figure 1: Locator Map for Kenai Peninsula

Methods

The program used in order to create our maps and analyze our data was ArcGIS 10.2.2 for desktop. Within ArcMap we used a variation of tools and methods in order to create our maps and analyze our data. First in order to create our data layers we researched our data collections through various data collection websites and found the majority of our data sets through The U.S. Geologic Survey, Kenai Peninsula Borough Geographic Information Systems, and the State of Alaska Division of Forestry. Through these websites we were able to download a variety of both raster and vector data in order to compile our maps. The main data sets that we used for the insect and disease infestation came from Alaska Dept. of Natural Resources and Land Records Info. Section and was collected through the DNR/USFS yearly aerial surveys. They are all vector data sets consisting of polygons representing areas of vegetation damage. Twenty-five percent of the state was surveyed per year showing a range from 1989 to 2010. These aerial surveys are conducted in July and August to show signs of insect presence. All of our data was published in Anchorage, Alaska and was last updated in 2005. Several data sets for the Kenai Peninsula came from The Kenai Peninsula Borough Geographic Information Systems website. The data sets were all vector data containing shape files. In addition, the data that would found regarding annual temperatures was through Weather Spark, an interactive historical database of weather trends throughout the United States. We were looking for GIS data regarding weather trends but have a difficult time locating the years needed.

First, we created a locator map for our area of interest, The Kenai Peninsula. We used a digital elevation model of Alaska in order to show the State boundary. Then we used the Kenai Peninsula Boundary shape file and layered it on top of the DEM file. We adjusted the transparency of both the Alaska State Boundary and the Kenai Peninsula Boundary to 45% in order to show an aesthetically pleasing representation of the area of interest as well as creating a limited map that provided all the information that was needed in order to explain our focus area.

We were interested in the amount of forested areas within the Kenai Peninsula. In order to do so, first we clipped each layer to show only the Kenai Peninsula. From these we created a map to show the acreage of spruce death for 1990, 2000, 2005, and 2010. First we converted all of the layers into our desired projection that best fit the area of study, NAD 1983, Alaska Albers Conic Projection. Then, we layered our desired years and added another layer representing the areas that are spruce forests and added a hydrology layer. We made the boundary layer hollow so we could easily show the areas that were affected. In order to extract data for analysis, we used the attribute tables of each layer in order to calculate the total acreage per year there were damaged by the spruce beetle outbreak. With the acreage data, we created a map adding the necessary labels and features to create a visual representation of our data. (See Figure 2)

Another attribute that we were considering was the temperature increase of the area; specifically interested in showing the temperature gradient over those years. We were unable to find a data set representing our specific years so we acquired historical weather data in order to compare our results. We also created a 500-meter buffer around the surface hydrology and a wetlands area to see if there was significant interaction between these attributes.

Results

Our results showed that the most damage caused to the Spruce forested area of the Kenai Peninsula was in the year 1990 and 2000 but we found no significance with the temperatures related to those years (See figure 3). We input our data into Xcel to create a chart showing the trend of temperature change per year, our graph shows a general increase in temperature per year. This is most definitely correlated to warming implications of climate change (see Figure 2). Due to the size of our data set we found it difficult to find any real correlation except for the acreage of damage caused in 1990 and 2000 (See Table 1). We were also interested in the relationship that the possible infestations had to proximity to a water feature. We created a 500-meter buffer around all of the hydrological features and due to their density in this specific area we found no correlation (See Figure 4). We also included four maps supporting our average high and low temperatures for 1990, 2000, 2005, and 2010 (See figure 4-8). The daily lows are represented in blue and the highs are represented. "The bar at the top of the graphs are where both the daily high and low are above average, blue where they are both below average, and white otherwise" (WeatherSpark).

Table 1: Relationship of Hottest Record Temperature in degrees and Total Damage in Acres per Year

Year	Total Acreage of Damage	Hottest Record Temperature (degrees)
1990	132,489 acres	74
2000	54,281 acres	72
2005	16,592 acres	74
2010	8,449 acres	77

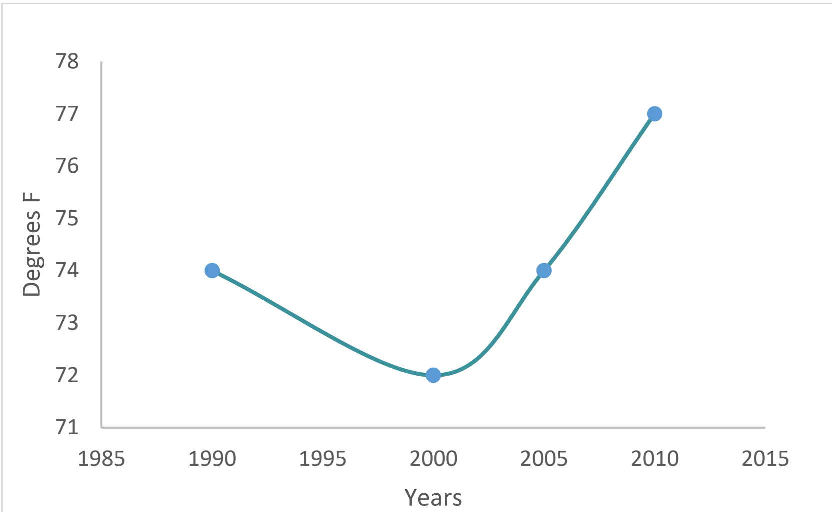

Figure 2: Graphing the General trend of Temperature and Years

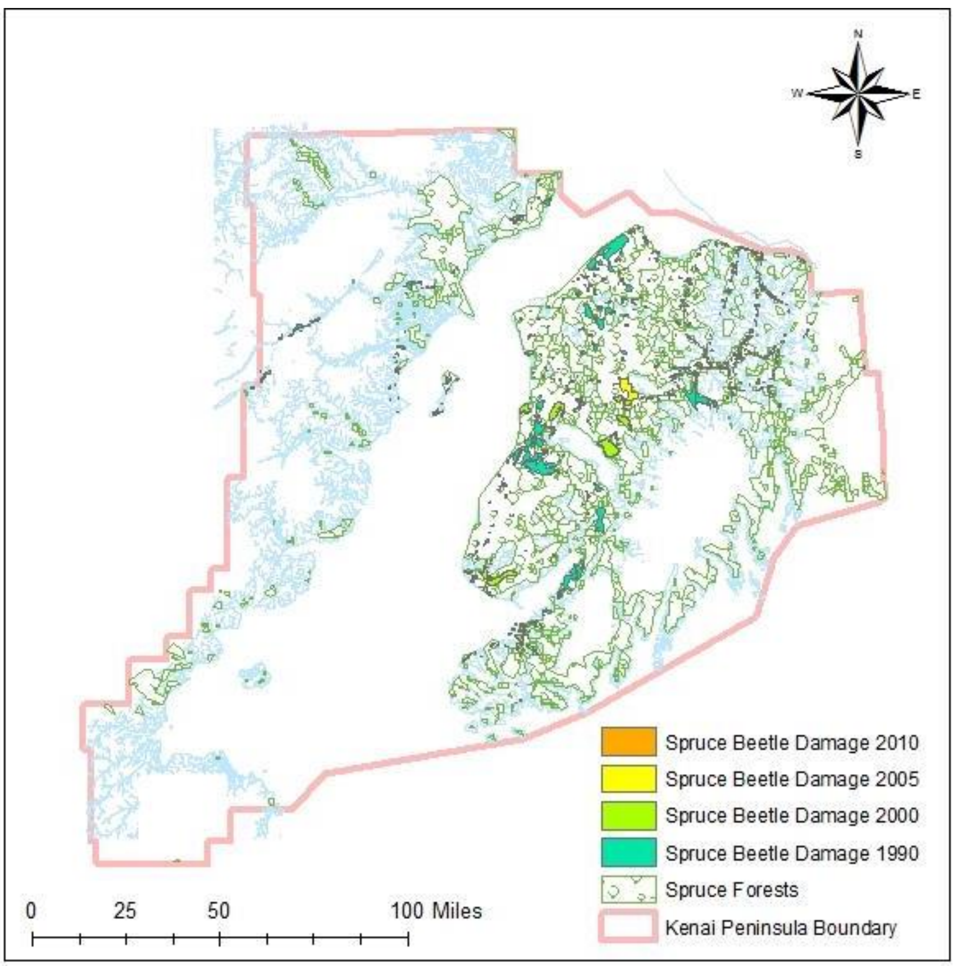

Figure 3: Map of Spruce Beetle Damage per Year

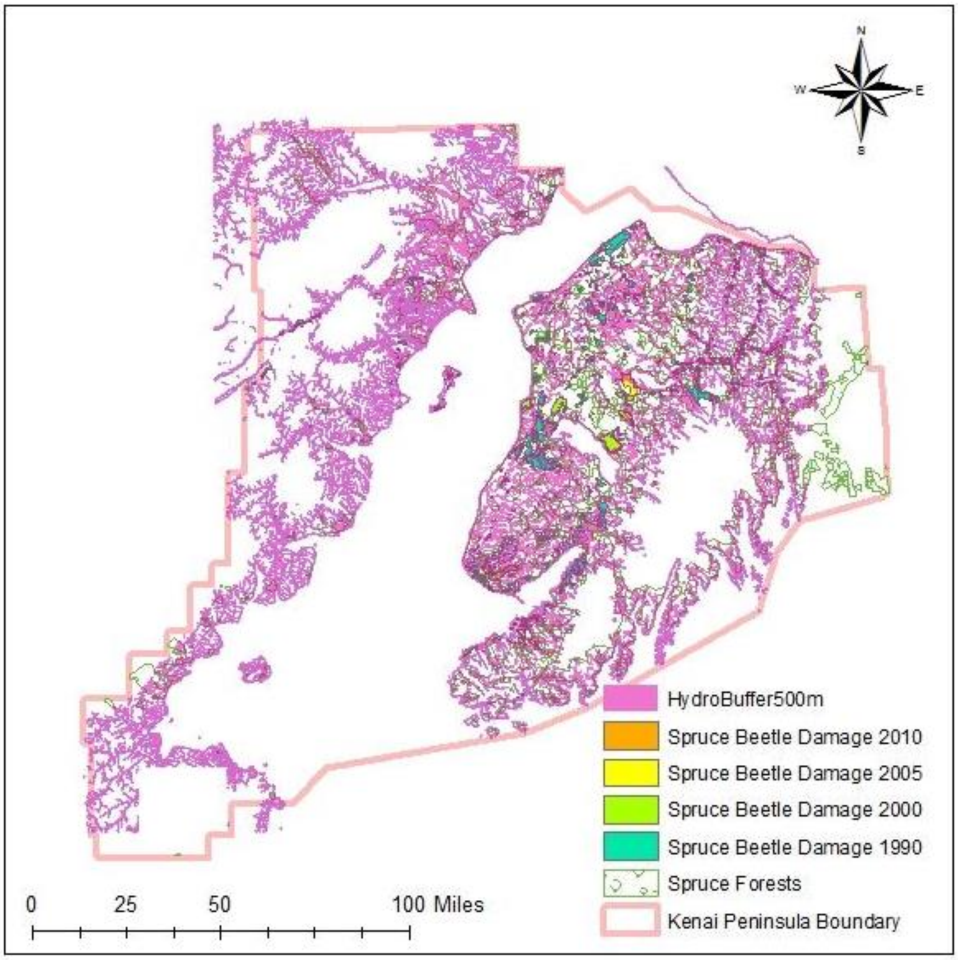

Figure 4: 500 Meter Buffer Around Hydrologic Features

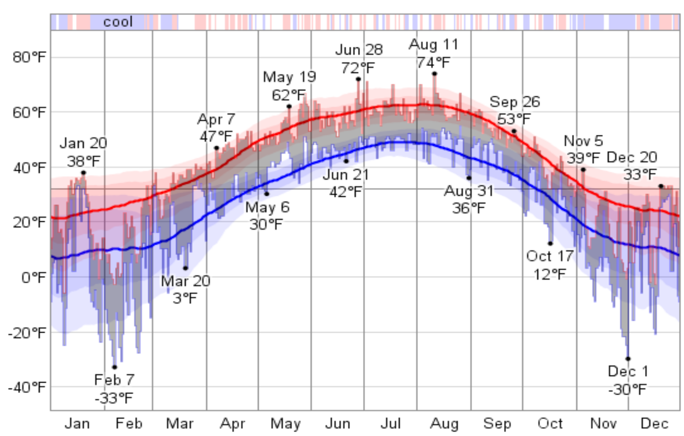

Figure 5: The daily low and high temperatures of 1990

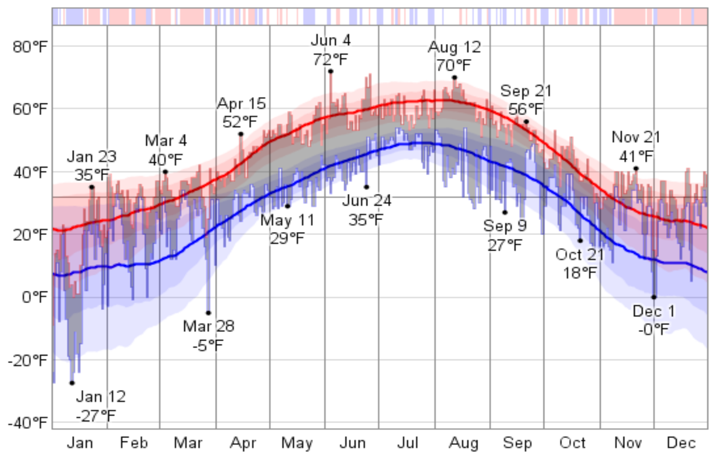

Figure 6: The monthly low and high temperature of 2000

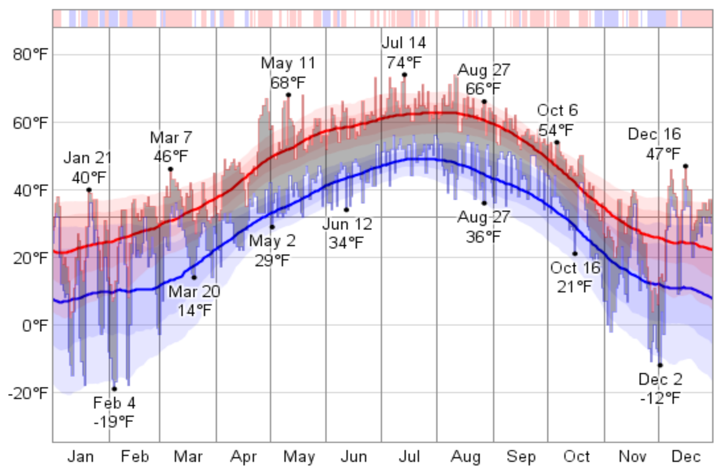

Figure 7: The Monthly low and high temperature for 2005

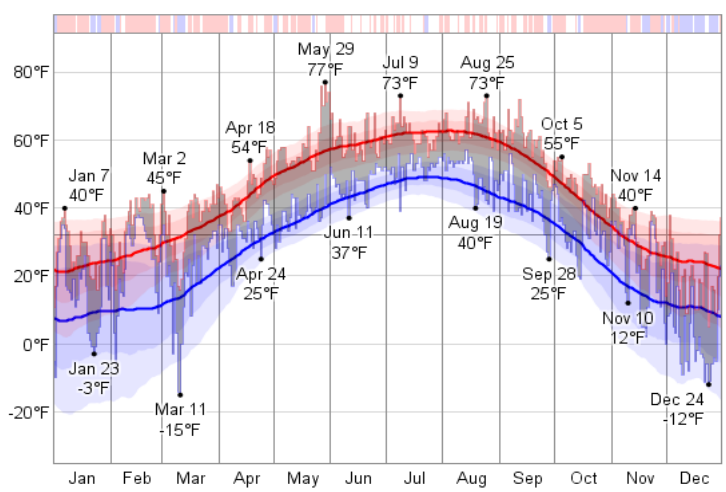

Figure 8: The Monthly low and high temperature of 2010

Conclusion

Based on our results we found that the spruce beetle infestations favor hotter condition and with the general trend of Alaska warming, there is a greater threat of lessening the return interval of outbreaks and seeing higher acreage of damage like the 1990 and 2000 outbreak. In order to show a greater correlation between the temperature and spruce beetle outbreak we would like to further our study to a larger time span. The hotter temperatures allow the spruce beetles to mature at two times the rate of normal maturation as well as a greater survival rate throughout the winter. Less spruce beetles are dying off during the winter months which then allows for greater reproduction rates as well. With all of these factors combines spruce beetles are creating a real problem for these forests. The temperatures rising and the drought conditions are also weakening the trees and making them more susceptible to these infestations.

There are many possible options for maintaining the health of the uninfected trees and saving the overall forests from a possible endemic. We have outlined just a few ways in which these forests can be managed. The first being, to maintain the health and vigor of the trees. The spruce beetle prefers to attack the weaker or fallen trees so watering and fertilizing trees early in the growing season will help develop and maintain its health. Although this is unlikely for large areas of forested land, it is an option for any small parcel that is threatened. Thinning may reduce competition for water and nutrients by your desired residual trees. Optimum stocking for tree vigor is dependent upon tree species, age and size, and growing site conditions. It would be beneficial to select trees for removal based on evidence of physical damage, insect damage, and tree form. The last management option that we researched is to spray the tree with an insecticide registered for use on spruce trees to prevent spruce beetle attacks. This should be done in spring by early May in order to protect the tree prior to the beetle's emergence and dispersal flight. Currently four pesticides are registered for preventative use against spruce beetles. These pesticides listed as active ingredients on the EPA approved label include carbaryl, permethrin, chlorpyrfos and lindane. These active ingredients may be sold under several trade names for different uses so it is crucial to double check the pesticide you purchased. Landowners should consider that a mixture of native tree species is your best approach to providing a healthy and insect resistant forest area. Numerous larger diameter spruce trees provide an ideal habitat for the spruce bark beetle. Landowners should be cautious about leaving fresh spruce firewood on their property.

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