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Intel Science Talent Search Article

Bark Beetle Infestations and Water Stress

Personal section:

The effects of Global Warming gain added reality as we watch images of immense glaciers breaking into the ocean, or learn of species of animals that are becoming extinct, but last summer I studied the effect of Global Warming on something the size of a grain of rice in my home state of New Jersey. At the end of my junior year, I contacted various science professors via the internet with hopes of securing a research internship. Dr. Shumate, a professor of Biology at Farleigh Dickenson University, said she would be researching bark beetle populations in the Pine Barrens and I could help her empty beetle traps and catalog their contents.

I met with Dr. Shumate and she explained why bark beetles have become a pressing environmental issue. The Southern Pine Beetle (*Dendroctonus frontalis*), is the genus of bark beetles causing the greatest amount of damage to pine trees. Southern Pine Beetles (SPB) live in the phloem, the layer just under the bark. The beetles tunnel their way through the pine tree's phloem as they eat, cutting off the circulation of nutrients, and ultimately killing the pine. Although SPBs can destroy a tree within a few months, cold winter temperatures control the bark beetle populations. At temperatures below -13˚C (the supercooling point), ice crystals begin to form in SPBs and the beetles are killed within minutes. When the temperature drops below -16˚C (the lower lethal temperature), an entire population of SPBs can be killed in one night. As the average temperature of

the globe increases, minimum winter temperatures are no longer reaching the lower lethal point in many areas. This warming trend has permitted SPBs to migrate north to areas such as the forests in southern New Jersey where they are destroying large stands (groups) of pine trees (see image above).

After Dr. Shumate explained the environmental problem the bark beetles posed, we began our field work. A typical day begins at six in the morning when Dr. Shumate and I would drive to the Pine Barrens in southern New Jersey. The beetle traps at the different sites consisted of a series of black tunnels that lead to a small cup at the bottom. Due to their poor vision, SPBs mistake the traps for trees; when a bark beetle, as well as other insects, land on the traps, they fall though a series of tunnels and land in a white cup

with a mild poison that prevents the beetle from escaping. At each trap, there is a different pheromone, or scent, that lures in bark beetles as well as other insects.

Dr. Shumate and I had two main responsibilities: Emptying each beetle trap into a labeled zip lock bag, and moving the pheromones from one trap to the next. Moving the pheromones ensured that we would attract beetles with the different scents at all the different points at a particular sight. Dr. Shumate would also check the nearby pine trees' bark for new entry holes drilled by bark beetles. Tearing away the bark of a pine tree reveals the tunnels bark beetles have created in the phloem (see image above). Occasionally, we would encounter a beetle encased in sap, indicating that the beetle had tried to enter the pine, but was killed by the tree's "immune system".

In the lab, Dr. Shumate and I would take out a zip lock bag filled with a sample of beetles from a trap from one of the sites. Under a microscope, we divided our samples into bark beetles, other beetles, and fragments of bark beetles. We counted the number of bark beetles in a sample, measured their lengths, and tried to piece together the fragments. Using a key we would then try to identify the species of the different bark beetles. A key is a book that asks questions about a specific bark beetle; the answer to each question leads to another question that eventually leads to the specie of the bark beetle. The key will ask questions that are often difficult to answer even with a microscope such as, *Are there grooves on the bark beetle's back*?

Emptying beetle traps in the Pine Barrens taught me the patience required in a scientific project and the steps required to give a more accurate result. Dr. Shumate took precautions to prevent people from handling the beetle traps: we emptied each trap with a small spatula, and froze the samples to prevent the bark beetles from drilling through the plastic bags and infesting Dr. Shumate's car. I could not determine the specie of each bark beetle or piece together beetle fragments perfectly, but I learned experiments have a level of uncertainty that makes scientific research more challenging and open to interpretation.

A junior in my school who was curious about the Intel competition asked me about my research and paper. As I told her about finding Dr. Shumate, the amount of science I had to learn, and the fieldwork my project required, I realized how overwhelming the experience can sound. When entering the Intel Competition, it's important to have guidance. I was very fortunate to find a professor who was not only willing to work with a junior in high school, but who made an effort to provide me with information on the Pine Barrens and read my paper.

I was intimidated at first because I assumed a college professor would not be interested in the research of a high school student, but professors who devote themselves to education are eager to help students reach their academic goals. Dr. Shumate was always supportive of my project and patient with me during my first few days of fieldwork as I slowly marched from trap to trap. She guided me in my research, demonstrated a true love of teaching, and helped me keep a sense of humor even when it would rain. Professor Matthew Ayres from Dartmouth University, who initiated the research, also took the time to read and respond to my paper. I greatly appreciate the time they spent helping me.

Research:

During my summer fieldwork, I thought that researching factors that make pine trees more vulnerable to southern pine beetle infestations would be an intriguing and relevant topic for a research paper. After researching SPBs on the internet, I discovered that the rise in minimum winter temperatures due to Global Warming is the chief factor responsible for the northward expansion of SPB populations. But, I wondered, could other factors be at play? The physiological decline of aging trees and water stress from drought are two factors that could increase the likelihood of a pine tree becoming infested.

The Southern Pine Beetle's inability to survive temperatures below -16˚C makes temperature a well accepted explanation for the increase and expansion of SPB populations. Between 1960 and 2004, the minimum winter air temperatures have increased 3.3˚C in the southeastern United States. The minimum monthly temperatures for Cape May in the Pine Barrens shows that from 1944-1996, the minimum winter temperature of the air reached the supercooling point (-13˚C) approximately once every two years and reached the lower lethal temperature (-16˚C) approximately once every four years. From 1996 to 2003, the temperature failed to reach the lower lethal temperature, and from 1994 to 2007, the temperature failed to reach the supercooling point.

Studies have linked SPB infestations to pines with poor physiological conditions. In my research, I determined the physiological condition of un-infested and infested pines by measuring the growth of each tree per year. To measure growth, I took samples of tree cores and measured the width of the annual tree rings. The local forestry service in the Cape May area directed me to areas of the Pine Barrens where I could obtain a good sampling of trees, and gave me a map detailing the year different areas of the Pine Barrens became infested. I took samples of tree cores in three different infested sights in

the Cape May area. The samples allowed me to see the growth of the tree per year (see image to the left). From the three infested sights, I gathered six samples from healthy trees and six samples from dead trees.

At home, I sanded the pine tree cores so I could see the growth lines more clearly and measure the growth of each pine tree per year. I measured the years with an accuracy of .1mm beginning with the most recent year (2007 for healthy trees and the year of infestation for the dead trees) until 1995 with a 40x magnification microscope. After completing my measurements, I cut up my tree samples by year back to 1995.

The ring growth measurements for infested and un-infested trees were entered into student t-test for statistical analysis. The mean level of growth in un-infested trees is higher than mean growth in infested trees, but the difference in growth is only statistically significant in 1997 to 2000. This could be connected to the significant decrease in the amount of precipitation in Cape May from 1997-1990.

These samples were also essential in helping me discover whether water stress in pine trees plays a significant role in bark beetle infestations. A pine tree experiences water stress when it does not absorb a healthy amount of water. A pine tree that does not suffer from water stress will absorb more carbon-12 than carbon-13 from the atmosphere because pine trees prefer using carbon-12 in photosynthesis. When a tree experiences water stress, the stomata (or small holes) on the tree's pine needles become smaller in order to retain more water, also causing the tree to absorb more carbon-13 that carbon-12. A carbon isotope analysis reveals the ratio of carbon-13 to carbon-12 in a tree, and can identify whether a pine tree is undergoing water stress.

I sent my samples to the Institute of Ecology at the University of Georgia for carbon isotope analysis. The results from the analysis showed that pine trees with SPB infestations had a higher average level of carbon-13 than healthy pine trees. The Student t-test showed that the level of carbon-13 in infested trees at all three sights combined is statistically higher than in un-infested pines. The higher level of carbon-13 in infested pitch pines indicates that water stress makes pines more vulnerable to SPB infestation.

My bark beetle project helped me understand the process of conducting a scientific experiment. When I took core samples from the Pine Barrens, I needed to procure samples from various areas of the forest; each of which were infested in different years. The simplest task of transferring a tree core sample from my hand corer to a straw intact was often unsuccessful. I needed to take precautions (such as covering my body from head to toe, taping my pants to my shoes and spraying myself with DEET) before entering the forest to avoid tick bites. That might not sound so bad until you realize we were often working in ninety degree plus heat. After one day of fieldwork, I needed to remove a colony of seed ticks from my ankles with shipping tape, but I didn’t let that experience discourage me.

When I finished collecting my samples of tree cores, I had to sand them before I could measure the growth of each pine per year. I had to be very careful not to break off the most recent "years" of the dry and fragile samples; each year contained valuable information. But the most stressful part of the experiment was cutting the tree core samples by year. I had to use a magnifying glass in order to distinguish the different years of tree growth, and a scalpel. I tried to maintain a steady hand while I cut the samples, hoping my data would not fly across the kitchen.

Science labs in school are relatively short, and yield data with small margins of error; the results of my research were less clear. At first, I was worried that my data would not lead to a definite conclusion. I imagined that the carbon isotope data would not explicitly indicate whether or not infested trees were undergoing water stress. But the statistical analysis of my carbon isotope results did show that the level of carbon-13 in infested trees was significantly higher than in un-infested trees.

I understand that my single experiment cannot absolutely confirm that water stress makes trees more vulnerable to beetle infestation; further experiments similar to mine need to be performed. I concentrated on the relationship between SPBs and temperature, growth and water stress; although this only represents a small aspect of the environment, the project helped me appreciate the combined effort required to develop, debate, and confirm theories.

I know that the summer before one's junior year can be stressful enough without the prospect of doing research. I suggest concentrating on one goal at a time. A few times during the summer, I was sure that my project would never be completed: I had difficulty finding a professor that would work with me, and I thought I would never find a lab for my cellulose extraction (a step necessary before performing a carbon isotope analysis on my tree core samples), but I was able to overcome these obstacles and complete my research paper.