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Temporal Comparison of Stream Temperature of Three Basins Located in the Cascade Range of Oregon, USA

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International Baccalaureate Diploma

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Hypothesis:
No change in stream temperature between post harvest, 1967 to 1970, and thirty years later, 1997

INTRODUCTION

Temperature is important to the biological rates and processes in a stream. With a change in temperature the biological rates of a stream are changed, which in turn changes the ecological aspects of the stream (Beschta, 87). Changes in temperature affect rates of decomposition, metabolism, growth and reproduction for many organisms. Examples of such change are increase in fish metabolism and a change in the growth of certain larva species. There is also a decrease in dissolved oxygen content with an increase in stream temperature. Such increases in temperature above or below the historical levels results in stress on the organisms in the stream. One such example is fish reproduction; certain species of fish, trout, have evolved to a specific temperature and when this temperature is changed then this species will be actively selected against and this in turn will positively select for another species of fish. With the abiotic factors selecting for different species, the entire ecosystem of that stream is then affected. Another factor is the historical evolution of streams. Historically, evolution has selected certain species that fit certain requirements. With a change in temperature these factors are no longer existent and totally different species will selected for.

Many factors influence temperature. These are convection, stream velocity, evaporation, direct solar radiation, and width to depth ratio of the stream (Brown, 1987). One of the important factors that influence temperature is direct solar radiation, and one of the controls of direct solar radiation is forest coverage. Forest coverage in turn is affected through disturbances such as logging, storms, and disease. As the amount of forest coverage increases or decreases the amount of direct solar radiation reaching the stream fluctuates respectively. Convection and evaporation affect the temperature through the exchange of heat with the layer of air right above the stream. Logging affects stream temperature because the trees in the riparian zone control the amount of air flow over the stream. Without these trees there is a higher air flow and more convection and evaporation taking place; there is also a higher amount of solar radiation reaching the water. There are many factors that influence the temperature of the stream; though one of the most important factors is direct solar radiation which is affected by the forest coverage of a stream.

Studies have been done on the effects of different influences on stream temperature (Beschta 87, Brown 70, McSwain 87, Salo and Cundy 87, Levno and Rothacher 67, Levno and Rothacher 69, Messer and Swift 71), although few have returned to the study after a lapse in time. In the late 1960's, an experiment was done in the Cascade Range in Oregon, USA, that involved a control Basin, a Basin that was modified by humans, and a Basin that was both modified by humans and natural disturbances (Levno and Rothacher 1967, 1969). Basin 1 was logged and then slashed and burned. Basin 2 was not harvested and was the control. Basin 3 had partial harvesting and then had a natural disturbance. There was a landslide and debris flow that scoured portions of the stream to bedrock. Stream temperature was measured in Basins 1, 2, and 3. An increase in water temperature was shown after the forest harvest treatment in Basin 1 and 3. I am interested in the affects that a change in forest coverage has on stream temperatures.

I was wondering whether or not temperature has been affected by the changes that would accompany 30 years of revegetation of a clearcut. I was able to retrieve the reports and old data for the study in the H. J. Andrews Experimental Forest in the Cascade Range in Oregon, USA for the years of 1967 through 1970 and gathered stream temperature for the summer of 1997. Basin 1 has had 30 years of regrowth of vegetation, Basin 2 nothing has changed, and Basin 3 has had another natural disturbance very similar to the one 30 years ago. The null hypothesis is no change in stream temperature between post harvest, 1967 to 1970, and thirty years later, 1997. A change in temperature implies that factors such as the regrowth of the riparian vegetation affects or influences stream temperature.

BACKGROUND

The area of study is located in the H. J. Andrews Experimental Forest in the Cascade Range of Oregon, USA. Three Basins were used for the study, known as Basins 1, 2, and 3. The Basins are all under 100 ha and the streams are all first order streams. The Basins were originally covered by a dense stand of old-growth Douglas-fir with little undergrowth. The Basins are adjacent to each other on steep northwest-facing slopes (Levno and Rothacher, 1969). Most of the elevation is below 1,000 metres. The climate for all three Basins is similar, with wet winters and dry summers. The summer air temperature ranges from 12^0 C to 35^0 C, with the hottest temperatures generally occurring in late June and July. The average yearly rainfall for this area is 200 cm (Levno and Rothacher, 1969).

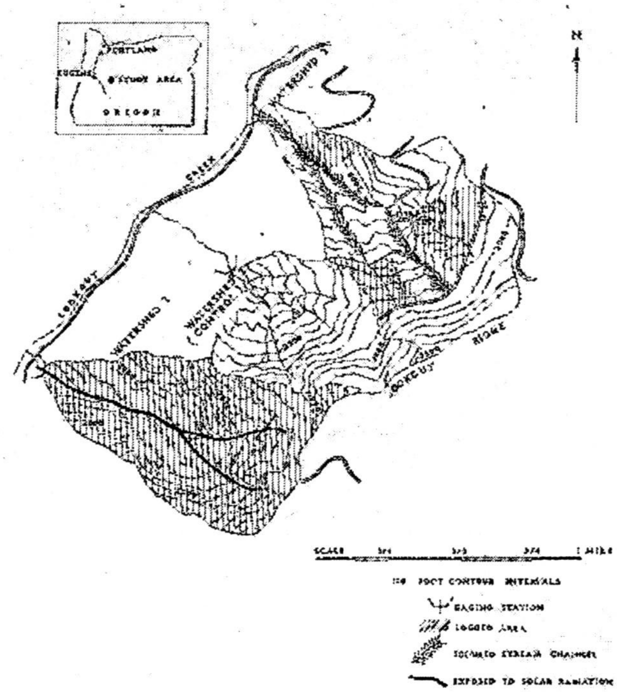

Figure 1. Experimental Basins, H. J. Andrews Experimental Forest (Levno and Rothacher, 1967)

Certain stretches of the stream channels in the Basins have been eroded down to bedrock. In general, however, the stream channel consists of bedrock covered with a layer of loose gravel, vegetation, and debris (Levno and Rothacher, 1969). Steep sections and waterfalls along the stream prevent the migration of most fish. Trout, however, are found in some of the lower reaches of these streams. The discharge ranges from 1500 L^3s^{-1} in the winter to a low of 1.4 L^3s^{-1} in the summer (Levno and Rothacher, 1967).

The vegetation was similar in all three Basins, and the treatments differed among the Basins. Basin 2 has been untouched and is still a dense stand of old-growth Douglas-fir. It is used as the control and for comparisons.

Figure 2. Stream channel with surrounding vegetation

Basin 1 was 100% logged from 1962 to 1966 and was slashed burned in October 1966 (Levno and Rothacher, 1969). Basin 1 was logged using an alternative method that involved no roads and used a cable sling to remove the logs from the Basin. The burning consumed almost all of the small vegetation, although the larger logs were not burned. These logs were then removed by hand to allow direct sunlight to reach the stream. Presently, the stream is relatively well shaded from the surrounding trees even during high noon. Douglas-fir and alder are the dominant types of tree with alder mainly in the riparian zone. The largest of these trees are approximately 30 years old and 3 to 5 metres in height. The stream channel is heavily covered with loose gravel and vegetation. Logs from the harvest are still abundant although none lie in the stream itself. Basin 3 was logged using normal means. Roads were put in which covered about 8% of the Basin. Then three clearcuts were made which covered about 25% of the Basin in 1962 to 1963. After the clearcuts were finished those areas were slash burned in September 1963. In 1964, storms, landslides, and debris flows scoured the upper part of the main channel down to bedrock and the lower portion contained debris deposits of wood and rocks (Levno and Rothacher, 1967). In 1996 another series of landslides and debris flows scoured large parts of the upper stream channel to bedrock. The lower portion of the stream, presently, has debris deposits of wood and rocks.

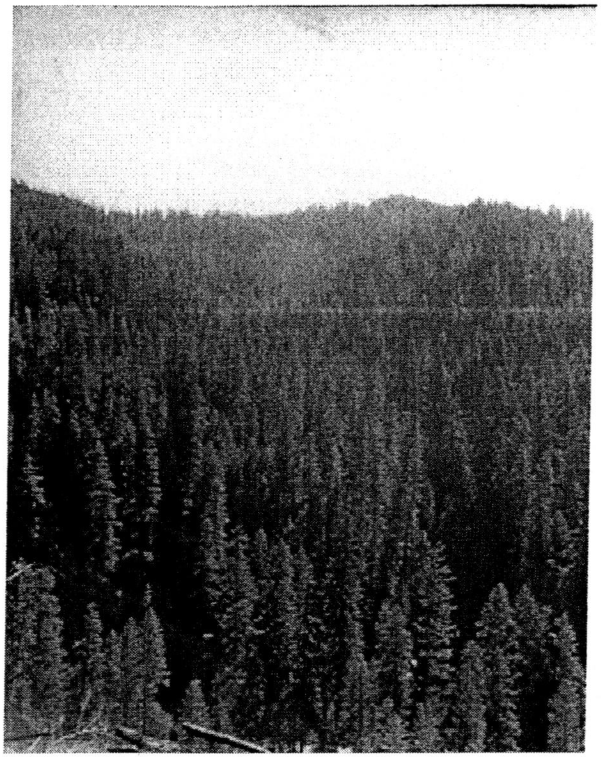

Figure 3. Overview of Basin 1 before the logging

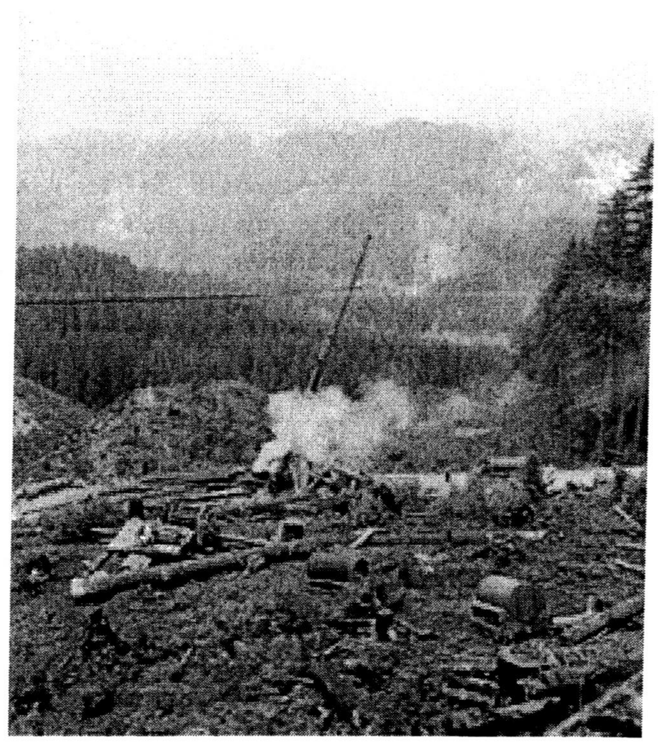

Figure 4. Basin 1 in the process of being logged

Figure 4. Basin 1 with the cut logs

Figure 5. Basin 1 after the stream being hand cleared

METHODS

The stream temperature has been periodically recorded in these streams since 1959. The methods have included hourly punch tape, "U" tube maximum-minimum thermometers, and in the past few years temperature has been gathered on portable stowaway sensors. These temperatures were measured at the gauging station located at the mouth of each Basin. For this report, the years between 1967 to 1970 were chosen and analyzed. These years were recorded on hourly punch tapes and the daily maximum and minimum calculated from this. The data for 1967 through 1970 was retrieved from the vaults at the P.N.W. Forestry Science Laboratory building at Oregon State University and then reentered into the computer. I chose 1967 through 1970 because this period of time had the most complete set of data. Some of the data for certain periods of time have disappeared and I was forced to leave certain dates out in certain years as a result of that. Daily maximum and minimum temperature were used instead of hourly temperature because I was interested in the temperature patterns among the Basins instead of the time at which each Basin had the maximum and minimum temperature for that day. The temperatures for the summer of 1997 were recorded on portable stowaway sensors with data recorded on the half hour. These were then summarized into daily maximum and minimum for comparison.

I entered all of the data into spreadsheets so that I could work with the data. To take in to account the overall fluctuations in average yearly temperature and after speaking with Al Levno and others as to the best way of comparing the results, I compared the Basins 1 and 3 with Basin 2 for each year. Another reason for comparing the treatment Basin to the control was to prevent daily fluctuations in solar radiation that influences all of the Basins from giving false highs in the treatment sections. I started with a simple difference to compare the treated and control Basins. Working with the maximums enabled me to see the differences that the different treatments will had on the maximum stream temperatures of the Basins. After that, each year was plotted, with the date along the x-axis and the difference in degrees C^0 between it and Basin 2 along the y-axis. I also analyzed the data by comparing the maximum temperature and the average maximum temperature. This was to show the differences between the daily maximum and the extreme peaks that were measured in the streams and then how the years compare to each other. A T test-paired two sample was used to compare Basin 1 to Basin 2 to evaluate the significance of the difference between the maximum daily temperatures.

RESULTS

During the years that were sampled, the maximum water temperature for the control Basin, Basin 2, ranged from 15.6^0 C in 1969 to a high of 17.2^0 C in 1967 (*fig. 6*). For those same years, the treated Basin that was logged and then slash and burned, Basin 1, had a maximum water temperature of 23.9^0 C in 1967 and 1968 (*fig. 6*). However maximum water temperature for Basin 1 was 16.5^0 C in 1997. Basin 3 had a maximum water temperature of 23.9^0 C in 1968 (*fig. 6*). In 1997, Basin 3 had a maximum water temperature of 18.3^0 C (*fig. 6*).

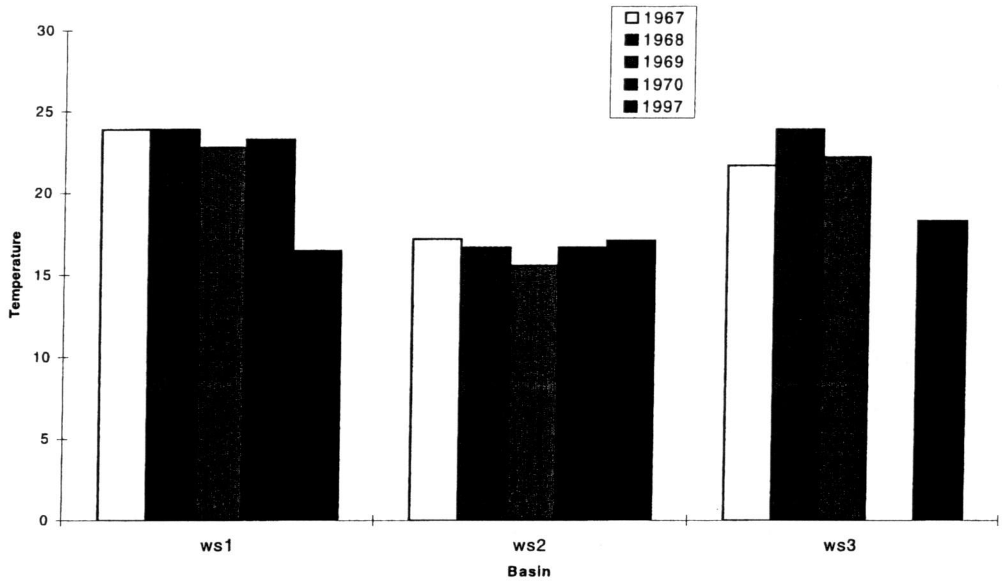

Figure 6. Graph "Maximum temperature per year"

Basin 2, the control Basin, had an average maximum water temperature ranging from 13.1^0 C to 14.4^0 C. 1997 was the second hottest summer, 13.9^0 C (*fig. 7*) and the lowest average maximum water temperature occurred in 1968 and 1969 (*fig. 7*). The warmest summer for the stream in Basin 2 was in 1967, with the average maximum water temperature 14.4^0 C. The average maximum water temperature for Basin 1 was between 13.5^0 C and 20^0 C. The maximum temperature that Basin 1 reached occurred in 1967(*fig. 7*). The average maximum water temperature for Basin 3 was between 15.8^0 C and 17.5^0 C (*fig. 7*). The lowest average maximum temperature for both Basin 1 and Basin 3 occurred in 1997, 13.5^0 C and 15.8^0 C respectively (*fig.*

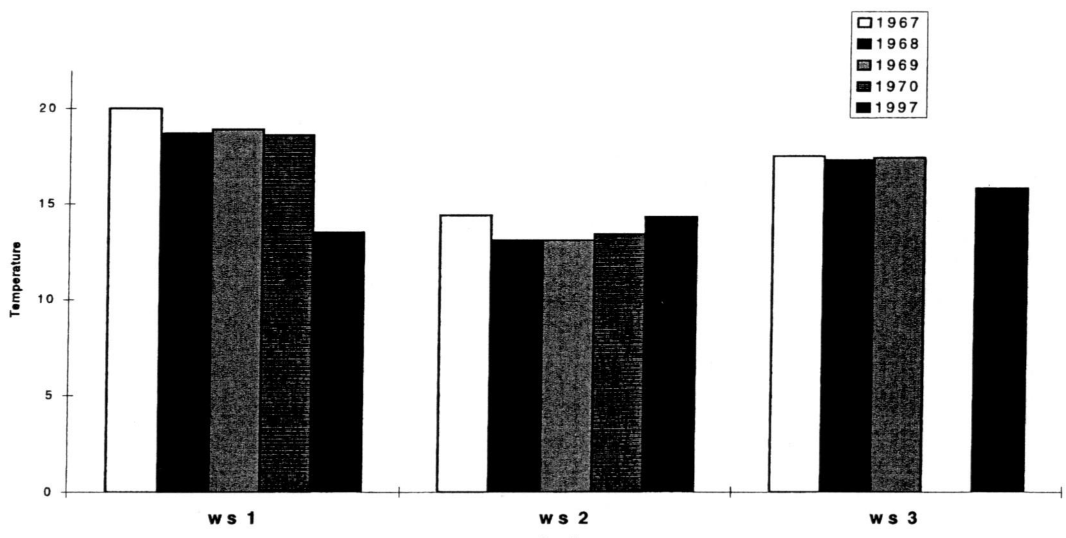

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Figure 7. Graph "Average Maximum stream temperature"

The graphs for 1967 through 1970 show the daily maximum stream temperature difference between Basins 1 and 2 and between Basins 3 and 2 (*fig. 8 to 11*). The warmest temperatures usually occur in late June and early July. The temperature then begins to cool through August and September. In 1967 and 1968, Basin 1's water temperature was generally warmer than Basin 3 (*fig. 8 and 9*). In 1969, the temperature in Basin 3 was generally warmer than Basin 1 up through the middle of July and then Basin 1 is once again warmer than Basin 3 (*fig. 10*). In 1970, Basin 1 follows the same trends in temperature as it did in the previous years (*fig. 11*).

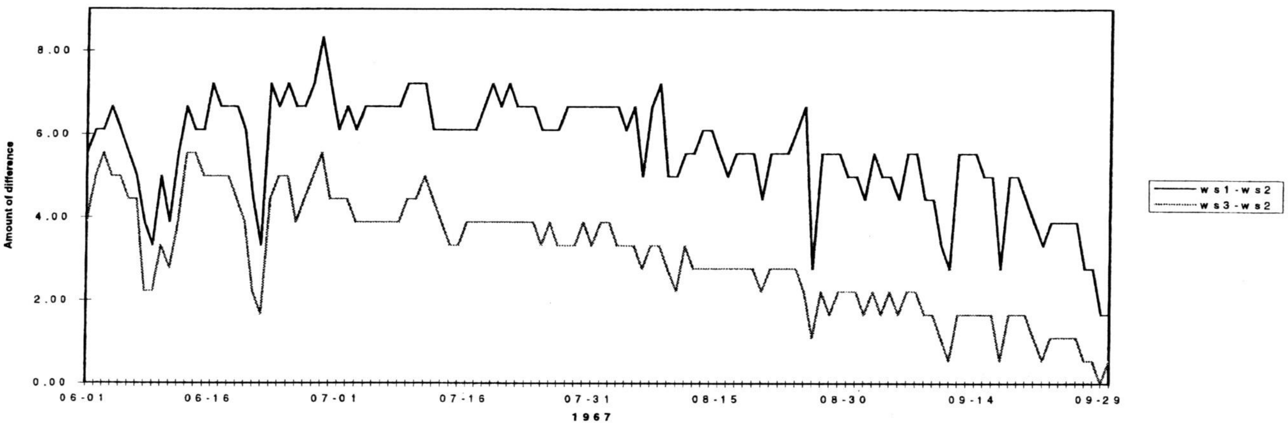

Figure 8. "Daily difference in maximum temperature between treated Basins and control Basin in 1967"

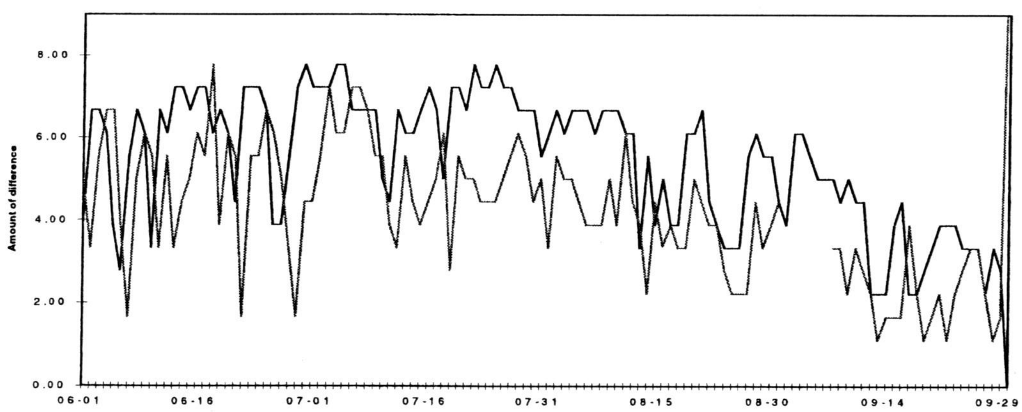

Figure 9. "Daily difference in maximum temperature between treated Basins and control Basin in 1968"

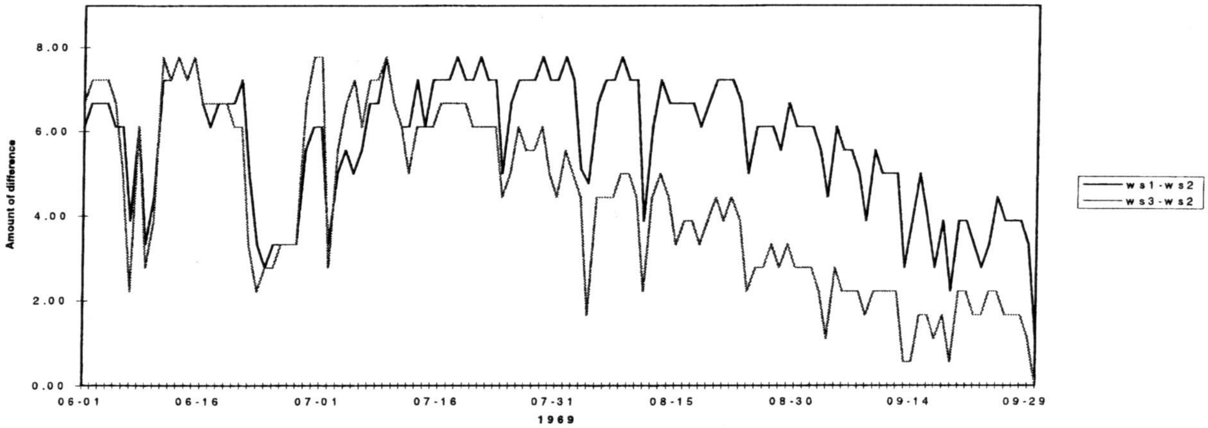

Figure 10. "Daily difference in maximum temperature between treated Basins and control Basin in 1969"

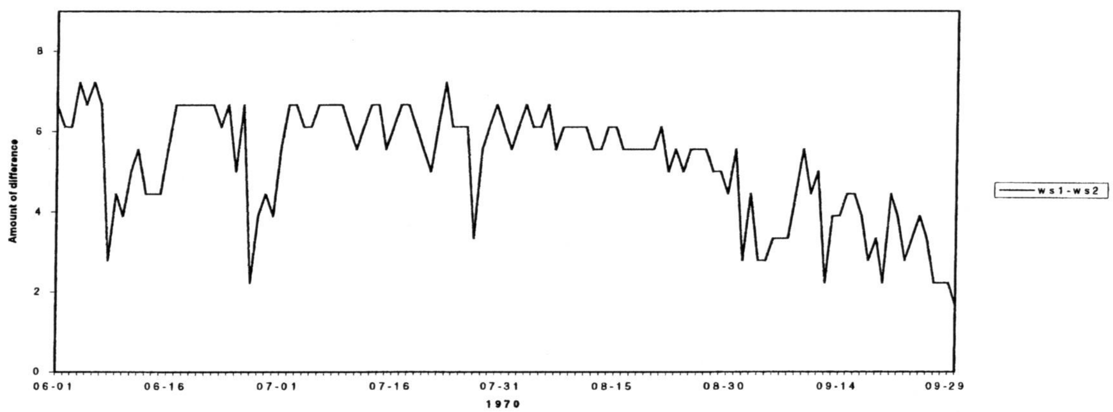

Figure 11. "Daily difference in maximum temperature between treated Basins and control Basin in 1970"

In 1997 (*fig. 12*), there was a trend in temperature that was not seen for the other years. In 1997, Basin 3 is warmer than Basins 1 and 2 and Basin 1 was very similar to the control, Basin 2, (*fig. 12*). In 1967, Basin 3 fluctuated between 5.56 degrees and 0 degrees warmer than Basin 2 (*fig. 8*). Basin 3, in 1997, fluctuates between 3.9 degrees and .59 degrees warmer than that of Basin 2. In 1967, Basin 1 fluctuates between 8.33 and 1.67 degrees warmer than Basin 2 (*fig. 8*). In 1997, Basin 1 fluctuates between .56 degree above and 1.22 degree below that of Basin 2 (*fig. 12*). There were significant differences between 1967 and 1997 (P= 5.8E-55, t-test paired two sample) for the daily maximum differences of Basin 1 and Basin 2.

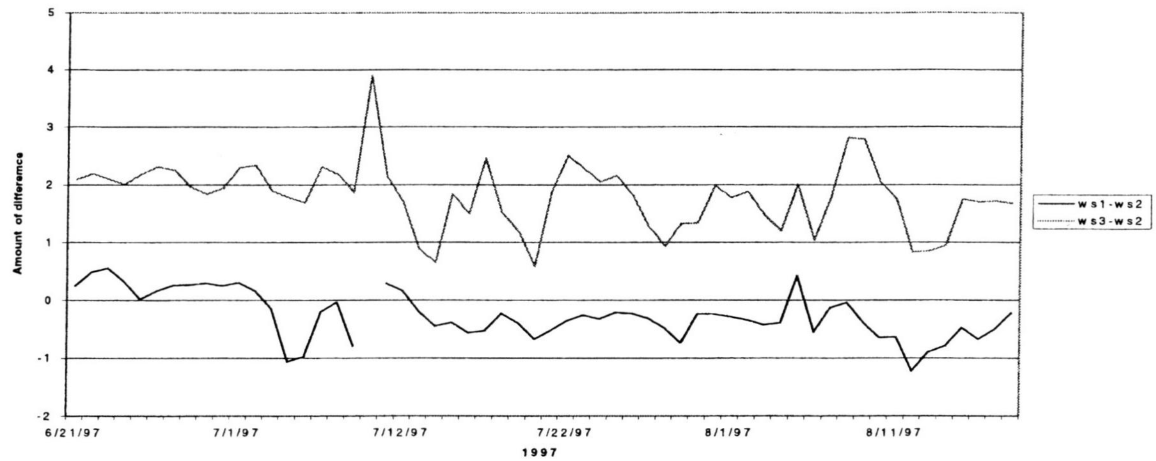

Figure 12. "Daily difference in maximum temperature between treated Basins and control Basin in 1997"

DISCUSSION

There are many reasons for the patterns of temperature. The summer highs appear in late June and early July because this is the hottest time for Oregon, with the most amount of direct solar radiation reaching the ground. This is because the sun reaches peak height in the sky on June 22, and then starts declining and this causes the temperature to fall gradually over the next few months. The sharp spikes and lows are what to be expected, considering the weather in the area. The skies are sometimes cloudy which affects the direct solar radiation considerably and in turn affects the stream temperature dramatically.

The differences between 1997 and 1967 through 1970 are understandable with the time lapse and the changes in the factors that affect the stream. In Basin 1, there has been a thirty year interval where no disturbances occurred in the stream, which allowed the vegetation to begin to grow back. Though not as extensive as that of an old-growth Douglas fir forest, the vegetation still provides enough shade to return the stream temperature to similar to the control Basin. Another factor that most likely assisted in lowering the difference in temperature between Basin 1 and Basin 2 was that the understory vegetation was denser in Basin 1 than Basin 2. This is to be expected, as Basin 1 was not an old-growth forest. This shows that any amount of coverage to a stream will assist in moderating the amount of direct solar radiation reaching the stream.

The differences in temperature between 1967 to 1970 and 1997 in Basin 3 can be linked to the changes that have occurred in that stream. The debris flow that came through in 1964 and the logging that occurred in the 1960's changed the stream temperature considerably compared to the control Basin. The stream temperature in 1997 is still considerably higher than that of Basin 2, the control Basin. The fact that the temperature is lower than it was in 1967 through 1969 could be from the regrowth of the harvested area. The debris flow of 1996 might be the reason that Basin 3 is still warmer than Basin 2. This debris flow scoured much of the channel to bedrock and the surrounding vegetation was removed. The debris flow deposit, just above the sensor, may be moderating the heating that occurs in the bedrock stretch (S. Johnson, Pers. Comm.). The debris flow in 1996 was incredibly similar to that of the one in 1964 (A. Levno, Pers. Comm.); which can account for most, but not all of the difference in stream temperature between it and Basin 2.

Figure 13. Basin 1 in 1997

The maximum stream temperature and the average maximum stream temperature are both important. The maximum stream temperature gave the one point in that entire summer that was the warmest. That point shows the temperature that the stream is capable of reaching. The average maximum stream temperature gives the average of the entire summer daily maximum temperature. This was done to give a more general picture of the temperature and to take into account conditions including cloudy days during the summer. The interesting fact is that the maximum temperature that was recorded in a stream is only a few degrees warmer than that of the average maximum for the summer.

The hypothesis of no changes in stream temperature is false. The trends in temperature following disturbances can easily be seen in the tables and graphs. After a disturbance that is large enough to be able to be noticed, there is a certain amount of time needed to return the stream to near its pre-disturbance conditions. This time varies with the size and degree of the disturbance, but also depending on factors of the stream you are considering. For this study, the only factor that I was considering was the temperature of the stream. Because I was unable to locate the pre-disturbance data, I used Basin 2 as my model of an undisturbed Basin. Basin 1 and 2 were similar before the disturbances (A. Levno, Pers. Comm.). After comparing the data, I found a trend that through the years 1967 to 1970 there was a small decrease in temperature difference between the Basins. This trend continued and the data from the summer of 1997 showed that the temperature in the stream in Basin 1 was almost identical to that of the control. The trend was also present in the stream in Basin 3, but the debris flow in 1996 affected the stream dramatically. This decrease in temperature in Basin 1 and Basin 3 thirty years post treatment shows the extent to which the surrounding vegetation affects stream temperature. With an absence of most riparian vegetation, Basin 1 in 1967 through 1970, there was a tremendous increase in the temperature of the stream. This difference in temperature decreases as time passes and there is regrowth of the riparian vegetation. The regrowth of the riparian vegetation along the streams had a cooling effect on the stream temperature.

ERRORS AND LIMITATIONS

There were many factors that I was unable to control and these are limitations in the study. One such limitation involved the collection of the old data. This was difficult because all the old data was on punch sheets and some of the sheets were missing. This caused gaps in the data and whole Basins to be unable to be graphed. The old data limited what I could compare and what years I could compare, because certain years were not measured and certain dates were also not measured. An example of this was in the maximum comparison graph of 1970 (*fig. 4*). On this graph Basin 3 in not present, because the punch sheets for this year were missing. Another major limitation was that the records for the pre-disturbance stream temperatures were unable to be found. This limitation forced me to consider the undisturbed Basin 2 a control for the other two Basins if they had not been harvested in the 1960's. The pre-disturbance data would have shown me if there were any initial differences between the stream temperatures, such as if Basin 3 is naturally warmer than Basin 2. Another limitation was the lack of time to do the data gathering. In this study, it would have been useful to have another summer's worth of data to compare to post treatment. If 1997 was an abnormal year with abnormal amounts of direct solar radiation, it could throw off my conclusion about the trends following disturbances in water temperature. Changes could have also occurred in the placement of the sensors. The natural shifting of the stream channel over time, which would slightly change the factors that influence the stream, could have had an effect on the data. There were many limitations and chances of error; they included limitations in the collection of the old data, lack of pre-disturbance data, lack of time to gather data, and changes in the placement of the sensors.

FURTHER STUDY

Further study could be done by extending the parametres. The study could also be extended for some more years to see if the trend continues. Extending the study over more summers would also enable you to see if Basin 3 stream temperature gradually decreases as the channel recovers form the debris flow. Another study could also look at the minimum values for the same time. Looking at the temperatures during the winter might enable you to see if the vegetation creates a blanket effect over the stream during these months. The study could also examine different Basins to look at the recovery after disturbances of these Basins.

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