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5/8/2022

GHY 423

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The Potential Uses of Dendrochronology in Freshwater Systems' Health Analyses

Introduction

Freshwater ecosystems are some of the most important ecosystems to our planet's overall health that exist. They are typically exceptionally biodiverse ecosystems that house a multitude of organisms. They also serve as a source of life for the surrounding ecosystems that depend on freshwater for survival. So, the survival and sustainability of these ecosystems is essential to the survival and sustainability of our own way of life. The ways that we monitor the health of these ecosystems over time are often restricted by our own capabilities. Water quality tests, temperature records, and observation-based assessments depend on the existence of a well-kept historical record and even the best well-kept historical records go back only so far. Organism population, temperature records, and water quality tests cannot be assessed over a long period of time because fossil records are not always easy to come by, especially in a system with deep water. Dendrochronology offers a unique perspective to assessing these things because trees hold records that go back further than our own records. Realizing that trees keep records of the environment around them better than we do caused me to imagine all of the ways that we can use their records to better understand our freshwater ecosystems. I have elected to explore three opportunities with this and discuss the potential use of dendrochronology in monitoring specific pieces of freshwater ecosystems. The first of these opportunities is using dendrochronology to monitor the structure of freshwater systems over time. This includes flood events, river course or bend alterations, or drought events. We know that tree rings can be used to see periods of extreme growth or extreme underdevelopment, so I hope to examine the extent of the ways in which tree rings can show structural integrity of freshwater systems over time. The second is disturbances by organisms, and the primary one that I will be focusing on. I will attempt to bridge the gap between the ways in which organisms, specifically tree-boring insects, interact with freshwater ecosystems. The existence and sustainability of insect populations is one of the more integral parts of sustaining a freshwater ecosystem. By finding the importance of these insects and showing how dendrochronology can be used to study insect activity, I can begin to have an understanding of the potential uses for dendrochronology in understanding insect activity around freshwater ecosystems. The third is water quality, which obviously determines the health and stability of all the surrounding organisms. I am going to assess the methods, if any, in which a researcher could monitor the health of a freshwater ecosystem by looking for indicators of water quality in tree rings.

Methods

The only method utilized for this paper is research based on studies performed by other people. I primarily used Google Scholar to find articles that contributed to this paper in a meaningful way. EBSCO Host was also used for a few of the articles. Many of the articles had absolutely nothing to do with dendrochronology, but were used due to their significance in freshwater ecosystems. This paper was not designed to be a study of tree-ring science, it was designed to be a study of how freshwater system health shows itself and could possibly show itself in the future in tree rings. So, many of the papers were solely used for this research paper as a point of connection for other pieces of research.

Results

Dendrochronology and the structure of freshwater systems

Flood events are becoming more and more likely to occur as climate change progresses. This can take the form of spring overflows, lake floods, or river discharges that exceed the normal amount. It has not been proven through climate change models that the increased amount of water discharge is necessarily due to atmospheric conditions, but it is undeniable that the amount of discharge is increasing and the amount that it increases by is growing. The length and strength of dry-periods for many rivers across the world are also increasing. This means that the wet periods are becoming far more wet and the dry periods are becoming far more dry. When lakes and springs flood or dry and rivers change their movement trends due to flooding or drought, it changes the structure of the land around it due to increased opportunity for erosion and growing to occupy more space (Bergeron 2002). This is something that has occurred for millions of years, but the rate at which it is happening poses a problem for our species, as many communities are built around sources of water. Many studies are being done to better understand the rate at which we can expect structural changes in freshwater systems, but we only have the power of observation, such as literally seeing where a river used to bend as opposed to where it does now, and data that only goes so far back. Dendrochronology offers a way for us to better understand the way that our freshwater systems evolve. A study done at the Morice River in British Columbia, Canada showed the significance of dendrochronology in understanding how rivers evolve over time. Flood events leave scars on trees that can be seen and identified. The scars are typically caused by debris crashing into the bases of trees. The Morice River is one of the major tributaries of the Bulkley River, a more popularly visited river in Canada. The Morice was chosen because it is mostly free of human contact. This also makes it difficult to understand the flood history of, because nobody was there to create records of it. Using dendrochronology methods, the researchers were able to find that thirty-one floods had occurred in the last one-hundred and five years, with the bulk of them occurring towards the end of the one-hundred and five year period. Tree-establishment dates from the area also show that the river occupied more space and the floodplain was larger during the Neoglacial period and the current floodplain was assumed around 1870. It has maintained that size and regimen since then. However, it was found that the evidence left on trees decreased with age (Gottesfeld 1990).

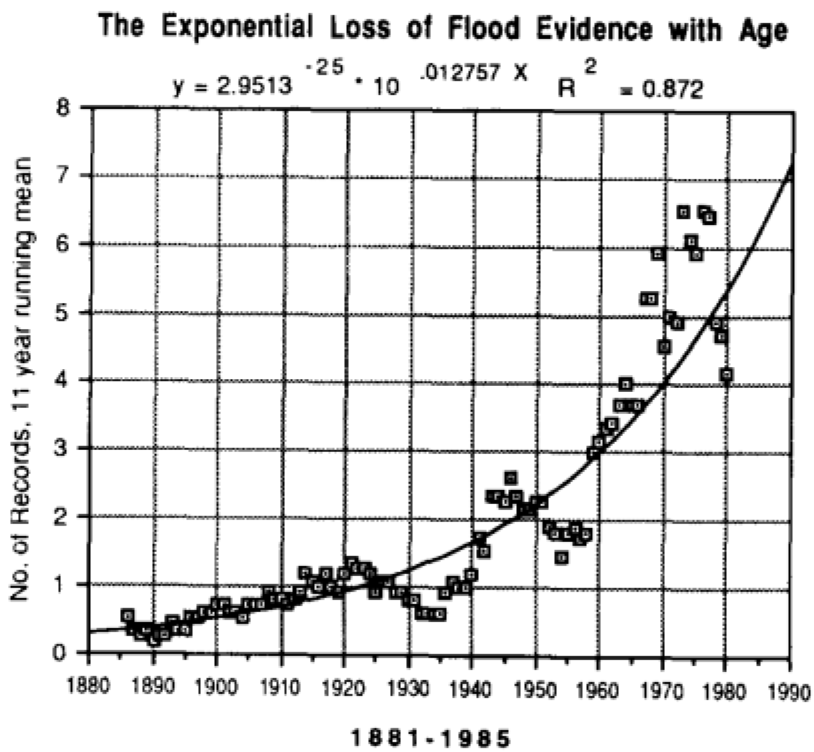


Fig. 1. This chart shows the loss of evidence left on trees over time. It is clear that as time goes on, it is harder to recognise evidence for flood impact events at the Morice River (Gottesfeld 1990).

The findings of that study do not mean that dendrochronology is unusable when creating reconstructions of flood history. This argument is strengthened by a study that was performed on over five-thousand subjects in the Low Countries of Northwestern Europe. In this study, the researchers analyzed flood events over a thousand year period to find patterns. They did this by utilizing dendrochronological methods. They found that over the course of a millennium, over one hundred and fifty flood events took place with twenty-one of them having a recurrence frequency at or below fifty years. One-third of the twenty-one flood events with a recurrence frequency at or below fifty years occurred between AD 185 and 282. This showed the researchers that that period of time was the most intense flooding period of the first millennium. The researchers were able to see periods of increased growth over the course of a thousand years, which shows that dendrochronological records are exceptionally valuable when it comes to developing flood histories. However, it seems to depend on the species chosen. Some species of trees show the involvement of water activity more clearly than others. In this study, oak, ash, and elm were chosen because they have larger capillaries and more visible signs of intense water activity (Jansma 2020).

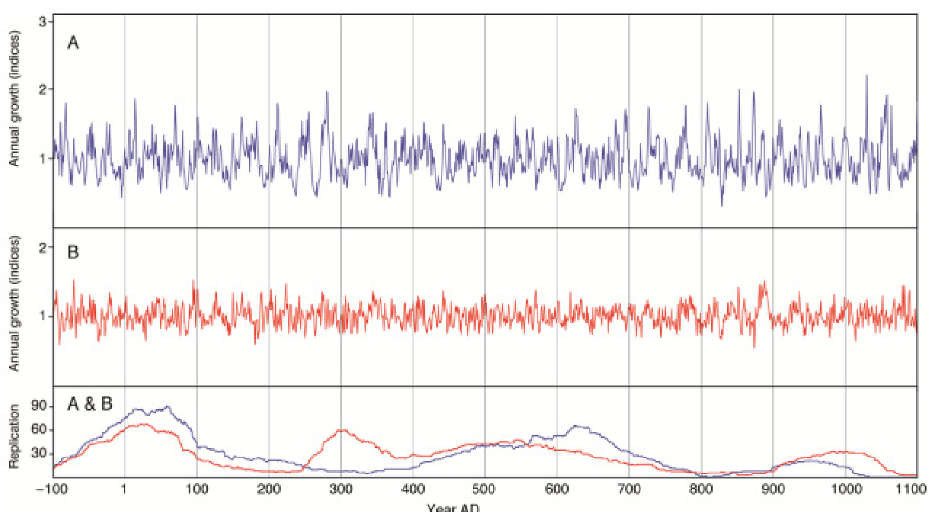


Fig 2. Shows the dendrochronological record of ring growth over the course of the first millennium AD (Jansma 2020).

These two studies show the two sides to dendrochronological analyses of the structure and movement of freshwater systems. The distance backwards in time that is achievable by dendrochronology is entirely dependent on the local ecosystem. That does not make it a method without value, but it does make it a specialized method that should be used as a case-by-case basis.

Dendrochronology and organism involvement

Freshwater systems make up less than one percent of the Earth's surface, but roughly six percent of insect species spend at least one stage of their life stages in a freshwater system. This means that insects are extremely prominent in freshwater ecosystems and are essential to the cycle. Insects are also commonly used as indicators of freshwater system health, due to their significant biodiversity and extreme dependence on water quality and flora success. A study done for the *Journal of Entomology and Zoology* sought to find how successful insects are when used as bio-indicators for freshwater stream health in Malaysia. Aquatic insects in the Liwagu River were sampled over the course of three months. A total of forty-four genera of insects were used for this study. They also sampled the water over the same period of time to test the salinity, pH, conductivity, and temperature. The results of this study showed that the correlation between water quality and insect biodiversity and population sizes was very high. The correlation was that when the water quality was good, the insect populations and biodiversity boomed. This means that insects can be a good indicator of health for freshwater systems, which brings me to my next point (Shafie 2017).

If insects are successful indicators of freshwater system health, then they are a valuable asset to analyzing freshwater systems over time. The catch with this is that studies done on insect species now do not mean much for studying freshwater systems over a long period of time. That is where dendrochronology comes in.

A tree-ring analysis of *Pinus sylvestris* and *Quercus* was performed in Eastern England. The research team was studying a prehistoric forest that was buried at Tyrham Hall Quarry in the Humberhead levels of Eastern England. They were studying insect assemblages in tree-rot holes to see if they could track the population and movement over time of xylophilous beetles. They chose to use this location because they knew that it was a maintained prehistoric forest and were looking to push for reconstruction within a concise time-frame. Through this study, the team was able to use dendrochronology to find connections between the forest's diminishment and the insect species' diminishment. By cross-referencing the subfossil rings of the trees with beetle-evidence and the rings of oak trees in another location, they were able to conclude that the disappearance of the insect was due to the decline of woodland habitats, which was likely due to climate change and lack of large scale migration capabilities. This study shows that if a tree-record is well preserved enough, it can be used to track the lives of large populations of insects over a rather long period of time (Bosjwik 2002).

The western spruce budworm is a popular insect for those combining entomology with dendrochronology. A study done in the Pacific Northwest of America showed that there is a connection between spruce budworm outbreaks and droughts. The researchers sought to study Douglas firs and the destruction brought on them by spruce budworms, which are thought to be the most destructive defoliator in Western North America. They said that while these outbreaks have had serious ecological and economic significance, historically, the reasonings are still not fully understood. The research team performed studies at thirteen sites across a transect line from Oregon to Montana and compared the outbreak reconstructions and area drought histories. The reconstructions revealed that many of the outbreaks lasted for more than a decade and were synchronous amongst sites. There was a fairly strong relationship between the beginning of these synchronous insect outbreaks and the periods of transitional climate conditions. The budworm outbreaks typically aligned with a period of below-average moisture availability prior to the outbreak. There was a noticeably weak relationship between the frequency of outbreaks and periods of high moisture-availability. The outbreaks tended to occur near the end of periods of low moisture-availability and droughts. It was found that climatic conditions and water availability was a contributor to the outbreaks of spruce budworm (Flower 2014).

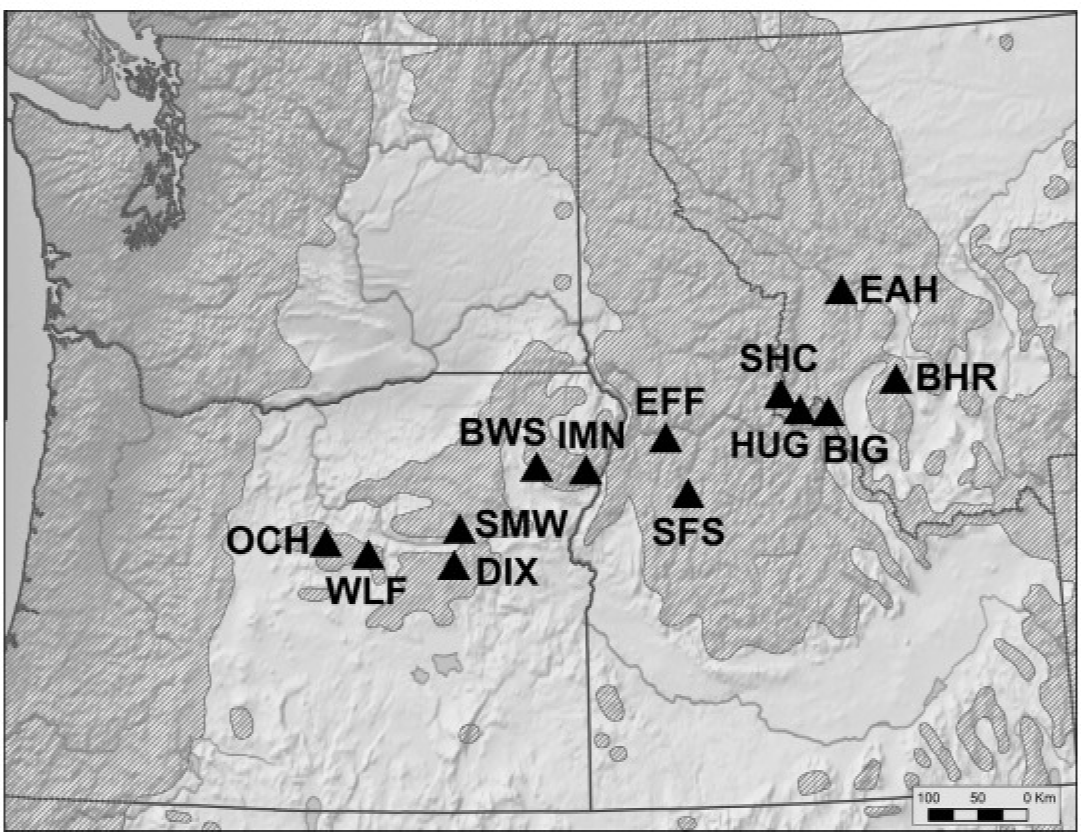


Fig. 3. This is a map of the transect that the study took place along (Flower 2014).

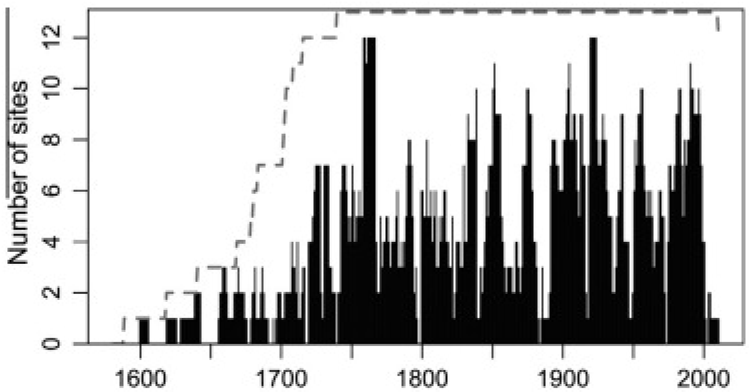


Fig. 4. Shows the number of sites recording an outbreak over a four-hundred year period (Flower 2014)

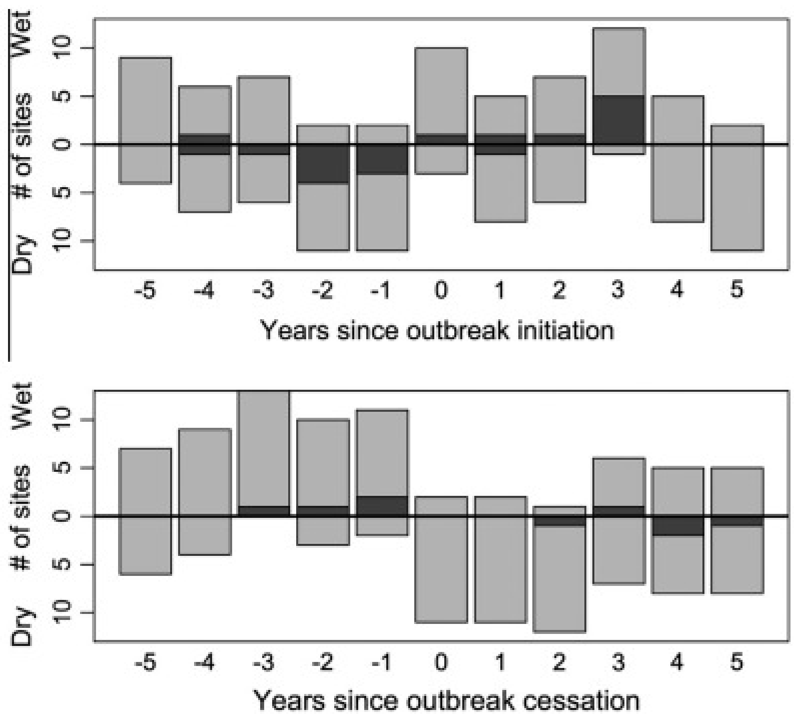
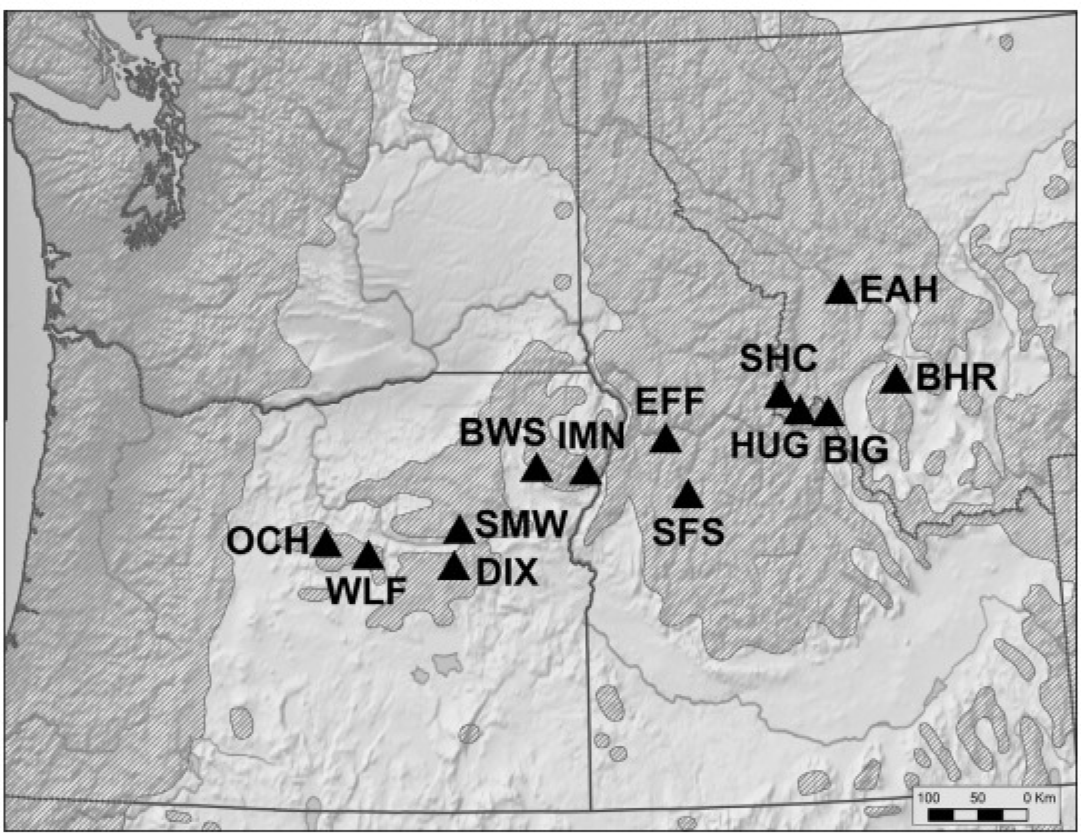


Fig. 5. Shows the connection between dry conditions and outbreak occurrences (Flower 2014).

It is clear that the conditions of freshwater systems can show itself in the populations of insects that surround it. It is also clear that dendrochronological records can show the movements and populations of insect species. So, hypothetically, a more targeted study on specific xylophilous insects that largely depend on freshwater systems could be used to better understand fully understood. The research team performed studies at thirteen sites across a transect line from Oregon to Montana and compared the outbreak reconstructions and area drought histories. The reconstructions revealed that many of the outbreaks lasted for more than a decade and were synchronous amongst sites. There was a fairly strong relationship between the beginning of these synchronous insect outbreaks and the periods of transitional climate conditions. The budworm outbreaks typically aligned with a period of below-average moisture availability prior to the outbreak. There was a noticeably weak relationship between the frequency of outbreaks and periods of high moisture-availability. The outbreaks tended to occur near the end of periods of low moisture-availability and droughts. It was found that climatic conditions and water availability was a contributor to the outbreaks of spruce budworm (Flower 2014).



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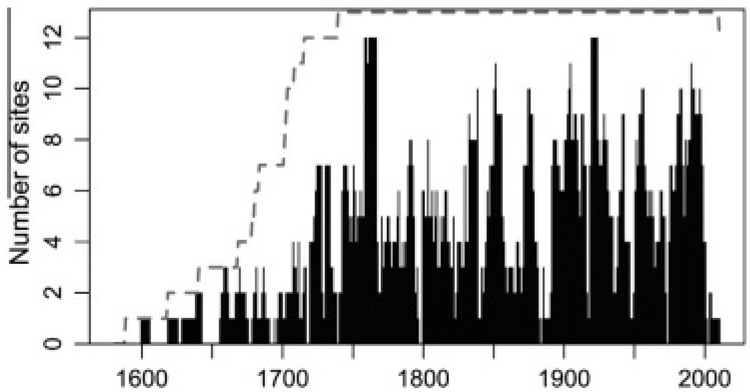

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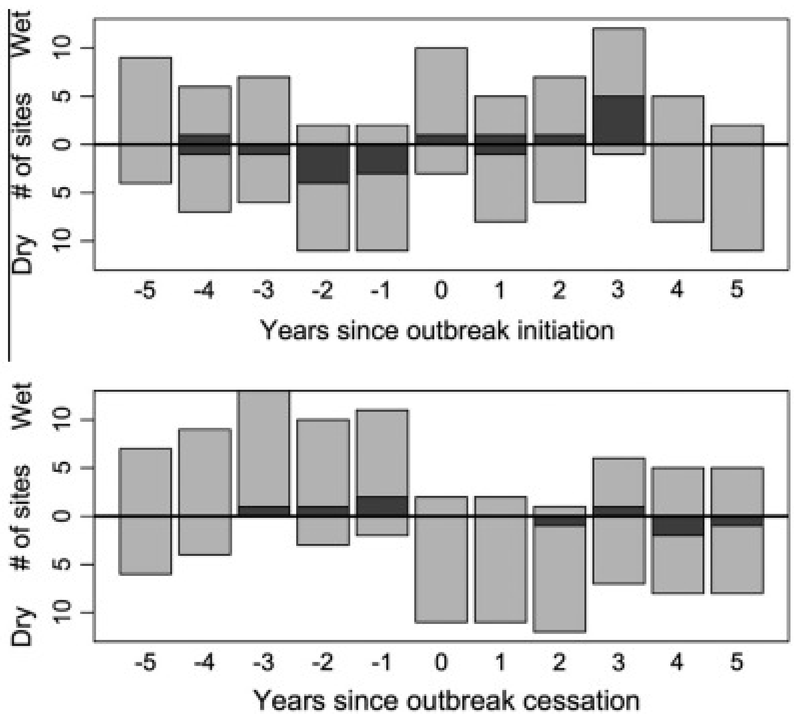

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Dendrochronology and water quality

It seems as though water quality is not yet measurable by dendrochronological records. Of course, the water quality must have some effect on the growth of trees, but studies performed on it are minimal or inconclusive. However, atmospheric conditions have been proven to affect the growth of trees. A study done across boreal and temperate forests in Canada showed that CO2 levels affected the speed at which the trees grew. It was found that there was a trend of decreased growth in trees due to atmospheric CO2 concentrations increasing, despite the efficiency of water-use efficiency increasing (Silva 2010).

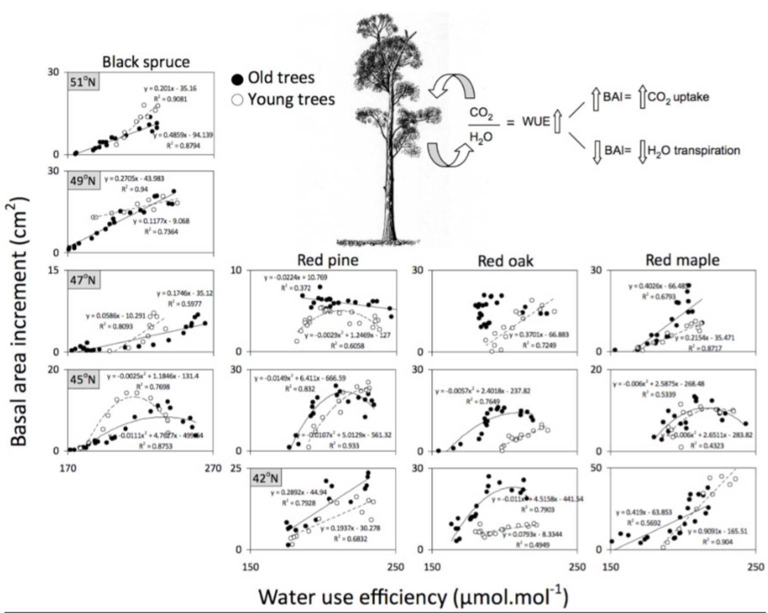

Fig. 6. This figure shows that CO2 concentration increased water use efficiency (Silva 2010)

I believe that a correlation between water quality and tree growth could be found if a study was done to prove that the quality of water affects the growth of trees, but the science is not there yet. It would take multiple studies across multiple locations that took place over a long period of time.

Conclusion

The use of dendrochronology when analyzing the health of freshwater systems is a new practice and not often used. However, I believe that there is serious potential across all three forms of indicators that I have talked about. The correlation between freshwater system health and insect population health has been found. The correlation between insect population booms and the effect they have on trees has been found. So, the gap just needs to be bridged and I believe that there is really something interesting there. Dendrochronology can certainly be used to better understand flooding and drought events, as proven by the first study mentioned. If we have an understanding of past events and the rate at which they occur, we can use that information to better prepare for the future. Water quality testing with dendrochronology is not a practiced science, but there seems to be real potential there and I am interested in seeing where academia takes it. The importance of freshwater systems to our biosphere cannot be taken lightly and dendrochronology offers a unique way of studying the health of these systems over a long period of time.

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