Comparison of Water Quality for Salmonid Spawners between Undisturbed and Restored Riparian Sites

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Abstract

In an effort to rehabilitate the damage caused to Stoney Creek by the overpassing bridge and adjacent highway stretches, the Stoney Creek Environment Committee launched a restoration project to return the stretch of water back to baseline spawning habitat conditions. To verify the efficacy of the restoration project, water quality indexes - based on stream characteristics (pH, temperature, dissolved O_2, turbidity) and invertebrates - from the Streamkeeper's Handbook taken at both the Stoney Creek site and an upstream stretch known as Tributary 3A were compared to illustrate the difference in environmental conditions. As well, large woody debris has been used as an indicator of pool habitat for spawning sites, an important aspect for success of salmon reproduction. The lack of large woody debris at Stoney Creek can be attributed not to a lack of effort to establish pooling habitat, but the length of time that is required for alder and douglas fir to mature and fall into the river. Based on the water quality indices from stream characteristics and invertebrates, we conclude that the efforts made by the SCEC have had a positive effect on the spawning habitat for salmon species.

Introduction

Salmonid fisheries are an important economic, environmental, and social resource on the west coast of BC. Salmonid species spend most of their lifetime in the open ocean, but return to fresh water streams to reproduce. Many streams in the lower mainland are salmonid bearing, and as such the quality of these streams is of extreme importance to western Canada. With an increasing need for development of roadways and housing infrastructure, the quality of these streams is in jeopardy due to sedimentation, pollution, and physical barriers created by construction. These disruptions have a profound effect on the ability of salmonid species to effectively spawn in the streambed. During post-disruption rehabilitation efforts, the quality of spawning environments can be described by indicators such as dissolved solids in the water, salinity levels of the stream, and streambed gravel size. Stoney creek has been disrupted and undergone rehabilitation to restore the viability of the creek for spawning grounds.

In 2012 the Stoney Creek Environment Committee completed a project with the intent of improving environmental conditions and accessibility for salmonid species to spawn, and to improve the wintering habitat for juveniles. We aim to address the success of the restoration project by comparing water quality indices between the Stoney Creek site, and the undisturbed upstream creek section named Tributary 3A.

Methods

Measurements were taken at two locations along Stoney Creek (Figure 1) in order to assess and compare data from a site that had been disturbed by heavy machinery (Stoney Creek Site) with another site upstream (Tributary 3A) that had not been affected by the restoration project. We made visits to the sites on multiple days during different weather conditions such as snow, rain, and sun over a period of four weeks starting in March 2013 to ensure a diversity of data. The same tools were used at both locations for each test to warrant compatibility between data and eliminate the use of different tools as a confounding factor. At both locations a proper reference mark and cross sectional area were established before any measurements were performed. Both cross sectional areas consisted of the stream width with measurements taken 10 meters upstream and 10 meters downstream for a total length of 20 meters.

pH and Temperature

pH was measured using an electronic pH meter with digital automatic and digital fine-tuning to attain the most precise measurements. Temperature was recorded by a mercury thermometer, which was held under water for 3 minutes. pH and temperature data were taken at the reference mark as well as at both locations upstream and downstream. pH was taken 3 times at each reference point to calculate a mean that could then be collaborated for increased accuracy. Temperature was taken upon arrival as well as once just before departure to account for the input of solar radiation that could alter the readings throughout the day.

Velocity and Turbidity

Electronic devices to measure velocity and turbidity were not available to us and therefore we used other methods found in the Stream Keepers Handbook, which has been approved by the B.C. provincial Canadian Fisheries and Oceans. Turbidity was measured by carefully gathering water into a bucket so as not to stir up any extra sediment and then, with a marked ruler, the ruler was slowly lowered along side the edge of the bucket towards the bottom until we could no longer see the marker. Velocity measurements were taken by placing a tennis ball 10 meters upstream from the reference mark and allowing it to freely float downstream where the duration of time for the ball to reach the reference mark 10 meters down was recorded.

Large Woody Debris

LWD were only considered in our assessment if they were directly within our sectioned off parameters. Logs that were more than half way within the cross section were considered to be valuable data. Many logs at tributary 3 were embedded deeply within the cut banks of the stream and therefore only the diameter was recorded. Logs visibly shorter than 3 meters were omitted from our results due to their potential inefficiency to properly get log jammed and produce a pond. According to a study conducted by Hilderbrand et. al., 1997, LWD with a diameter smaller than 10cm were not considered to have a substantial impact on river morphology. Therefore, for our study, only logs with a diameter lager than 10cm were measured and recorded at both locations.

Invertebrates

Invertebrate species were gathered using a 30x30 cm surbur sampler that was placed securely into the bottom of the stream. Rocks found within the channel were then carefully picked up and rubbed so as to detach any invertebrates that have secured themselves to it. Using magnifying glasses, tweezers and an ice cube tray, species were separated and counted.

Results

In comparing the results of both sites, the average pH of the restored site of Stony Creek had an average of 7.267, compared to tributary 3A, where the average pH was 7.767. Both of these values are within the acceptable range of Salmon tolerances; however there is a significant difference between the two.

Temperature was recorded at Stony Creek on March the 3rd and at tributary 3A on March 24. When sampling at Stony Creek, there was recent snowfall, and general temperatures were warmer when compared to late March when we sampled at Tributary 3A. The average temperature recorded at Stony Creek was 5.5°C, and the average temperature at Tributary 3A was 7.92°C.

The ‘pollution intolerant’ invertebrates include the caddisfly larva, gilled snail, mayfly nymph, and stonefly nymph. The only taxon of ‘somewhat tolerant’ invertebrates we found was the watersnipe larva. Lastly, the only taxon of ‘pollution tolerant’ invertebrates was the aquatic worm. At the Stoney Creek site we found 5 taxa of pollution intolerant, 2 taxa of somewhat intolerant, and 1 taxon of pollution tolerant. Table 4 shows a pollution tolerance index of 18, which according to the Streamkeepers Handout Module 4, gives an ‘acceptable’ index. At Tributary 3a, we found 8 taxa of pollution intolerant, and 1 taxon of pollution tolerant species. This yields a pollution tolerance index of 25. Table 5 shows that an index of 22 or greater is regarded as ‘good’.

LWD was found to be abundant at tributary 3A compared to Stoney Creek. One log was found at Stoney Creek but the diameter was less than 10cm, which did not fit into our parameters and was discarded as having any effect on river morphology. The lack of LWD at Stoney Creek could be due to the recent disturbances before and during the rehabilitation project where larger logs within and around the stream would have been moved to make way for large machinery. No LWD was found to create a positive habitat for salmonids at Stoney Creek. Comparatively, the undisturbed site at Tributary 3A had six measurable pieces of LWD (figure 2), where some of them showed visible signs of altering the flow of water. One of these logs measuring a diameter of 17.7 cm redirected the flow in such a way that it created a pool behind it creating a preferential habitat for salmonids. This positive correlation to salmonid habitat and the abundance of LWD parallels the naturally occurring phenomena within riparian areas where trees of a certain age tend to fall naturally and alter the natural landscape. The naturally occurring LWD would have been extracted from Stoney Creek whereas tributary 3A has been undisturbed and pool forming LWD remains.

Discussion

For both Stoney Creek demonstration site and Tributary 3A, the temperature readings upon arrival more or less match the one before leaving, indicating other measurements such as pH were taken under a constant solar radiation input. This further strengthens the reliability of our data set. The only temperature readings that do not match are the ones taken at the reference point at Tributary 3A. There is a 0.5 C difference between the readings and that might be due to an observational error since all the other readings are identical (8°C). The associated Q-value for all the temperature change is 93, implying a good stream condition for salmonid species.

In a study conducted by A. Moore which looked at river temperature effects on Salmon behavior, he noticed that Salmon lay eggs in locations which their body temperature is lower than the water temperature. It is also important to note that Salmon prefer stream temperature to be between 5°C-20°. Both measurements from each site fall within this comfort range, however Stony Creek was near the threshold for the low temperature. This was likely due to the seasonal pattern, and could indicate the beginning of the spawning period. Temperature changes within a stream seasonally, which is to be expected. However, it is important to know how different the seasonal changes are with regards to temperature fluctuation. Late winters or early springs can often occur every so often, which the Salmon can adapt too, although if climate change is occurring, then these shifts may be large enough to affect the spawning rate and time of the salmon population.

Electronic pH meter is preferred over Litmus paper because observational error is likely to be made when identifying the color change of Litmus paper. The pH reading obtained from the demonstration site ranges from 7.2-7.4 (0.2 unit difference), which is rather narrow. The pH values for all sections are fairly close to neutral (pH 7), indicating a satisfactory water condition for fish species as many of them cannot endure acidic condition. For Tributary 3a, the pH readings ranges from 7.67-7.86 (0.19 unit difference), which is also a narrow range. These pH values imply the water is slightly basic and the associated Q-values for all 6 sections are within 91-92, suggesting the stream would still be considered an acceptable condition for the salmonid species. The restored Stoney Creek shows a decrease in pH compared to Tributuary 3A, but that could possibly be the different weather condition when we were taking the measurements since carbon dissolves better in cool water and the resulted product carbonic acid might affect the pH. In a study conducted by F. Kroglund, it was found that when pH levels drop below 6, there is an exponential increase in mortality rates for salmon population. Since the pH level is lower in the restored site, it is important to know whether it is increasing, decreasing, or staying the same each year. We currently have empirical data for this year, so monitoring the levels over the next few years could prove to be beneficial towards a better understanding of the health of the stream.

We applied the bucket-ruler method to measure turbidity because the stream discharge was very high during the day we surveyed at the demonstration site. In order to reflect a meaningful comparison, we applied the same method to measure the turbidity for Tributary 3A for consistency, even though it was sunny the day we conducted the survey. The turbidity measurements for the three sections at the demonstration site show variation, indicating the composition and deposition of sediments might be different from section to section. The turbidity of Upstream and downstream have Q-values of 80 and 70 respectively, but the midstream only has a Q-value of 50, which is not satisfactory. However, the values of upstream (33cm) and downstream (30cm) are in fact fairly close, so the deviated value of midstream (23.5cm) might be contributed by our constant, rapid movement, since fine sediments (< 0.2 cm) have low density and can easily be uplifted. On the other hand, Tributary 3A had really clear water, so we were able to see the all numbers of the submerged ruler in the bucket. That is reasonable because Tributary 3A is an undisturbed area therefore all the sediment is probably in deposition, and the amount of fine sediments would probably be lower than the disturbed site in Stoney Creek. The precipitation and discharge was also low when we conducted the turbidity measurement at 3A, so the clear water we observed was reasonable. In contrast, the stream in Stoney Creek demonstration site has lower visibility possibly due to the huge amount of sediments deposited from past constructions, as well as the high discharge resulted from the high precipitation during that week (Feb 24). We are concerned about turbidity because fine sediments can potentially reduce the hatching and survival of salmonid frys by decreasing the level of dissolved oxygen or by entrapping them.

Dissolved oxygen in water helps to sustain biota, and oxygen is generally dissolved in water as a byproduct from photosynthetic organisms, aeration (rapid movement) or diffusion between different concentration gradient (Cooke, n.d.). In general, the level of dissolved gas concentrations will be harmful to fish species if it exceeds 110 percent, because excessive dissolved gases will produce bubbles in the blood vessel of fish and interfere with blood flow

(Cooke, n.d.). According to the data we collected, the concentration of dissolved O2 in Tributary 3A ranges from 120-140%, which is much higher than 110%. However, the salmonid species probably would not be threatened later during migration season because: 1) oxygen generally dissolves better in cool water and the temperature will increase later during migration season (early summer to fall), so the dissolved oxygen level is expected to be lower; 2) the evaporation rate is also higher in the summer, so the surface area to volume ratio is expected to be higher and the water heats up more easily, resulting in an even lower oxygen level; 3) Less turbulence is produced from the low discharge rate due to high evaporation, and low precipitation in the summer, resulting in less mixing of water and a lower dissolved oxygen level. At the Stoney Creek site we found that the dissolved oxygen was consistent for all three tests, at a percent saturation of 85%. Although this percent is suboptimal, it gives a Q-value of 90, which is acceptable for salmonid species in the stream.

The total count for invertebrates at Stoney Creek was lower than that at Tributary 3A, and this may be caused due to a number of factors: the downstream site has greater public access, and as such the growth patterns of invertebrates may be affected by human or animal disturbance; the samples taken at the downstream site may have been taken at a time of less ideal conditions for invertebrates to reproduce; or, the restoration of Stoney Creek falls short of bringing the water quality completely back to normal conditions. With regards to the invertebrate survey, the quality of the two streams resulted in a similar WQI – 3 versus 3.25 for Stoney Creek and Tributary 3A, respectively (Table 4 & 5). The lower reading for Stoney Creek is both expected and acceptable, due to the restoration that has taken place to rehabilitate spawning habitat. As well, the number of specific taxa found at each site provides insight into the water quality difference between the two sites. Specimens such as the larvae of mayfly, caddisfly, and stonefly, found in abundance at both sites are tolerant to a small range of environmental conditions, while other specimens such as aquatic worms can tolerate a wider range of conditions. The presence of high numbers of pollution intolerant species indicates that the stream is clear, has high levels of oxygen, and contains abundant nutrients. As both streams receive at minimum a rating of “good”, it can be concluded that Stoney Creek has been returned relatively close to its baseline condition before the disturbance occurred.

It is important to note that while the results indicate a similar reading for both sites, the WQI for Trib.3A has been affected by the total count of tolerant specimens. At the 3A site, we found a large number of aquatic worms, and this count affects the EPT to total ratio, which received a rating of marginal. The high number of aquatic worms is not indicative of the water quality, as aquatic worms are pollution tolerant and are capable of existing in less than desirable conditions. A high count such as the one we observed has the potential to occur in a large number of environmental conditions. This skews the EPT/total ratio, resulting in a lower rating overall. If the aquatic worm is discounted in the specimen count, the site rating increases significantly, and the conclusion that the restoration was a success is not as strong due to the larger difference between sites.

LWD influences geomorphic processes, water flow, and fish and invertebrate habitats. According to Mossop and Bradford (2004), it takes roughly seven years for red alder (*Alnus rubra*) and 15 years for Douglas-fir (*Pseudotsuga menziesii* ssp. *menziesii*) to grow to a breast-height diameter of 13 cm and be recruited to a stream as debris if some force causes the tree to fall. Both of these species of trees are naturally growing at both locations. The lack of LWD at Stoney Creek indicates that it may not have had enough time to fully recover back to its natural state where naturally falling trees would typically occur at a higher frequency. It should be noted that correlations between juvenile Coho salmon density and reach scale LWD abundance are commonly reported (Murphy et al, 1986), and this correlation is often attributed to increased pool habitat. Stoney Creek had no LWD to form pools whereas Tributary 3A had an abundance of pool forming LWD due to the location having been undisturbed where years of accumulated LWD remains. A possible tactic to enhance favorable salmonid habitat could be to physically implement LWD to disturbed locations such as Stoney Creek. Hilderbrand et al (2007) conducted a study about random and systematic placement of LWD and their effects on pool formation. Their results concluded positive for pool formation following the placement of LWD and recommend adding logs with branches or root wads attached because straight, clean boles are much more likely to move during elevated flows. Further readings on this study can be found in the peer-reviewed paper by Hilderbrand et al (1997) found in the references.

Conclusion

The tests that we conducted on both Stoney Creek and Tributary 3A were to compare the effects of the restoration project at Stoney Creek to that of an upstream, undisturbed riparian area in order to assess river quality and the effects this has on salmonid spawning habitat. Some of the data was similar between the two sites, and others showed significant difference. Temperature, pH, and dissolved oxygen were very similar between each site. Meanwhile, the measurements of large woody debris, invertebrate count, turbidity, and velocity, showed discrepancies between the restoration and undisturbed sites. Large woody debris was significantly greater at Tributary 3A compared to Stoney Creek. Invertebrate index proved to be ‘good’ in three categories for Tributary 3A, which compared to Stoney Creek, was only ‘acceptable’. Tributary 3A had a lower amount of suspended sediments, but this could be due to the much lower velocity and stream discharge. In conclusion, the restoration on Stoney Creek was successful, and has brought many of the stream quality characteristics close to that of an undisturbed stream. The discrepancies between the two could be due to the time scale. Stoney Creek has shown improvement, however it will need more time to completely develop into a healthy stream again.

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Appendix 1 - Tables

Table 1 – Stoney Creek water quality index

10m Downstream	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	85	90	0.17	15.3
	pH	7.4	92	0.11	10.12
	Turbidity/depth of visibility	30	80	0.08	6.4
				TOTAL	41.12
Reference	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	85	90	0.17	15.3
	pH	7.2	91	0.11	10.01
	Turbidity/depth of visibility	23.5	50	0.08	4
				TOTAL	38.61
10m Upstream	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	85	90	0.17	15.3
	pH	7.2	91	0.11	10.01
	Turbidity/depth of visibility	33	70	0.08	5.6
				TOTAL	40.21
				AVERAGE INDEX	39.98

Table 2 – Tributary 3A water quality index

10m Downstream	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	120	91	0.17	15.47
	pH	7.77	91	0.11	10.01
	Turbidity/depth of visibility			0.08	0
				TOTAL	34.78
Reference	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	140	89	0.17	15.13

	pH	7.86	91	0.11	10.01
	Turbidity/depth of visibility			0.08	0
				TOTAL	34.44
10m Upstream	**Chemical Test**	**Result**	**Q value**	**Weighing Factor**	**Index Value**
	Δ Temperature °C	0	93	0.1	9.3
	Dissolved 02 %sat.	140	89	0.17	15.13
	pH	7.67	91	0.11	10.01
	Turbidity/depth of visibility			0.08	0
				TOTAL	34.44
				AVERAGE INDEX	34.55333333

Table 3 – WQI chart

WQI rating	Score
Good	40-45
Acceptable	30-40
Marginal	20-30
Poor	<20

Table 4 – Stoney Creek invertebrate assessment

pollution tolerance index	3 x (PI taxa)	15		good	>22
	2 x (SI taxa)	2		acceptable	22-17
	1 x (PT taxa)	1		marginal	16-11
	TOTAL	18		poor	<11
EPT index	# EPT taxa	5		good	>8
				acceptable	5 to 8
				marginal	2 to 5
				poor	0-1
EPT to total ratio	#EPT count/total count	0.677419355		good	0.75-1.0
				acceptable	0.5-0.75
				marginal	0.25-0.5
				poor	0-0.25

Predominant taxon ratio	#dominant taxon/total count	0.548387097		good	0-0.4
				acceptable	0.4-0.6
				marginal	0.6-0.8
				poor	0.8-1.0
Site Rating Assessment	good = 4 points	3	PTI		
	acceptable = 3 points	3	EPT index		
	marginal = 2 points	3	EPT : total ratio		
	poor = 1 point	3	PT ratio		
		3	***Average***		

Table 5 – Tributary 3A invertebrate assessment

pollution tolerance index	3 x (PI taxa)	24		good	>22
	2 x (SI taxa)	0		acceptable	22-17
	1 x (PT taxa)	1		marginal	16-11
	TOTAL	25		poor	<11
EPT index	# EPT taxa	7		good	>8
				acceptable	5 to 8
				marginal	2 to 5
				poor	0-1
EPT to total ratio	#EPT count/total count	0.466019417		good	0.75-1.0
				acceptable	0.5-0.75
				marginal	0.25-0.5
				poor	0-0.25
Predominant taxon ratio	#dominant taxon/total count	0.32038835		good	0-0.4
				acceptable	0.4-0.6
				marginal	0.6-0.8
				poor	0.8-1.0

Site Rating Assessment	good = 4 points	4	PTI		
	acceptable = 3 points	3	EPT index		
	marginal = 2 points	2	EPT : total ratio		
	poor = 1 point	4	PT ratio		
		3.25	*Average*		
pollution tolerance index	3 x (PI taxa)	24		good	>22

Appendix 2 - Figures

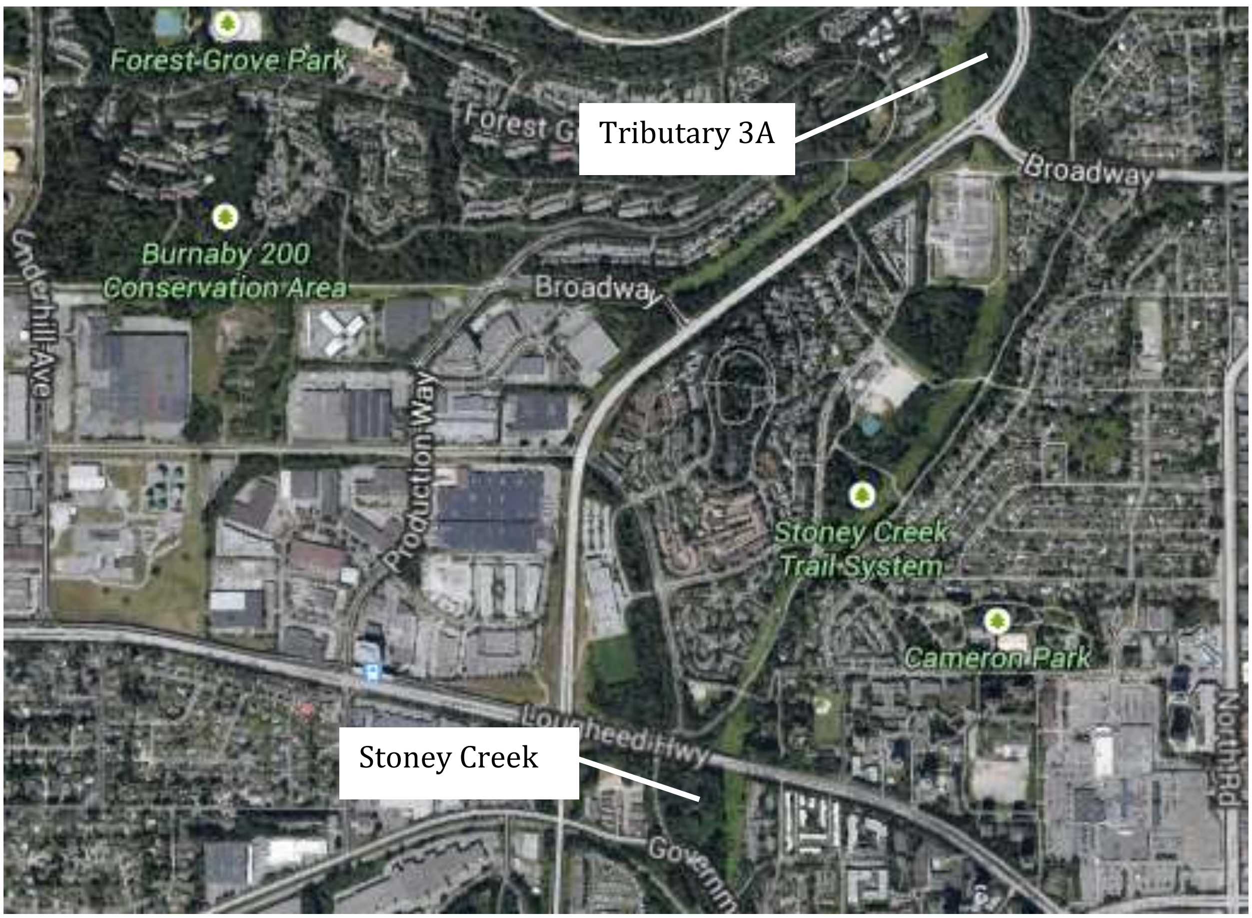

Figure 1 – Stoney Creek and Tributary 3A sites; Google Earth, 2014

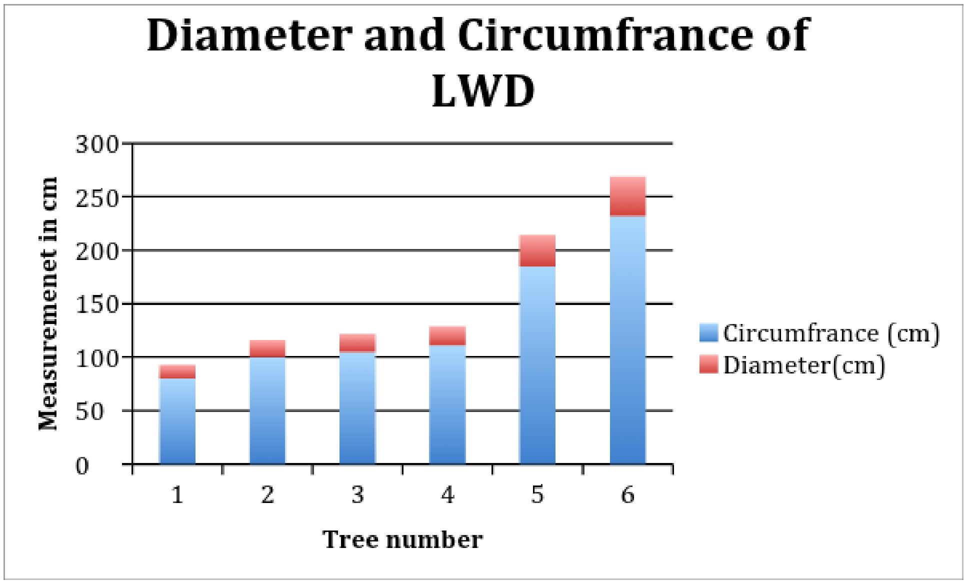

Figure 2: Measurements of the six (6) pieces of LWD found at tributary 3