Assessment of Sediment Quality in Stoney Creek Tributary 3a and its Suitability for Salmon Spawning

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EVSC 205 - April 23, 2014

Abstract

Sediment quality is an important factor in the survivorship of salmon eggs and Stoney Creek's restoration effort has recovered stream bed spawning sites. Sediment analysis at Tributary 3a is assessed to determine if the restoration provides a successful spawning habitat. Based on the site's pool and riffle characteristics, ideal spawning sites are most likely in riffle zones as the sediment composition were dominated by gravel. Stream discharge and velocity affects the lithology of the two zones, such that erodibility is much higher in the riffle due to higher velocity and the difference in the distribution of particles. The amount of gravel content and large pore space in the sediment indicate that the riffle space is a suitable spawning habitat for salmon and the restoration proves profitable. Due to natural erosion of soils over time, management strategies are recommended to preserve future salmon populations.

Introduction

Stoney Creek in Burnaby, B.C. is one of the most accessible and well known urban salmon spawning streams in the Lower Mainland, and is closely monitored by municipal staff and members of the public. Situated on the southern slope of Burnaby Mountain, the creek is influenced by activities at Simon Fraser University and urban and commercial development in the Lougheed area.

In recent decades, the creek has been the focus of bioengineering efforts organized by the Stoney Creek Environmental Committee. The bioengineering strategy aims to modify vegetation and banks in order to maintain the creeks suitability as a spawning site for salmon as well as restore habitat that has been modified or destroyed by development. In 2012, the Stoney Creek Environmental Committee counted record numbers of salmon, suggesting that Stoney Creek is indeed a suitable habitat for salmon.

Stream bed quality is one of the most important factors determining survival of salmon eggs, alevin, and fry. In order to assess the suitability of Stoney Creek Tributary 3a as a salmon spawning ground we measured sediment size, sediment composition, and stream discharge. In addition, we measured bulk density and texture of adjacent banks.

Methods

We collected samples and measurements from a field site located along Tributary 3a of Stoney Creek, at N 49°15’,55.2” and W 122°54’00.4” near East Grove Park. The specific 20m stretch of stream we surveyed was chosen because it included a pool and a riffle, appeared undisturbed by humans. (Fig. 1).

Stream wetted and bankfull depth was measured to create a stream profile. Water velocity was measured in both the pool and riffle site with a digital water velocity meter and was used to calculate pool and riffle discharge.

25 pieces of streambed sediment were measured in both the pool and riffle area for their length, width, and height in order to determine percent composition of fines, gravel, cobble, and boulder. Embeddedness of 10 pieces of streambed sediment was measured in both the pool and riffle site in order to determine average embeddedness of stream sediment in the sample area.

Mineral soil samples were collected from the undercut bank and the point bar (depositional bank) and volumes were deduced using sand and a graduated cylinder. The samples were taken to the lab, and were weighed and then dried overnight in the oven at 105°C, allowing any moisture to evaporate. The samples were reweighed in the morning. With the volume, dry weight, and wet weight of the samples, bulk density could be calculated. Hand texturing of soil was also conducted on the two samples to determine soil composition and erodibility, as both influence future stream sediment quality.

Sediment size, embeddedness, stream velocity and discharge were compared to values previously determined to be favourable to salmon spawning. Previous research by Sternecker et al., MacDonald et al., McNeil and Ahnell has established these values.

Results

Sediment Composition

From the samples of 25 collected at the stream, it was found that the pool zone consisted of sediments that were composed of 99% fine materials and 1% gravel. The majority of the pool's embeddedness was 50% or above. In contrast, the riffle zone consisted of larger particles, being 44% cobbles and 56% gravels. Embeddedness here was variable – there were some low and some high values, but averaged at about 38%.

Stream Profile and Discharge

The 20m stretch of stream on our site had varying characteristics at different points, but was a large pool followed by a riffle zone. In the pool, the velocity was 0.6m/s, whereas in the riffle zone it was 6.76m/s. These speeds correspond to discharges of 0.31m^3/s and 0.962m^3/s. Even though the speed was approximately eleven times faster in the riffle, its discharge was only three times larger than the pool. This is due to the much greater depth in the pool, which carries more water than the shallow riffle. The riffle had a wetted depth of 3.44cm, whereas the pool had a wetted depth of 21.85cm.

Bulk Density

The bulk density values of both samples taken were less than 1, 0.755g/cm^3 for the undercut bank and 0.506g/cm^3 for the point bar. The values seem accurate based on their textures. Being that sandy clay loams and sandy loams are somewhat intermediately-textured (not too much sand or too much clay), it makes sense that their bulk densities are somewhat low.

Discussion

Sediment Distribution

Sediment composition influences infiltration rates of water in between soil particles and the movement of nutrients. Salmon eggs require loose gravel conditions that allow oxygen flow and anchorage in between spaces to prevent the eggs being carried away by the current.

Fast moving currents can easily pick up suspended fine grain sediments which is evident from the riffle zone composition data. The pool zone, which is subjected to slower stream discharge, allows drifting particles from a previous riffle zone to settle. Physical actions of spawning fish and movement of salmon while creating redds also aid in the redistribution of particle sizes by suspending deep laying grains into the current (Rex and Petticrew, 2006). Stream bed density changes as a result of mechanical movement, in which nesting spots are continuously reformed, creating less dense gravel beds while undisturbed, fine grain beds remain compacted and dense. As a result, embeddedness varies between the different zones. High values in the pool zone indicate that fine sediments are deposited while low values in the riffle zone are due to eroding soil and displacement of fine particles.

Clay soils eroding into Tributary 3a may increase the proportion of fine particles over time, and this may inhibit the ability of salmon to effectively dig redds. Sternecker et al. determined that substratum alteration techniques such as excavation of streambeds can be beneficial for salmon but are likely to influence many other sites downstream as well as the surrounding terrestrial ecosystem. Further research is needed to determine the extent to which fine particles may increase in tributary 3a and whether human intervention would increase salmon spawning success.

Velocity and Discharge

As stream's velocity decreases, so does its competence and capacity, the ability to carry maximum sediment sizes and the total volume of sediments the stream can transport. This relationship explains the deposition of fine sediments observed at the pool zone, as well as the presence of cobbles and gravel along the riffle zone. The location of salmon spawning depends on the size of the surface sediments of the stream. Previous research has identified spawning activity occurring in areas of a "cobble-gravel substrate that is low in sand content" (Davey & Lapointe, 2007). Kondolf and Wolman (1993) statistically calculated from multiple spawning streams that salmon have the potential to lift up to "10% of their own weight". If salmon were to spawn within this tributary, it would most likely occur around the riffle zone, which is dominated by cobbles and gravel.

Discharge depends on the width, depth and velocity of a stream or river. It is intuitive that the riffle zone has a larger discharge than the pool zone as it is much shallower. It's possible that the pool zone was formerly a riffle zone, where the water's high velocity eroded the riverside's wall (Fig.5), creating the deep undercut that was seen in the field. Therefore, due to an increase in depth, velocity has slowed down greatly, which later increases in velocity again when the water reaches the shallower riffle zone.

Discharge and stream velocity are two of multiple factors that control the distribution of sediments and profile, which would determine the suitable locations for salmon to successfully spawn.

Bulk Density

The bulk density values of both samples were quite low, which could be explained by a number of different factors. The two main factors that affect bulk density are the textural class of the soil, and the soil structure itself. These values being low indicate that there is a large amount of pore spaces, which can be infiltrated by water. With water filling up the micropores and flowing between macropores, there is a greater likelihood of the erosion or breaking off of soil particles.

The undercut bank, with a sandy clay loam texture, contained larger and more plentiful soil aggregates, as shown in fig. 2. This makes sense as a sandy clay loam contains 20-35% clay, and since clays are attracted to each other it formed larger aggregates. This attraction makes the soil somewhat stronger and less vulnerable to erosion, so the speed of which the undercut bank has been eroded is most likely very slow. On the opposite bank, the soil was less aggregated due to its greater sand content and is more susceptible to erosion by the river. As the water cuts into the banks and removes soil, small mineral and organic particles are being incorporated into the stream. They can be deposited into salmon redds in which eggs are already present and smother them, or take up empty spaces which might be used by salmon in the future (Lazar et al. 2010).

Therefore, a stream with more cohesive/adhesive soil aggregates, or soils that are more compact (higher bulk density) would be more suitable for salmon spawning. Our site in tributary 3a did not have a high bulk density, but the clay content caused cohesion and adhesion, ultimately making salmon spawning favourable.

<u>Biotic Factors</u>

Tributary 3a runs through a park and near roads and other areas that have been disturbed and are frequently accessed by humans. Intermittent coverage of dense trees and underbrush, such as that covering the 20m stretch of stream that we sampled, aids in inhibiting access by humans in some areas (Fig. 1). This type of habitat heterogeneity is likely beneficial to the salmon as it increases the likelihood that some areas of the tributary that will have the conditions required by salmon. In addition, vegetation provides intermittent shading that provides heterogeneous microhabitats for salmon redds.

Conclusion

Our analysis, as well as many years of observed salmon spawning counts indicate that Tributary 3a of Stoney Creek is a healthy stream that is suitable for salmon to spawn in. Features such as alternating pools and riffles that contain areas with gravel and cobbles, heterogeneous macro environment containing areas with dense overgrowth, and banks that are composed of soil unlikely to erode very quickly all contribute to a relatively stable salmon suitable environment.

Further research could examine the extent to which streambed composition changes over time and whether bioengineering techniques such as excavation would increasing salmon spawning success. Continued collection of salmon return data could help correlate environmental changes with improvement or decline in salmon spawning success and could aid management efforts.

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Tables

Classification of Sediments

	Pool Zone (%)	**Riffle Zone (%)**
Boulders	0	0
Cobbles	0	44
Gravels	1	56
Fines	99	0

Tributary 3a Streamflow

Location	**Velocity (m/s)**	**Discharge (m^3/s)**
Pool Zone	0.6	0.31
Riffle Zone	6.76	0.962

Soil Samples

Location	**Volume of Sample (cm^3)**	**Wet Weight (g)**	**Dry Weight (g)**	**Bulk Sample (g/cm^3)**	**Texture**
Undercut Bank	260	303.7	196.4	0.755	Sandy Clay Loam
Point Bar	270	215.9	136.6	0.506	Sandy Loam

Figures

Figure 1. Photograph of Tributary 3a sampling site. A outlines riffle site. B outlines pool site. C shows undercut bank, and D shows the point bar. Vegetation may limit human access and disturbance.

Figure 2. Photographs of point bar soil sample (left) and undercut bank sample (right) after drying. Soil in the undercut bank shows more cohesion and has formed more aggregates that are also larger in size.

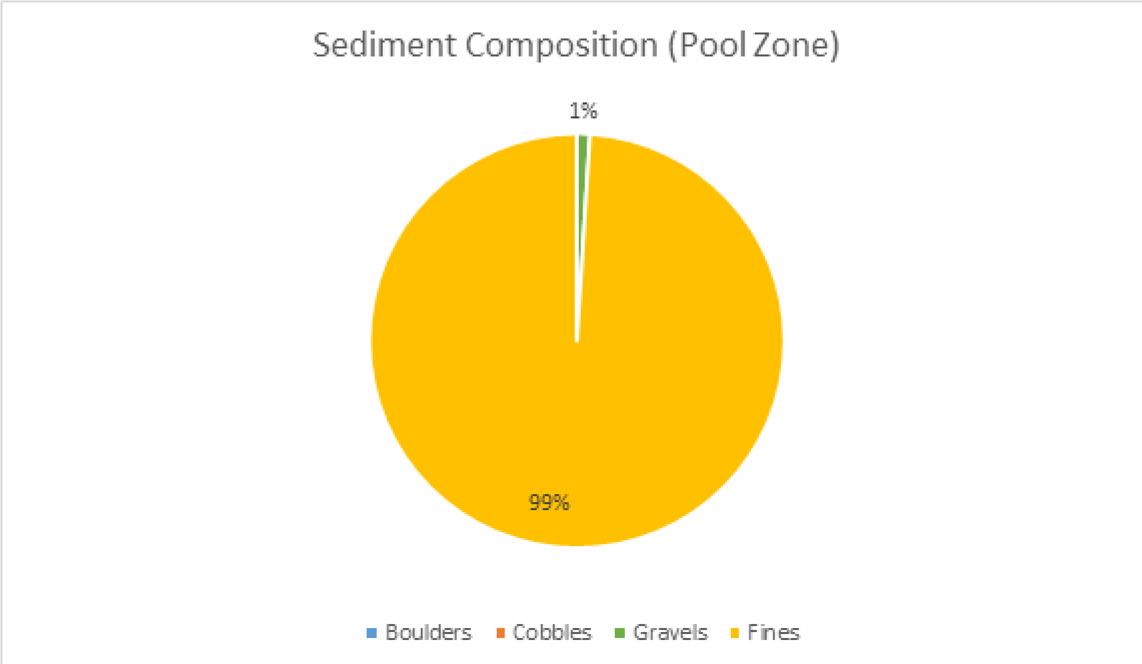

Figure 3. Pie chart showing the amounts of boulders, cobbles, gravels, and fine materials in the pool zone.

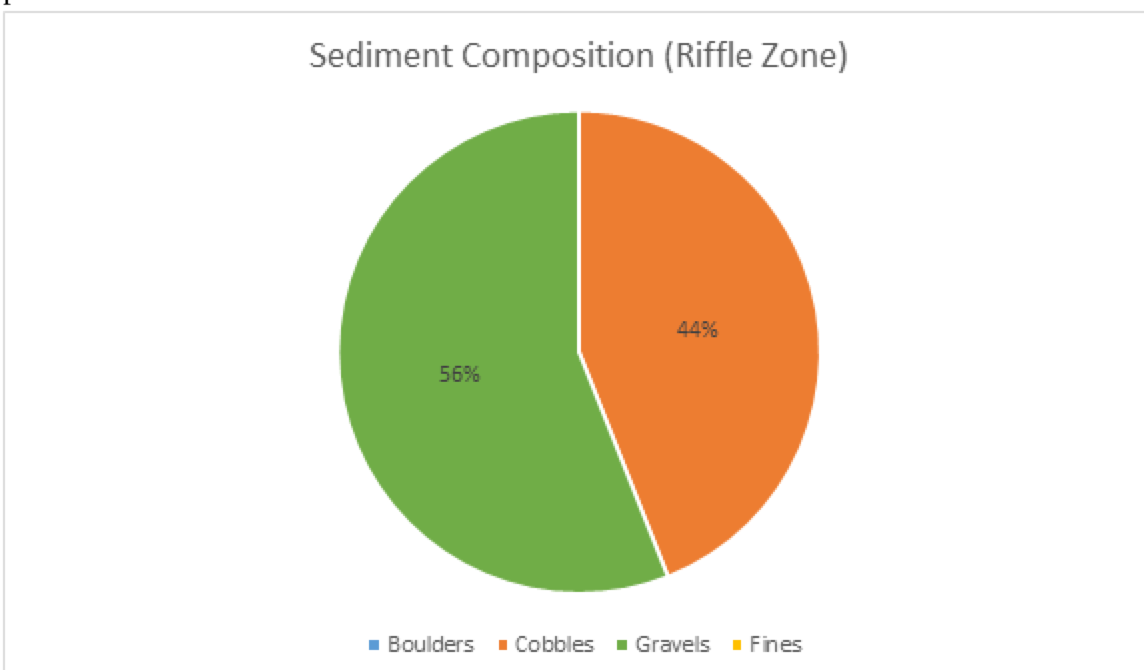

Figure 4. Pie chart showing the amounts of boulders, cobbles, gravels, and fine materials in the riffle zone.

Figure 5. A steep profile of soil exposed above the undercut pool zone. As this pool zone may have formerly been a riffle zone, the high velocity of the stream carves underneath the ground and the sides of the wall.