STANLEY PARK ECOLOGY SOCIETY

Background Information on Beaver Creek, Stanley Park

The Stanley Park Ecology Society recognizes the Habitat Conservation Trust Foundation and anglers, hunters, trappers and guides who contribute to the Trust, for making a significant financial contribution to support the production of this report. Without such support, this project would not have been possible.

HABITAT CONSERVATION TRUST FOUNDATION

Contents

Introduction

In the face of a changing climate and an uncertain future for our region's species and ecosystems, a rare naturally occurring, salmon bearing stream in the heart of a major metropolitan city is critical to its biodiversity. Even common species, which are becoming rarer with increasing urban pressure, find safe harbour in Beaver Creek and Beaver Lake (Ahka-chu so named by Coast Salish people) at its source.

In 1985 an environmental consultant submitted a report to the VPB, recommending that immediate action be taken to deepen Beaver Lake so that it could support salmonids (Hatfield, 1985). Their research found that the lake was undergoing rapid infilling due mainly to the introduction of invasive water lilies in the late 1930's. Although the plans for dredging the lake were not followed through at that time, some of the recommended actions pertaining to improving habitat along the stream (eg. complexing the channel and re-vegetating the riparian areas) were implemented.

In recent years, mainly following the 2006 windstorm and subsequent windstorms, SPES has moved beyond its role as the provider of terrestrial education in Stanley Park, and has become active in planning and conservation initiatives in Stanley Park in collaboration with the VPB. For several years SPES has been undertaking ecological research and restoration interventions in the Park and has compiled an up-to-date set of information on the park including Beaver Creek and its environs. This information was compiled initially into the *State of the Park Report for the Ecological Integrity of Stanley Park* which was officially approved for information by the VPB Commissioners in 2010. The report also used ecological indicators to assess the park's health and found that aquatic ecosystems in the park were in decline and needed attention.

In response to that report the VPB, with input from SPES, completed a *Stanley Park Ecological Action Plan* (SPEAP) which was unanimously approved in January 2011. This plan called for a variety of actions including hiring a consultant to devise a remediation plan for Beaver Lake. Aqua Terra Environmental Ltd., Northwest Hydraulic Consultants, Lees + Associates and other partners were chosen in April 2013 to begin the process of gathering information, researching methodologies and devising a series of options for what to do with the lake. The plans are still being formed, the public consultation process is ongoing and includes recommendations to allow fish to move from the creek into the lake. The final plan will be brought to the Vancouver Park Board (VPB) in early 2014.

The purpose of this project is to propose a technical solution to solving two fish barriers currently preventing salmonid access into Beaver Creek. This is in keeping with SPES's mission to *promote awareness of and respect for the natural world and play a leadership role in the stewardship of Stanley Park through collaborative initiatives in education, research and conservation,* as well as the Park Board's values of maximizing biodiversity and respecting cultural integrity.

The enhancement work we hope to pursue will focus to a large extent on accommodating salmon which have been released as fry into the creek for over 20 years by students undertaking the DFO's salmonids in the Classroom program. Although thousands of coho fry are released each year, we have seen no returns in recent memory. Coastal cutthroat trout, a Species at Risk in BC, have been known to reside in the creek, but have not been documented for the past two years of minnow trap monitoring.

Beaver Creek Historic Information

The Beaver Lake watershed encompasses 112 hectares of Stanley Park, about one quarter of the park's Beaver Creek, its main outflow draining into Burrard Inlet. Lying beneath the watershed is a narrow band of bedrock that has low permeability, making it difficult for water to seep through, thereby creating a higher water table in that area (Talisman 1995).

Beaver Creek is the only outflow for Beaver Lake and is one of only four intact salmon-bearing streams in the City of Vancouver. The 370 m creek was significantly altered near the turn of the century when an outflow weir was installed, creating a barrier to any upstream fish passage. Since Park Drive was built across the creek in the late 1800s, access to the creek for fish movement from the ocean has been limited except during periods of extreme high tides.

An official survey of the creek was done in 1985 by Hatfield Consultants. Although they observed one spawning redd and several fry at that time, they noted that spawning gravel was limited. The habitat in the creek includes glides (48%), pools (20%) and riffles (32%) and a small waterfall; the creek ranges in depth from 9 cm to 27 cm; and has a width of 2.1 m to 2.6 m (Hatfield, 1985). Although the creek is shaded by a dense canopy cover of coniferous trees, at the time of the study there was limited riparian vegetation. The substrate of the creek was dominated by fines and small gravel and most of it was deemed unsuitable for salmon spawning habitat. It was also found that the discharge rate in the creek did not vary substantially, presumably due to the input from the municipal water supply into the system.

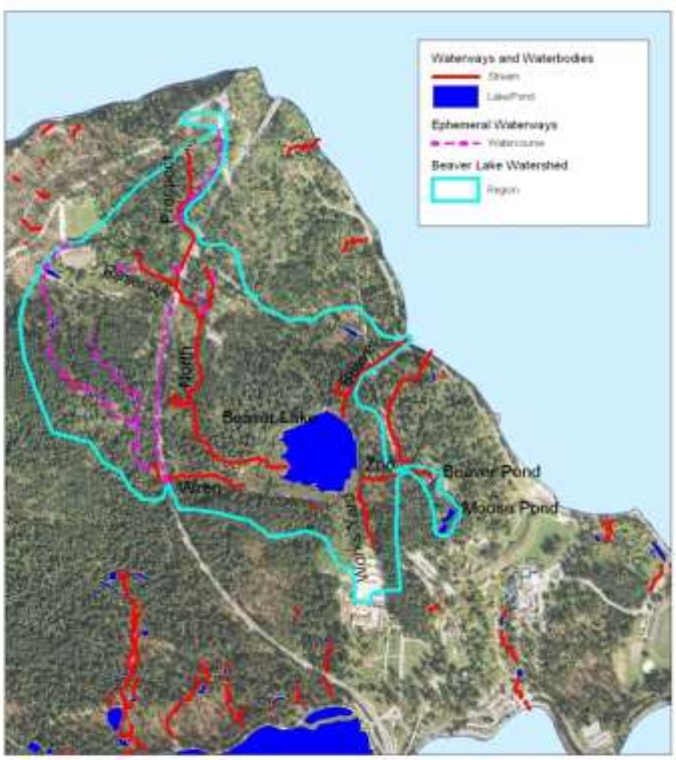


Figure 1: Beaver Creek and its associated watershed.

Following this study, the Capilano River hatchery began releasing coho fry into Beaver Creek in 1990 and various enhancement efforts have been undertaken by other societies, including the Vancouver Salmon and Stream Society and the Salmonid Enhancement Program (Coast River, 1995). Their projects included riparian planting, streamside fencing, instream habitat complexing, and armoring of some of the banks.

Despite its name, Beaver Lake has lacked a beaver population until the arrival of one individual in 2008. This first Beaver is believed to have swum across First Narrows from the Capilano watershed and entered the lake via Beaver Creek. To mitigate the impacts of the Beaver to human infrastrucuture, SPES and park staff have installed a "beaver baffler" on the Beaver Creek outlet, which allows water to drain from the lake despite the Beaver's attempts to dam the flow of water (Sibbald and Gibbons, 2013).

Beaver Creek Details

Fish

Historical Fish Data

In the early 1980's monitoring studies indicated that Beaver Creek supported wild populations of spawning cutthroat trout (*Oncorhynchus clarki*) and also the possibility of coho salmon (*Oncorhynchus kisutch*) (Jonhson, pers. Comm; Coast River, 1995; Parks Canada 2002). The population of cutthroat trout in the creek is thought to have been introduced by a hatchery through stocking operations carried out in the Beaver Lake watershed in the early 1900's (Steele, 1988).

The earliest recorded freshwater fish monitoring on Beaver Creek took place in December 1983 and June 1984 by Hatfield Consultants Ltd. Monitoring took place at two locations along the creek, one upstream of the waterfall under the Pipeline Road Bridge and a second downstream of this waterfall. In total five fish species were identified in the survey: cutthroat trout, coho salmon, carp (*Cyprinids sp.*), three-spine stickleback (*Gasterosteus aculeatus*) and western brook lamprey (*Lampetra richardsoni*). Of the identified species, cutthroat trout and coho were the most abundant found in the creek during the survey period (Hatfield, 1985).

The December 1983 trapping determined the overall stream densities to be 0.34/cutthroat trout/m^2 and 0.26/coho/m^2. The total salmonid density in the creek at that time was 0.60/fish/m^2 (Hatfield, 1985). Trapping in June 1984 determined the overall stream densities to be 0.97/cutthroat/m^2 and 1.81/coho/m^2 for a total salmonid density in the creek of 2.84/fish/m^2 (Hatfield, 1985). The downstream densities observed in June were five times higher than those found in December and the upstream densities were twice as high (Hatfield, 1985). These significantly higher June populations were attributed to the influx of coho fry that would have entered Beaver Creek in April 1984. However, no spawning redds were observed during the study period and it is unlikely that coho fry entered from another stream via marine access (Hatfield, 1985). It is interesting to note as well that during both sampling attempts no coho were caught upstream of the waterfall.

Despite the high density of salmonid species observed in Beaver Creek in June 1984 the density was similar to other local coastal streams (Hatfield, 1985). Beaver Creek contained all of the essential habitat requirements for salmonid species and enhancement activities were recommended to be limited to minor improvements to habitat and creating better stream access from the ocean and over the Pipeline Road Bridge waterfall (Hatfield, 1985).

In 1990, coho fry from the Capilano River hatchery were released into the Beaver Creek system. Unfortunately no follow up data was recorded in the fall of 1994 when spawning adults would have returned to measure the success of the release (Coast River, 1995). In 1999, a second freshwater fish study was conducted in the Beaver Lake watershed by students from Capilano College (Gennai et al. 1999). The students evaluated fish habitats within the watershed and found them to be unsuitable for salmonid species as a result of the eutrophication of the lake from introduced fragrant water lilies and the poor spawning substrate that was observed in both North Creek and Beaver Creek (Gennai et al. 1999).

Recent Fish Data

Since December 2010 SPES has been conducting freshwater fish sampling in North Creek, Beaver Lake and Beaver Creek (see figure 1). Five long term trapping locations were established in each of the above mentioned waterbodies both above and below major fish barriers and at strategic sites chosen on their varying substrate, vegetation cover and anthropogenic influences. A mixture of both high quality and low quality habitat sites were chosen to hypothetically show which fish populations were attracted to these specific sites. Despite the Capilano College, 1999 study indicating that habitat was unsuitable for salmonid species, cutthroat trout have been captured in North Creek and cutthroat trout, coho salmon, three-spine stickleback and prickly sculpin (*Cottus sp.*) have all been captured in Beaver Creek. In Beaver Lake, only three-spine stickleback have been found.

Between the months of April and September 2013 fish monitoring on Beaver Creek took place for a total of six 24 hour periods which resulted in 144 trapping hours. Five minnow (gee) traps placed along the 370m creek from its headwaters at Beaver Lake to its outflow at Burrard Inlet. Traps were placed in the same location during each trapping session unless water levels were too low for the traps to be submerged; in that case they were moved to the nearest suitable location for trapping. Traps were checked on April 24th and 25th, July 16th, August 9th and 25th and September 6th.

During this trapping period 9 coho salmon fry were recorded (see figure 1). These fish were found in traps BC01, BC02, BC03, and BC05, all of which except for BC05 are upstream of the Pipeline Road Bridge waterfall (see figure 2). Coho were not recorded in the lowest reach of the creek which also has the lowest habitat quality due to sandy substrate, stream channelization, invasive species and a cement bridge running over it. The fork length of the coho ranged from 51mm to 75mm. The source of these fish is likely the DFO's Salmonid in the Classroom Program which sees coho fry released into Beaver Creek in March and April. The release site for this program is upstream of the Pipeline Road Bridge waterfall, directly downstream of the Beaver Lake weir. No spawning adults have been observed in Beaver Creek for several years.

Aside from the above mentioned salmonid species, 136 threes-spine stickleback, 2 northwestern salamanders (*Ambystoma gracile*) and a number of dragonfly (*Odonata sp.*) and caddisfly (*Trichoptera sp.*) larvae were captured. It is worth noting that of the stickleback caught 81 were found in April in the two traps located closest to Beaver Lake. This is likely due to the VPB staff removing the beaver dam at the inflow of Beaver Creek to ensure that the surrounding trails do not flood. As a result, these sticklebacks likely get washed into the stream from the lake since Beaver Creek does not have the slow-flowing water and emerging vegetation that they prefer. It is a possibility that many juvenile salmonid species are also flushed out of the creek during these beaver dam releases.

A final point of interest is that cutthroat trout have been captured throughout the creek since SPES began monitoring in December 2010. However, the last trout was captured in September 2011. This date coincides closely with when the beaver began to dam the outflow and the VPB began to remove the dam sending large bursts of water and sediment through the creek system.

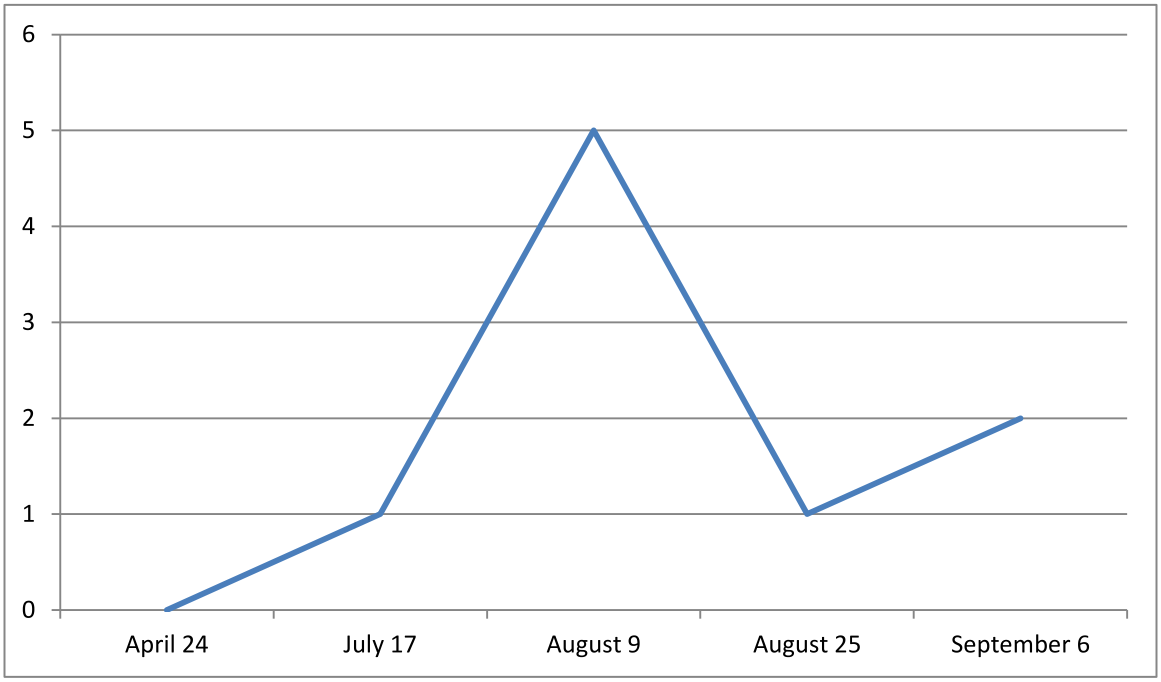


Figure 1. Number of coho fry caught in Beaver Creek during each trapping session

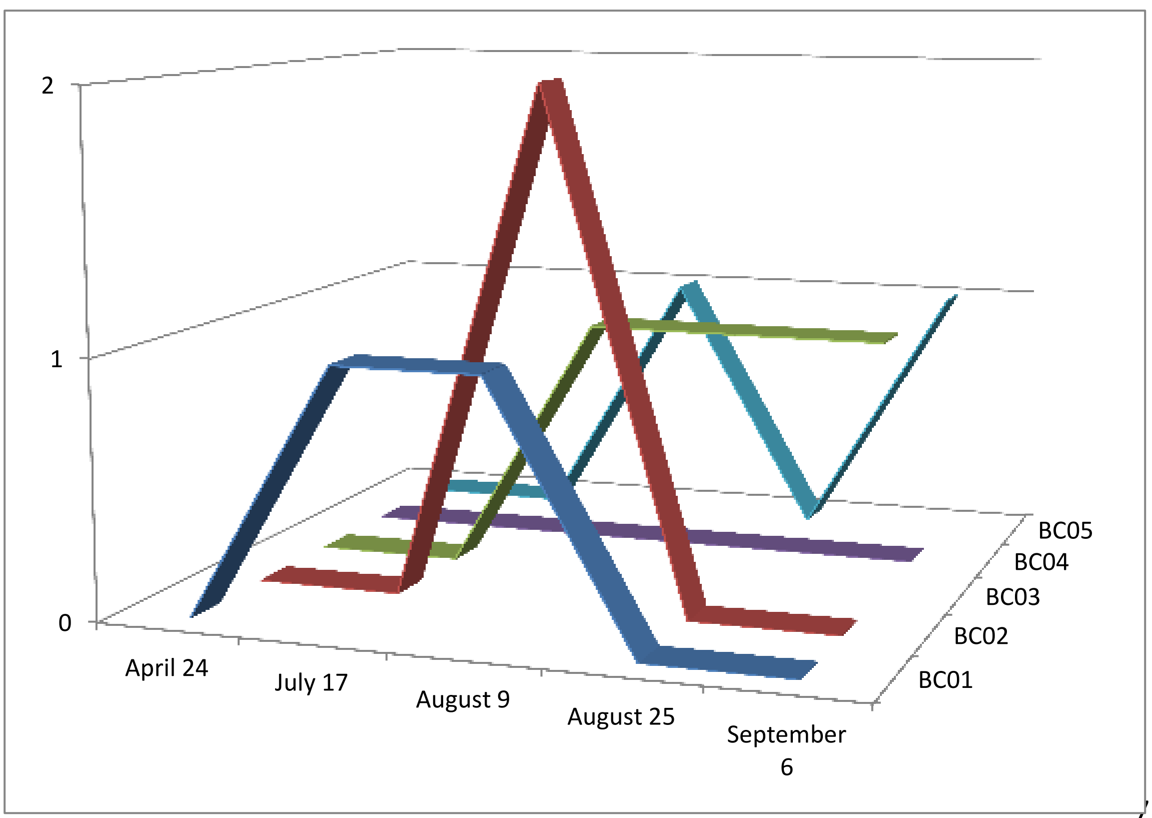


Figure 2. Number of coho fry caught at each trap location per trapping session

Channel Characteristics

Due to the relatively short length of Beaver Creek, Hatfield (1985) surveys delineated it into one reach encompassing its entire length. The survey for channel characteristics was conducted in December, and though it would typically be conducted during low flow conditions, because of the low seasonal variations in flow throughout the year this was not considered a major factor (Hatfield, 1985).

Along Beaver Creek six hydraulic units were identified: pools, riffles, glides, falls, ditches and sloughs. Of these hydraulic units, pools, riffles and glides covered an estimated wetted area of 644m^2 (Hatfield, 1985). The glide sections compromised the majority of the creek area at 47.8%; pools and riffles made up 19.7 and 32.4% respectively (figure 3).

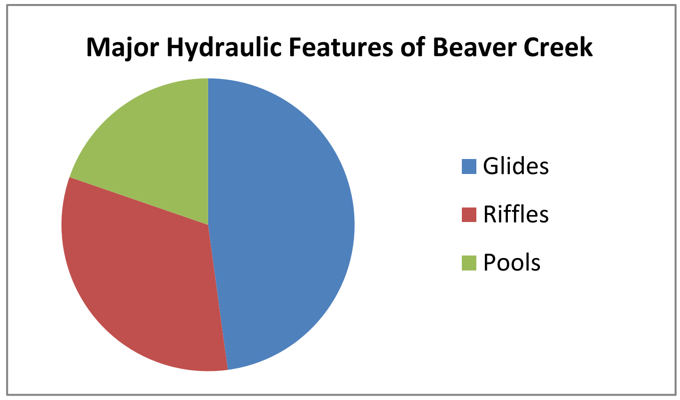


Figure 3. Major Hydraulic features of Beaver Creek

The average depth of these areas was 0.11m in glides, 0.27m in pools and 0.09m in riffles. The average wetted width in these areas ranged from 2.1m in riffles and glides to 2.6m in pools (figure 4). Several small waterfalls were also identified along the creek, with the largest being that under the Pipeline Road Bridge which acts as a major fish barrier (Hatfield, 1985).

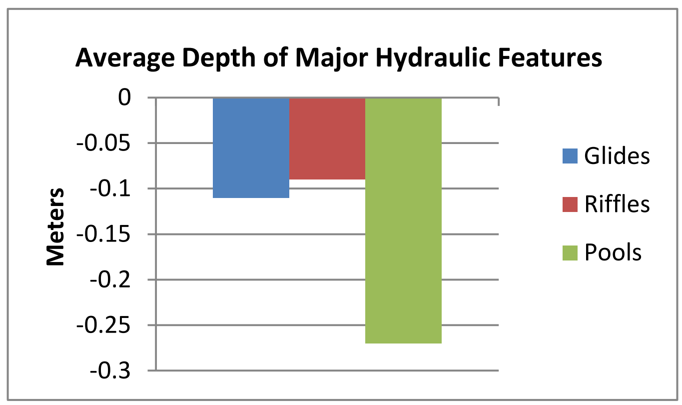


Figure 4. Depth of major hydraulic features

The Beaver Lake area was determined to be dominated by Newtown stony clay and Surrey till, which can be observed along the deeply incised banks of Beaver Creek (Hatfield, 1985). There are also several locations along the creek with large glacial boulders forming natural flow controls resulting in the widening of the ravine (Hatfield, 1985). Substrate in the creek was dominated by fines (0.0-0.1cm) and small gravel (0.1-4.0cm) (Hatfield, 1985).

A second survey conducted by Zimmerman (1999) also found the area to be dominated by glacial till. During this survey large rows of cobble were also noted to have been installed along the stream to confine the channel. It is unclear why this was done since the banks did not appear to be actively eroding and it was not mentioned in the Hatfield (1985) report that this was a problem. It was determined that due to the low stream gradient (1.3%) the flow in the creek would not be powerful enough to move introduced cobbles and as a result of this the stream would be less likely to meander and use the full width of the ravine to create a natural pool-riffle system (Zimmerman, 1999). Due to the trails, the creek is forced to remain fairly straight with pools only forming at the bottom of small falls on the creek (Hickin and Nanson, 1984). The most recent survey in Beaver Creek focusing on channel characteristics took place in 2012 conducted by students from the BCIT Ecological Restoration Program. These surveys confirmed what past reports had indicated, that the pre-dominate substrate throughout Beaver Creek was fines of less than 2mm in diameter (Alards-Tomalin, 2012; Matthews, 2012).

Riparian Vegetation

Beaver Creek is in the Coastal Western Hemlock (CWH) biogeclimactic zone, typically found at low to mid elevations along the BC coast (Pojar, Klinka, & Demarchi, 1991). Within the Beaver Creek riparian area the forest is dominated by western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and Douglas fir (*Pseudotsuga menziesii*). The soils of the area are most commonly characterized as Ferro-Humic Podzols and due to previous glaciations of the area segments of glacial till are exposed and can be seen along Beaver Creek where the bank has been cut back (Pojar, Klinka, & Demarchi, 1991; Zimmerman, 1999).

The CWH biogeoclimatic zone is divided into several subzones, of which Beaver Creek falls into the Dry Maritime (CWHdm) zone (VBPR, 2009). Further division into site associations within this zone are distinguished by indicator plant species that provide details on the underlying soil moisture and nutrient regime of that specific site. Four site assoications are found within the Beaver Creek riparian area (see figure 5 below).

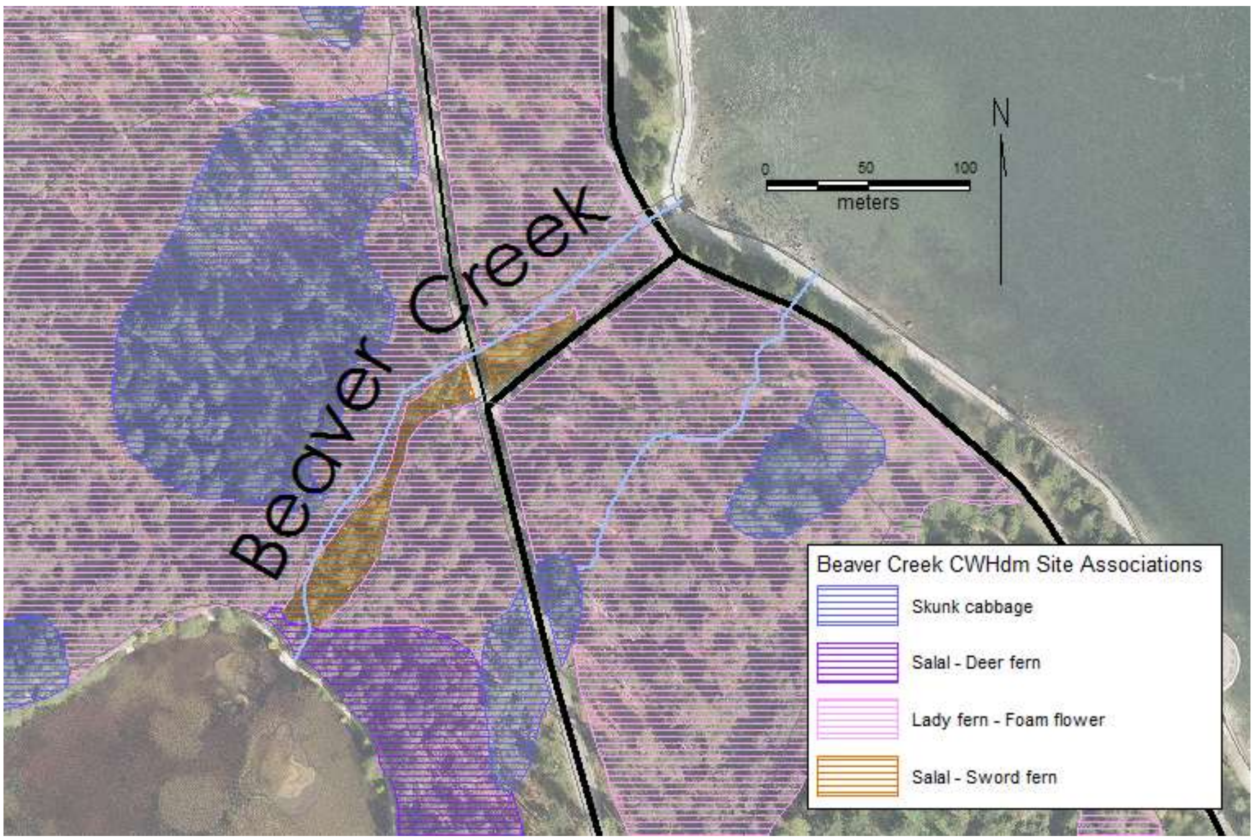


Figure 5. map of site associations along Beaver Creek.

<u>*Skunk Cabbage (CWHdm)*</u>

Located on the outreachs of the Beaver Creek riparian area this site association is found on sloped topography or in depressions. Skunk cabbage (*Lysichitum americanum*)is the dominant plant species with the following shrubs also being quite abundant: stink currant (Ribes bracteosum), red elderberry (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), false azalea (*Menziesia ferruginea*)and oval-leaved blueberry (*Vaccinium* *ovalifolium*). Other abundant plants are lady fern (*Athyrium fillix-femina*), deer fern (*Blechnum spicant*), bunchberry (*Cornus canadensis*), horsetail (*Equisetum spp.*) and sedges (*Cyperaceae spp.*).

Salal- Deerfern (CWHdm)

This site association is the least common in Stanley Park but is found in a narrow area on either side of the headwaters of Beaver Creek. Soils are poorly drained and lack nutrients and therefore cannot support skunk cabbage. Salal (*Gaultheria shallon*) is incredibly abundant in this area due to light penetration. Other common plant species in this region include false azalea, salmonberry, red huckleberry (*Vaccinium parvifolium*), oval-leaved blueberry and Alaskan blueberry (*Vaccinium alaskaense*). Three-leaved foamflower (*Tiarella trifoliata*) and lady fern are uncommon in this site association.

Ladyfern-Foamflower(CWHdm)

This is the most common site association in Stanley Park with moist soils and represents level to gently sloping lower to middle slopes althought sometimes includes steeper slopes that have greater seepage. Amost all of the western shore of Beaver Creek is comprised of this site assoication as well as the last 1/3 of the eastern shore. Dense herbaceous vegetation is abundant, particularily lady fern and foamflower. Sword fern (*Polystichum munitum*) and spiny wood fern (*Dryopteris expansa*) are also common and dense patches of salmonberry, red elderberry and vine maple (*Acer circinatum*) are plentiful in canopy openings.

Salal-Swordfern (CWHdm)

The dominant presence of salal and sword fern signify sandy, well-drained, dry soils. The first two thirds of Beaver Creek are made up primiarly of this site assoication. Red huckleberry and salal are the two most common shrubs and dull Oregon-grape (*Mahonia nervosa*) is found only within this site association in Stanley Park.

Despite the short length of Beaver Creek, the diversity of site associations provide an abundance of plants species as described above as well as foraging and habitat opportunities that these plants provide for wildlife that live within the riparian area.

Water Quality Monitoring

Water quality monitoring was conducted by SPES staff and volunteers between July and October 2013. Sampling was conducted using LaMotte measuring equipment except for the last sampling date in which a Milwaukee MW 600 dissolved oxygen (DO) meter was used to measure the DO. On this sampling date an electronic pH reader (pHep by Hanna) was also used for the first time. In these cases it is likely that the last measurement taken for DO and pH are in fact the more realistic measurements compared to those taken prior with the less reliable equipment. Throughout the sampling period the following aquatic parameters were measured:

- Water Temp (°C)
- pH
- Dissolved Oxygen (ppm)
- Turbidity (JTU)
- Nitrate (ppm)
- Phosphate (ppm)
- Flow Rate (m/s)

Sampling took place at two locations along Beaver Creek (figure 6). The first sampling location was just north of a small footbridge (blue star) off Ravine Trail. The second sampling location was just north of the Pipeline Road bridge (red star). Both sites were sampled on each monitoring day.

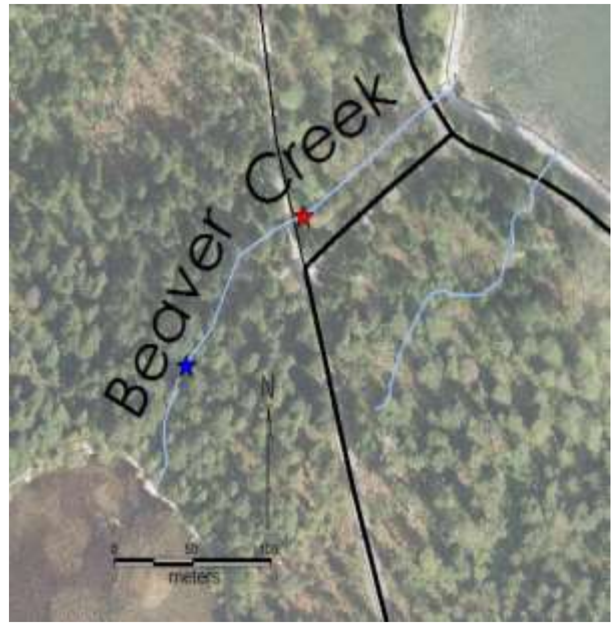


Figure 6. Beaver Creek water quality test sites

Water temperatures in Beaver Creek decreased at both monitoring sites throughout the sampling period. This is likely a direct result of the daytime temperatures also decreasing over the sampling period and influencing the water temperatures in Beaver Lake, the main source of water for Beaver Creek. The primary water source for the entire system is North Creek which contributes a constant volume of water at a temperature of approximately 12°C (Coast River, 1995). The water entering Beaver Lake from North Creek is likely close to 12°C and is warmed considerably during the summer months in the shallow depths of the lake before flowing into Beaver Creek; this is evident in figure 7 from July 11th through September 26th, 2013. It is not until October that we begin to see the water cooling at the sampling locations on Beaver Creek.

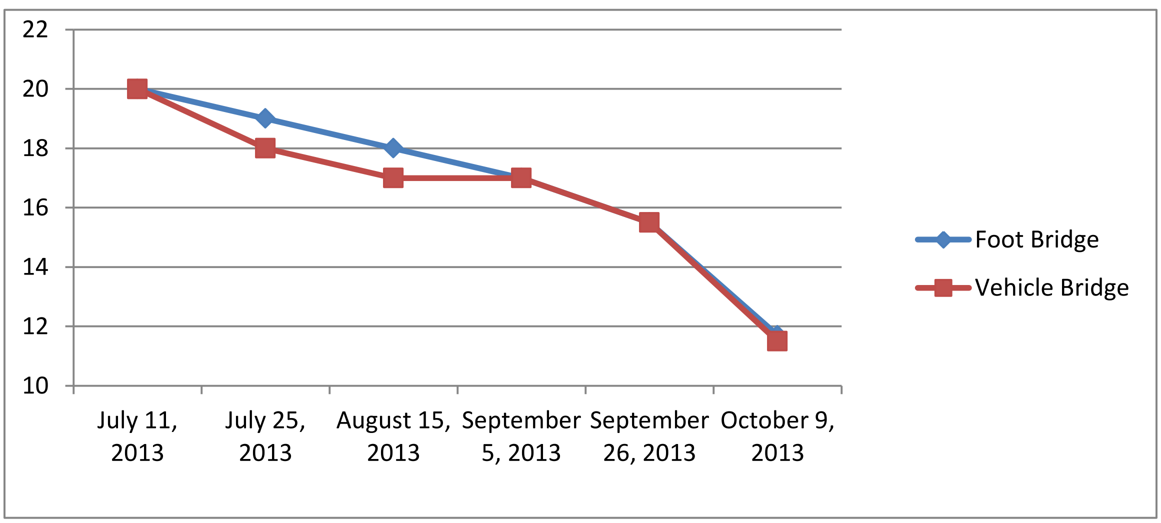


Figure 7. Beaver Creek water temperature (Degrees Celsius)

The pH in Beaver Creek remained consistent throughout the sampling period (figure 7). It is unknown what caused the pH to rise as it flowed farther from the lake (towards the second, downstream sampling site). It should be noted that during the Hatfield, 1985 survey, little variation in pH was observed between Beaver Lake and Beaver Creek (Hatfield, 1985).

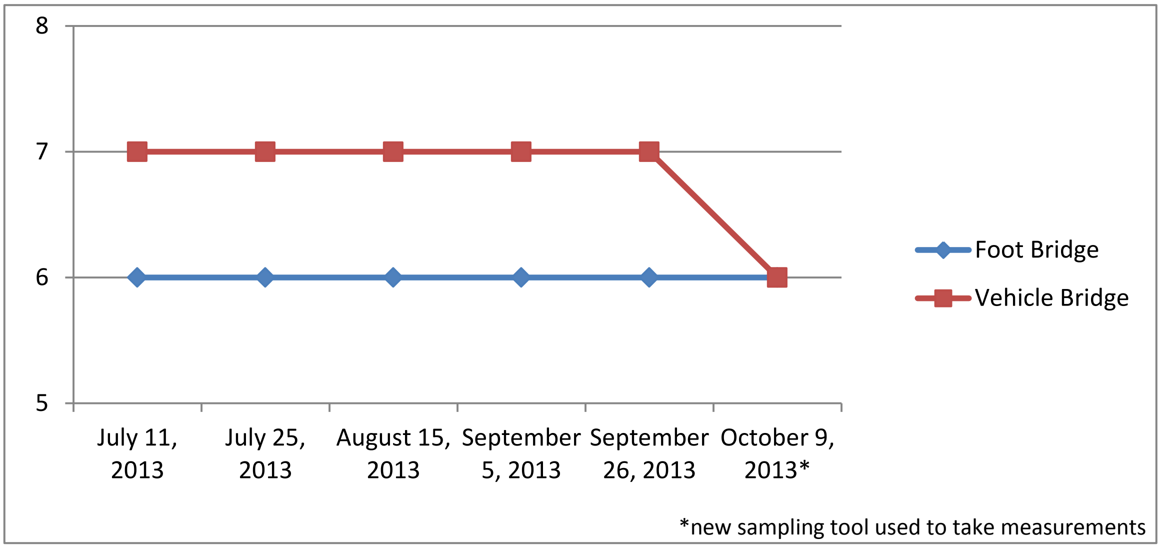
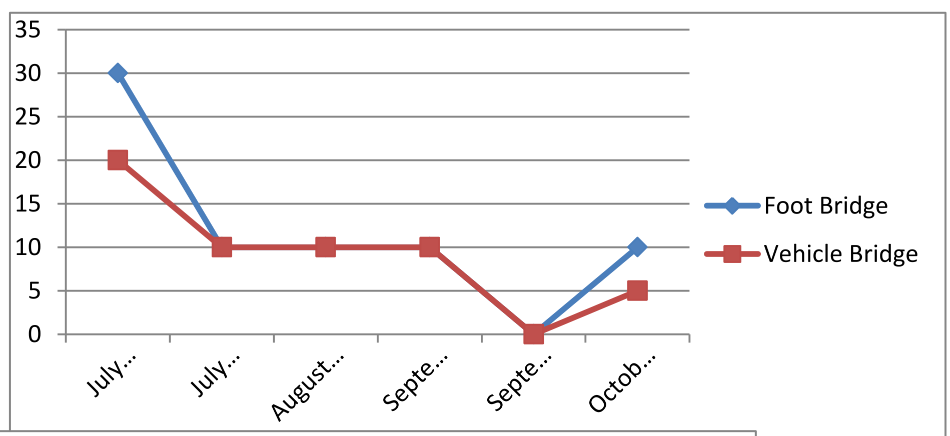


Figure 7. Beaver Creek pH recordings between July – October 2013

The data on the dissolved oxygen testing throughout most of the sampling period for the creek was deemed not usable due to the low accuracy of the testing equipment (LaMotte test kits showed an average DO of 1ppm). However, for the last day of sampling (October 9th) a more robust sampling tool was used and it provided DO measurements of 5.5ppm at the Foot Bridge and 7.5ppm at the Pipeline Road bridge. These values are more in line with survival requirements for juvenile coho salmon and are also more reflective of the results found by Hatfield in 1985. They determined that DO was lowest in August at 7.0ppm and highest in January at 12.6ppm, creating a range suitable for all salmonid species to survive in the creek year round (Hatfield, 1985). Coho swimming speed is substantially reduce when the DO drops below 6.5ppm and fish will avoid water altogether when the DO is below 4.5ppm (McMahon, 1983).

Turbidity throughout the Beaver Creek system is highly variable as the inflow of sediments is regulated largely by the whether or not VPB staff have recently removed the upstream beaver dam. When the dam is removed large amounts of sediments that would have been deposited slowly over time are introduced al



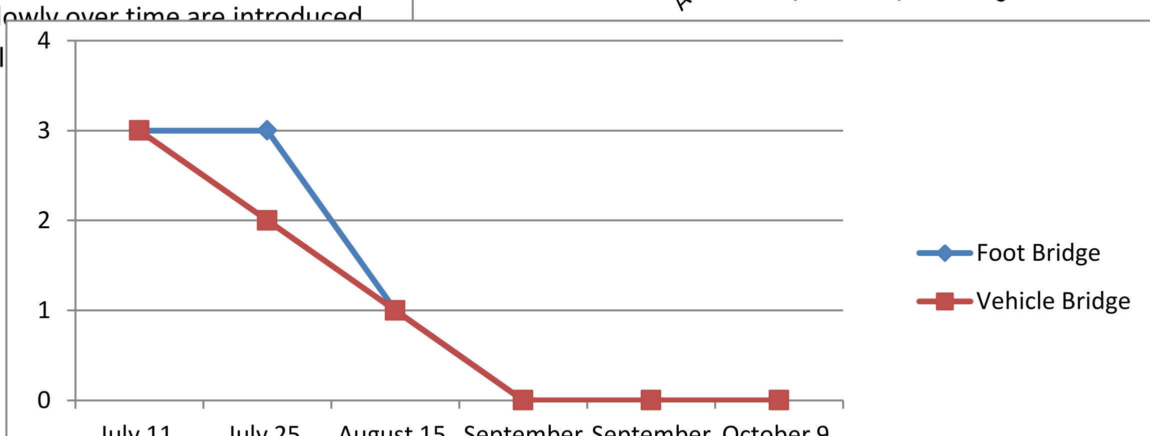


Figure 9. Beaver Creek nitrate level (ppm) between July – October 2013

Throughout the sampling period nitrate levels in Beaver Creek dropped from 3 to 0 ppm (figure 9). It is unclear as to why this happened although higher initial values could be attributed to the decomposition of aquatic plants in the lake over the summer months releasing nitrate into the water and flowing downstream. As the summer months drew to a close and these decomposition activities slowed it is possible that the amounts of nitrate being release into the lake and flowing downstream also dropped.

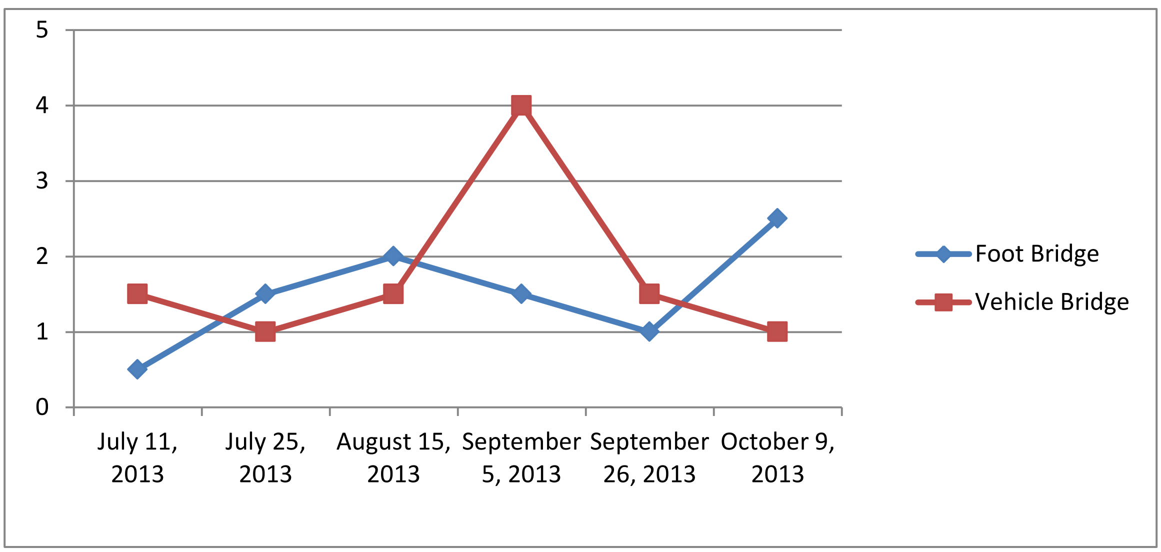


Figure 10. Beaver Creek phosphate level (ppm) between July – October 2013

Phosphate levels seemed to remain consistent throughout the monitoring period except for a spike at the Pipeline Road Bridge during the September 5th survey (figure 10). It is unclear as to what caused this increase since the only suitable sources of phosphate into Beaver Creek would include human and animal wastes or soil erosion. It is possible that this is simply an outlier in the results or there was point source contamination from some sort of waste nearby when sampling took place. In either case the phosphate levels dropped to their consistent range during the next monitoring session.

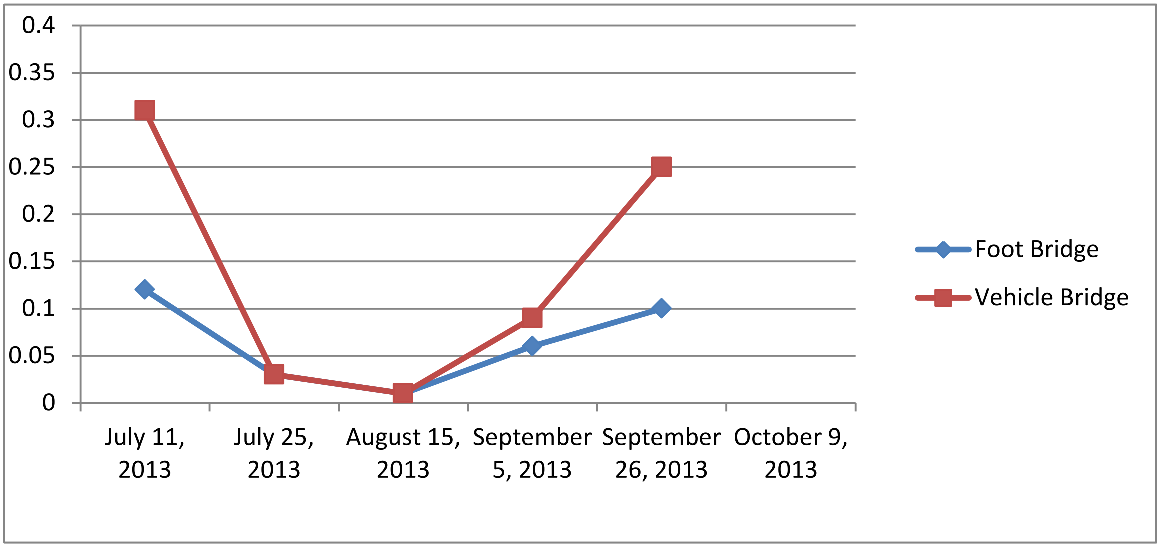


Figure 11. Beaver Creek flow rate (m/s) between July – October 2013

Prior to our water quality monitoring, data was collected during the Hatfield (1985) surveys. They found that the weir outflow from the lake had a capacity of 0.6m/s and that a flow rate greater than 1.0m/s would cause the lake to flood and spill over the pathway (Hatfield, 1985). They also determined that the average flow rate along the creek was 0.3m/s while the base load flow was 0.02m/s and the flood high was 1.0m/s (Hatfield, 1985).

Despite the fact that the flow rates in Beaver Creek can be highly variable due to the removal of the beaver dam, the results collected during the recent sampling tend to align with the results provided by Hatfield (1985). The peak flow rate recorded at the Pipeline Road bridge site aligns with the predicted creek average; while the lowest flow rate recorded at both sites also align closely to the predicted base load flows (figure 11).

Bird Life

SPES has been monitoring breeding birds in Stanley Park and recording the data since the spring of 2008. One of the monitoring stations during our breeding bird surveys (R1-1) is located in the riparian area of Beaver Creek. The method of monitoring breeding birds is through point count surveys which involves spending a prescribed time (5 minutes) at each site during which all bird species observed and heard are counted. The direction and distance from the surveyors is also recorded for each species identified. The site is then returned to at least once more a week later and the process is repeated. Through this we hope to identify if a bird is breeding in the area by hearing it at the same location, the same distance and direction from the recorder multiple times over several weeks. In total 36 species of birds have been identified during breeding surveys from the riparian area of Beaver Creek (Table 1). The number of bird species seen each year during breeding surveys can be seen in the figure 12.

Table 1. List of bird species recorded during breeding surveys on beaver Creek between 2008-2013.

American goldfinch	Great blue heron	Purple finch
American robin	Golden-crowned kinglet	Red-breasted nuthatch
Bald eagle	Hammond's flycatcher	Red-breasted sapsucker
Black-capped chickadee	House finch	Red winged blackbird
Brown-headed cowbird	Mallard duck	Song sparrow
Black-headed grosbeak	MacGillivray's warbler	Spotted towhee
Brown creeper	Nothwestern crow	Swainson's thrush
Black-throated gray warbler	Northern flicker	Townsend's warbler
Canadian goose	Orange-crowned warbler	Varied thrush
Chestnut-backed chickadee	Pacific wren	Wilson's warbler
Downy woodpecker	Pine siskin	Wood duck
European starling	Pacific-slope flycatcher	Yellow-rumped warbler

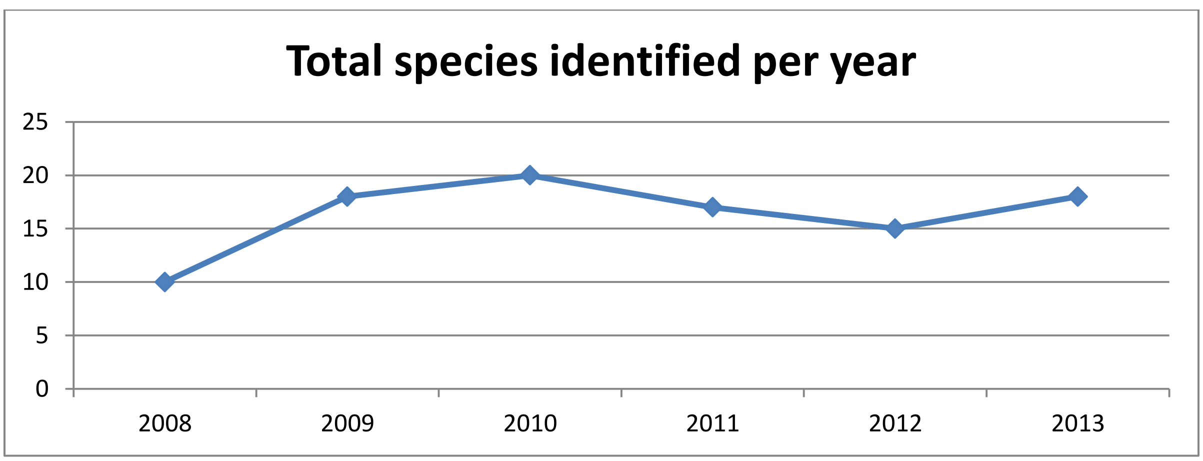


Figure 12. Breeding bird species diversity at Beaver Creek between 2008-2013

Invertebrate Sampling

Historical Invertebrate Data

Hatfield (1985) conducted in-stream invertebrates sampling in Beaver Creek as part of their report. At that time the creek was classified as heterotrophic due to the restricted light through the forest canopy. They also identified the primary invertebrate food sources in the creek to be bacteria, fungus and fine and coarse detritus material (Hatfield, 1985). Overall, Beaver Creek was determined to be a productive system typical of west coast streams and was home to most of the common stream invertebrates except for plecoptera (stoneflies). Their absence is likely due to the fact that most plecoptera species are predators and the food sources available in the stream do not fit their habitat requirements (Hatfield, 1985).

The invertebrate distribution along the creek showed the highest concentration in riffle areas with small to medium sized gravel compared to areas with fines and small gravels. Macro-benthic populations were also predictably higher in riffle areas than pools and glides. The highest concentrations of invertebrates were found in the creek during the June surveys and these numbers were attributed to an abundance of chironomid and/or simulid larvae. Diptera (true flies) were noted to have one of the strongest seasonal influences (Hatfield, 1985).

In 2008 a ground-dwelling invertebrate study using pitfall traps was conducted in Stanley Park with some surveying taking place at SPES's long term monitoring site along Beaver Creek (R1-1) (Yagi, 2008). At this monitoring site the forest soil did not have a rocky substrate and was primarily organic despite the lack of decaying logs present (Yagi, 2008). The highest number of amphizoid larvae (trout-stream beetles) was found at this monitoring site compared to any other site in Stanley Park. In particular the concentrations were highest at one of the pitfall traps located adjacent to the creek but not at the drier trapping locations at this site (Yagi, 2008). Both amphizoidae adults and larvae are characteristic of cold water and often relatively quiet mountain streams. The larvae lack gills and do not swim and will crawl out of the water to obtain oxygen and to scavenge on dead insects (Evans and Hogue, 2006). This is likely why such a high concentration were found in pitfall traps directly adjacent to Beaver Creek.

Recent Invertebrate Data

Our most recent invertebrate data was collected by several experienced scientists during SPES's Stanley Park BioBlitz event on August 24th, 2013. Identifying invertebrates is a difficult task that requires field workers to diligently collect specimens and then identify them in the laboratory to ensure proper identification down to a species or genus level. The lead on this project was Karen Needham, curator at the Spencer Entomological Museum through the Department of Zoology at UBC. Karen specializes in taxonomy, systematics, and biodiversity of aquatic insects. Along with a team of trained entomologists, Karen undertook an invertebrate survey in and along Beaver Creek during the bioblitz collecting both terrestrial and aquatic invertebrates.

In total 115 specimens were collected from this survey and of those 65 different species were identified. Of special interest was the identification of the provincially blue listed Blue Dasher (*Pachydiplax longipennis)* as well as the identification of *Bryocoris pteridis* which is native to Europe and newly identified in Canada. The most identified order of invertebrates was *Diperta* which includes insects known as true flies; they made up almost 1/3 of the invertebrates identified. The second most identified order was *Hempitera* compromising of true bugs which include cicadas and aphids. *Hymenoptera* which includes wasps, bees and ants and *Lepidoptera* which includes months and butterflys were the third most commonly identified order (figure .

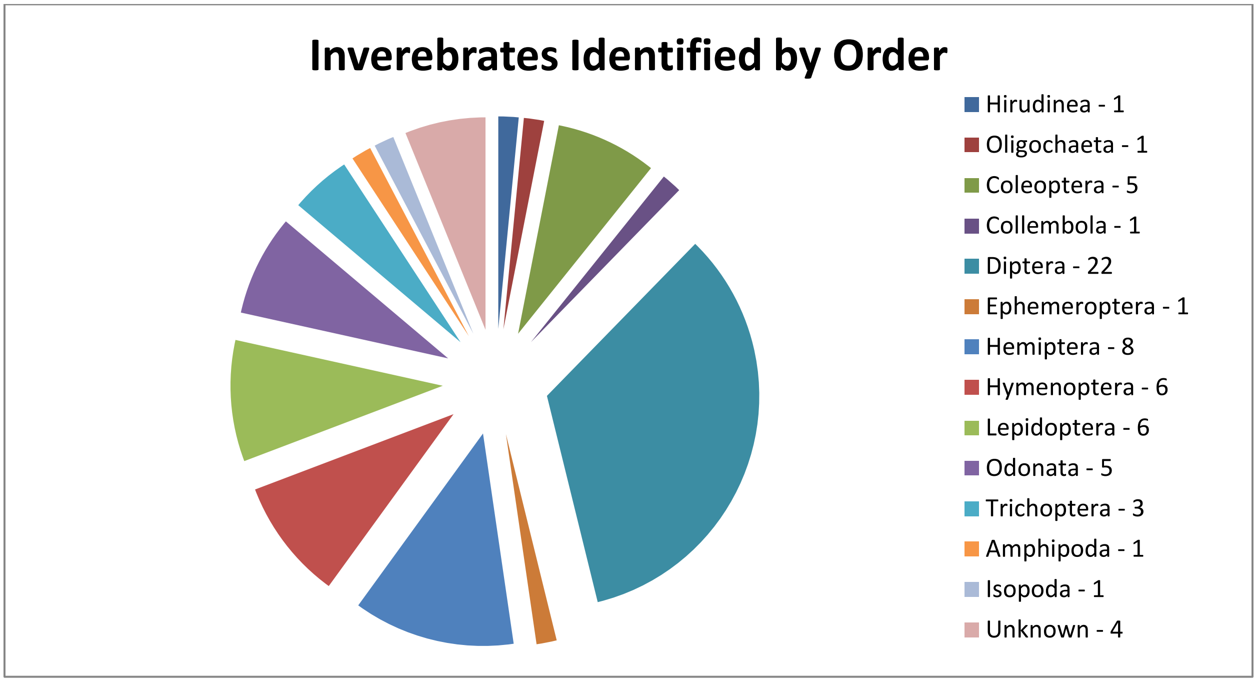


Figure 13. Invertebrate species diversity collected from Beaver lake/Creek on August 24th, 2013.

Beaver Creek Stressors

Beaver Creek is exposed to many stressors mostly due to human use in the area. Along with barriers to fish passage, excess sedimentation and low stream complexity also plague the creek. The following list outlines some of the major challenges in the creek:

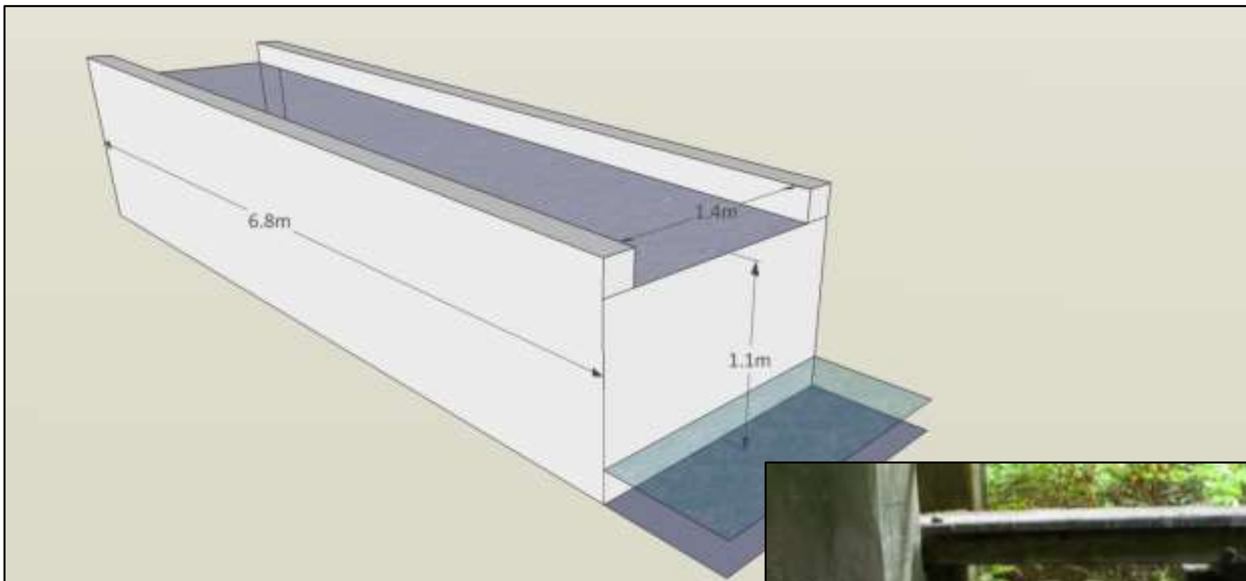
- Channelization and compaction to the stream edge from walking trails
    - trails have compacted the soil, altered drainage patterns and added sediments to the system. The
- Reduction in Stream Complexity (Matthews and E. Van de Water, 2013):
    - Logging and construction has removed in-stream features,
    - Decreased boulders and CWD,
    - Minimize rearing habitat
- Bank Erosion (Matthews and E. Van de Water, 2013):
    - Public access has led to bank erosion and compaction,
    - DFO salmonid program adds largely to this each spring (no proper facilities in place),
- Increased Sedimentation (Matthews and E. Van de Water, 2013):
    - Interstitial space between gravel provides cover for young salmonids and habitat for invertebrates
        - Pore space and permeability are used to determine the quality of gravel used for spawning salmon species (Lotspeich and Everest, 1981).
        - Increase in-stream gravel in creek
- Invasive species
    - Removal is required in riparian areas around Beaver Creek
    - This creek has also recently been colonized by invasive Japanese knotweed (*Polygonum cuspidatum*), and if not effectively controlled it may take over as the dominant riparian and instream vegetation.
- Beaver dam (Matthews and E. Van de Water, 2013):
    - The first beaver noticed at beaver Lake in recent years was in 2008
    - It is now damming the stream in multiple areas; primarily at the weir where Beaver Lake joins Beaver Creek, and just downstream of the weir.
    - Daily removal of the dam by Park staff in winter months is leading to increased variation in water levels, sedimentation, turbidity, noise pollution, and vegetation loss in and around Beaver Creek.

- Without this regular dam removal, however, Beaver Lake would flood the heavily used walking trail and change the hydrology of Beaver Lake and Beaver Creek, likely reducing habitat quality for fish in the stream.

Barriers to Fish Movement

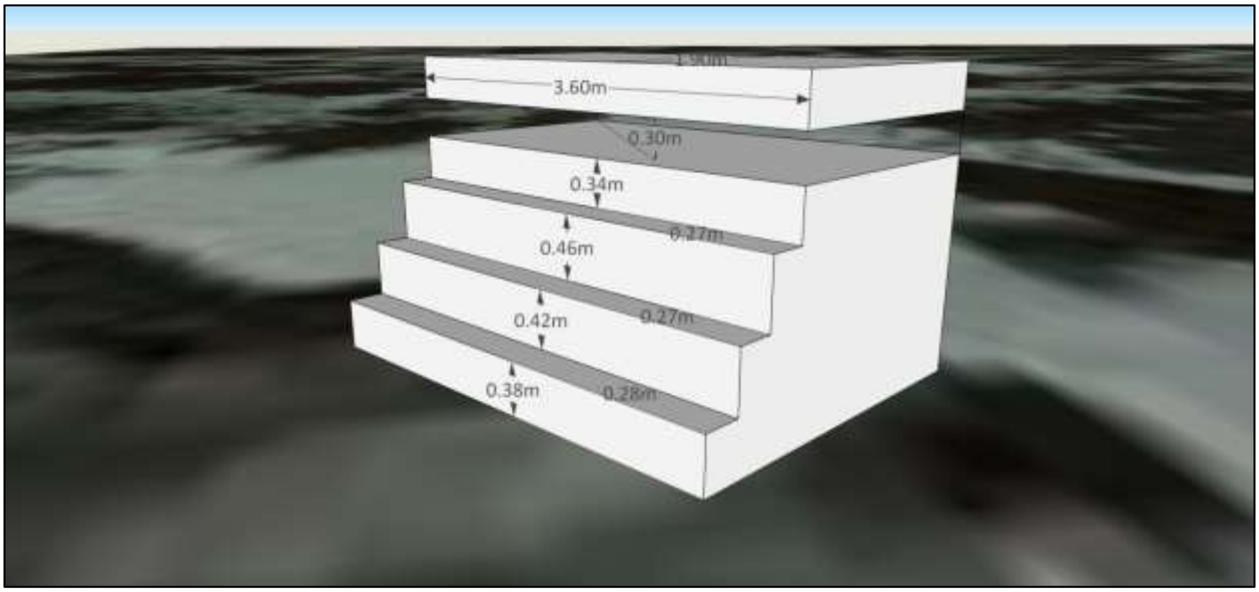
Pipeline Road bridge waterfall

- 1.38m wide
- 1.1m drop from top of falls to creek bed
- 7.8m from beginning of fish channel upstream to deepest point below waterfall
    - -20^{O} slope (1.5m drop) from top start of fish channel to creek bed below waterfall.



Seawall Outflow

- Opening dimensions:
  - 30cm height and 3.6m wide
- Staircase dimensions (3.6m wide):



Beaver Creek Restoration and Enhancement Recommendations

From: Worcester, R. 2010. State of the Park Report for the Ecological Integrity of Stanley Park. Stanley Park Ecology Society, Vancouver. 229 pp.

- Future Park stewardship efforts should focus on the following areas:
    - Aquatic Habitats: wetlands, watercourses, and intertidal areas are the habitats in the most need of stewardship attention. Specific actions may include increasing structural diversity within and connectivity between these areas.
    - Environmentally Sensitive Areas (ESAs): they are particularly rich in species diversity and represent areas of particular importance to the Park's ecological integrity (including streams.
    - Species at Risk: restoration and enhancement programs should focus on helping those species which are undergoing the greatest declines in population.

From : Hatfield Consultants Ltd. 1985. A technical and economic feasibility study of the Beaver Lake/Creek Enhancement Project. Hatfield Consultants Ltd., Vancouver.

- Properly sized gravel and boulders can be placed in the creek to create spawning and rearing habitat.
    - Coho spawn in gravel between 1.3 – 10.2 cm in diameter
    - Appropriate composition is 80% 1.3-3.8cm diameter to 20% 3.8 – 10.2cm diameter.
    - Locations of gravel will be determined during design phase
    - Boulders will be placed based on size and the flow stability in the creek.
    - A bobcat with a backhoe attachment will be used to remove the current substrate and then backfilled with gravel.
- From a spawning standpoint the creek is not suitable in most places due to the small particle size. Coho prefer 2.5-10cm and cutthroat trout prefer 1.0-6.0. (Burner 1951, Hamilton and Buell 1976, Hickman and Raleigh 1982).
- With a low gradient of 1.3%, pools and glides making up 70% of the total stream and fines, small and large gravel predominate throughout the system it should be capable of supporting relatively high numbers of fish from a gradient and substrate particle size standpoint.

From: T. Matthews and E. Van de Water. (2013) Proposed Beaver Management Strategies for Beaver Creek in Stanley Park, Vancouver

- Bank Erosion:
    - Install side channel viewing platform to reduce erosion
    - Platform provides viewing and area for school childrens salmon release
    - Pathway leading to platform

- Install interpretive signage
- Remove invasive species and plant native species

- Fish Barriers
  - Water control structure under Pipeline Road bridge requires a depth of 1.25 times the height of the obstruction to create ideal leaping conditions.

- LWD (> 2m length and 10cm in diameter)
  - Logging in park resulted in significant reduction of natural LWD
  - Improve habitat complexity by increasing CWD by 25%
  - Creates complex stream environments such as pools used for rearing
  - Supplementation of LWD is required
    - Use Douglas Fir and WR Cedar for long term stability
    - Formula to determine number of LWD pieces required in stream:
      - N = 80 m3/V x L/100
      - Where N = suggested # of LWD
      - V = average volume/piece of available LWD (appendix i)
      - L = length of reach (m)
      - LWD placement will likely be focused in reach 4 with the most degradation
- Substrate:
  - Increase interstitial space between in-stream gravel by 50%
  - Dominate substrate is 0.0-0.1cm(fines) and (0.1-0.4cm) (gravel) and too small for optimal salmonid habibtat. Came from trails, etc…
  - 1.3 – 10.2 cm for optimal rearing habiat for salmon and 0.6 – 10.2 cm for CCT rearing (Ashley, 2012)

  - Sediment between gravel reduces flow through substrate and lowers oxygen in water. Can prevent egg development and limit invertebrate numbers (DFO, 2010)
    - Cleaning gravel: hand tools or high pressure water pumps to move gravel and shake free fines.
    - Should take place during medium – high stream flows so particles are washed out of the area (Ashley, personal comm. 2012).

  - Install additional spawning gravel
    - Add where stream flow is stable and hydraulic criteria suitable (DFO 2010)
    - 80% small gravel (1-5cm) and 20% large gravel (10cm) make up total portion of additional substrate (Ashely, 2010, personal comm.).
      - Most beneficial in lower reaches (3 and 4) of stream as substrate is mostly sand.

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