Brooklyn Creek Juvenile Salmon Out-migration Study

Comox Valley Regional District

June 21, 2010

Prepared for:

Camosun College, ENVR 208b

Brooklyn Creek Watershed Society (BCWS)

Department of Fisheries and Oceans (DFO)

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Executive Summary

A study of the abundance of salmonids migrating from, Brooklyn Creek, Comox Valley, BC, an urban stream, to marine waters from April 17 to June 6, 2010 was completed using a smolt-fence. The objectives were to construct and maintain the fence, enumerate the species within the creek, and determine if correlations exist between migration and water quality.

The species inventory within Brooklyn creek included; Coho (*Oncorhynchus kisutch*), Cutthroat trout (*Oncorhynchus clarki*), Sculpin (*Cottus spp.*), Three-Spined Stickleback (*Gasterostreus aculeatus*) and Freshwater Crayfish (*Pacificastacus leniusculus*). The primary species observed in this study was Coho; there were a total of 3680 Coho smolts and 620 Coho fry. The length and weight of Coho salmonids were measured weekly.

The number and type of species were recorded daily along with other parameters, including air temperature, water temperature, dissolved oxygen, % saturation, total dissolved solids, pH, conductivity, precipitation, stage, and general weather observations. It was determined that each water quality parameter was within the desirable range for salmon health. This concludes that the state of Brooklyn Creek is supportive to salmonids.

To determine if a correlation exists between total number of migrating Coho salmonids and any of the water quality parameters, a statistical examination was done. Using a non-parametric Spearman ρ test a positive correlation was found between water temperature and the migration of total Coho Salmon where ρ_{calc} (0.269)> ρ_{crit} (0.283) (df = 49; α = 0.10 – 0.05). There was no other significant correlation between the total number of migrating Coho and any other water quality parameter.

The outcomes of this study provide a baseline dataset of rearing salmonid numbers supported by the watershed for comparison against other creeks in the region and future restoration efforts in Brooklyn Creek. The benefits of this study include increasing the body of empirical data known about the creek, involve local residents in its stewardship, and satisfy the requirements of Camosun College's ENVR-208b course.

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5.0 Introduction

5.1 Project Rationale

Since 2007, significant efforts to manage and restore Brooklyn Creek have been made by the Town of Comox (ToC) and the Brooklyn Creek Watershed Society (BCWS) with the objective of improving salmon habitat. The Brooklyn Creek watershed predominantly resides within the ToC on the East Coast of Vancouver Island, BC (Figure 1). During past restoration projects in Brooklyn Creek, data was collected on young salmonid species abundance using trapping and electrofishing techniques. Spawning salmon numbers were visually estimated by walking the creek along a number of reaches.[2] According to Wong, R. (2009), estimates of salmonid abundance were calculated based on data collected during past habitat enhancement projects (Table 1). However, for all the recent efforts to construct salmonid habitat an accurate enumeration of salmonids migrating to marine waters from the creek has not, until now, been realized.

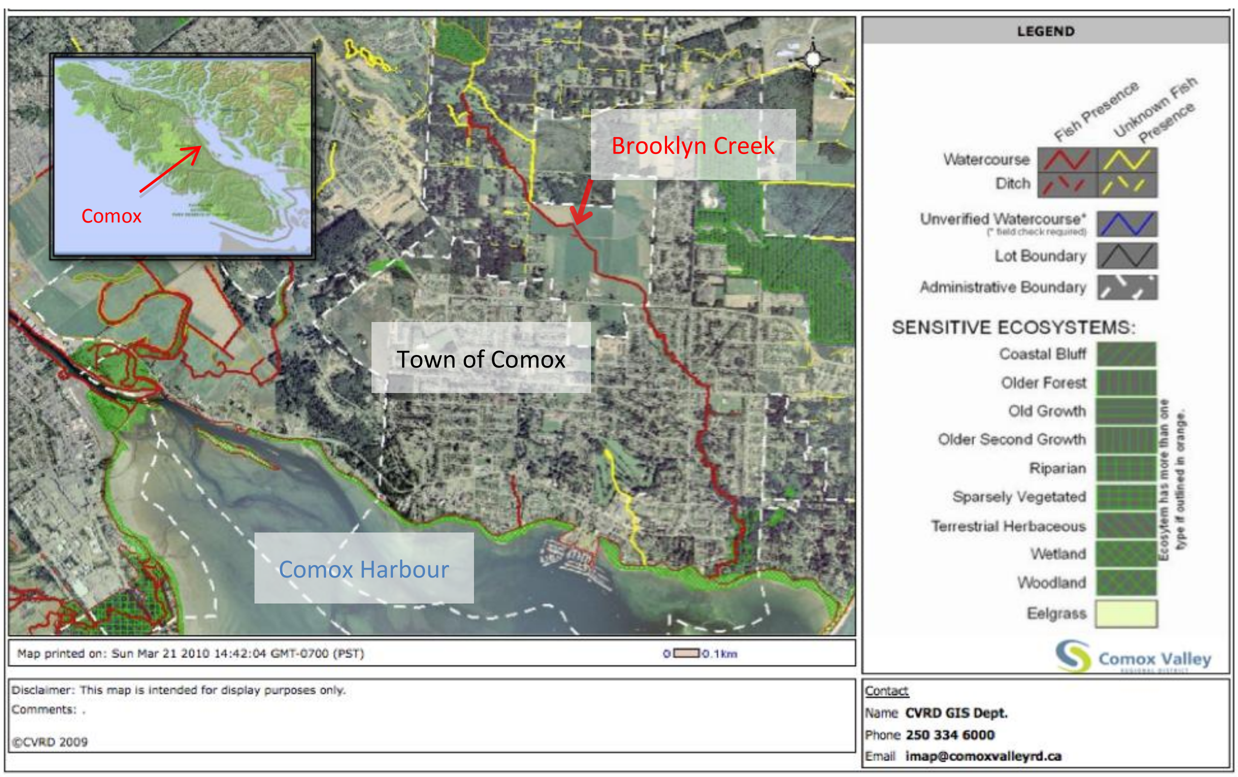

Figure 1: Orthophoto of the Town of Comox including Brooklyn Creek and the Comox Harbour Source: CVRD (2010)

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[2] Pers. Com. Dave Davies, Community Advisor, DFO. April, 2010.

Table 1: Brooklyn Creek fish production estimates based on past fish abundance and the predicted population increase from habitat enhancement projects.		
	Annual Production	
Enhancement year	Coho (smolt)	Cutthroat Trout (smolt)
2005	660	315
2008	473	225
2009*	870	264
* Anticipated numbers		

Source: Adapted from Wong, R. (2009)

The primary purpose of this project was the erection and maintenance of a smolt fence within Brooklyn Creek to provide an accurate baseline data set of fish species type and abundance migrating out of the creek (Photo 1). This data will be used to quantify and qualify the ability of Brooklyn Creek to support salmonids. With knowledge of salmon numbers leaving the creek, we can begin to predict how many may return, and over an extended period of time determine the general trend of salmon abundance in this ecosystem: valuable information that will help to direct the progression of future projects and management decisions in the Brooklyn Creek watershed.

This baseline data set will be made available to the BCWS, ToC, Department of Fisheries and Oceans (DFO), enhancement personnel, and local residents. Below is a list of future management goals that this study will help to support:

Photo 1: Brooklyn Creek smolt fence, spring 2010.

- Increase the amount of information that exists about Brooklyn Creek in order to help direct future management decisions and areas of focus;
- Provide a more specific means of evaluating watershed management initiatives in the Brooklyn Creek watershed;
- Quantify the results of restoration efforts;
- Determine the health, size and diversity of salmonids in Brooklyn Creek relative to those migrating out of other creeks in the region;
- Compare species diversity in Brooklyn Creek relative to other creeks in the Comox Valley and Vancouver island;[3]

[3] There are a number of smolt fences operated within various Vancouver Island watersheds, the data from these fences is collected and analyzed by Steve Baillie, Program Head of the Georgia Basin Salmon Stock Assessment, DFO.

- Increase public involvement, expertise, and knowledge about salmonid utilization in the watershed.

5.2 Watershed Background & Characteristics

The Brooklyn Creek mainstem and tributaries are approximately 10.2 kilometers long and discharge into Comox Harbour, approximately 900 meters east of Comox Marina (Figure 1). The creek's watershed area is 650 hectares (1619 acres) and spreads over three municipalities; the ToC, City of Courtenay, and the Comox Valley Regional District (CVRD). The creek is characterized by low late summer flows (Figure 2), and high peak flows during storm events, in part a result of the creek being an integral part of the ToC storm water management plan. The upper reaches of Brooklyn Creek have been impacted by urban and agriculture development, with headwaters originating in Crown Isle and Longlands Golf courses in Courtenay, BC, and the Comox Valley Regional District (CVRD) respectively (Section 5.3.1). The lower reaches flow through parkland, agricultural, and urban residential developments and have in some cases been the focus of restoration efforts (Sections 5.3.1 & 5.3.2). The topography of the watershed is relatively flat with low hills. The geographical region of Brooklyn Creek watershed has no snow pack; therefore, the drainage regime is not directly influenced by snow melt, and the annual hyetograph shows that rainfall and, in all probability, stream flow in Brooklyn Creek, is influenced by winter storm events (Figure2).

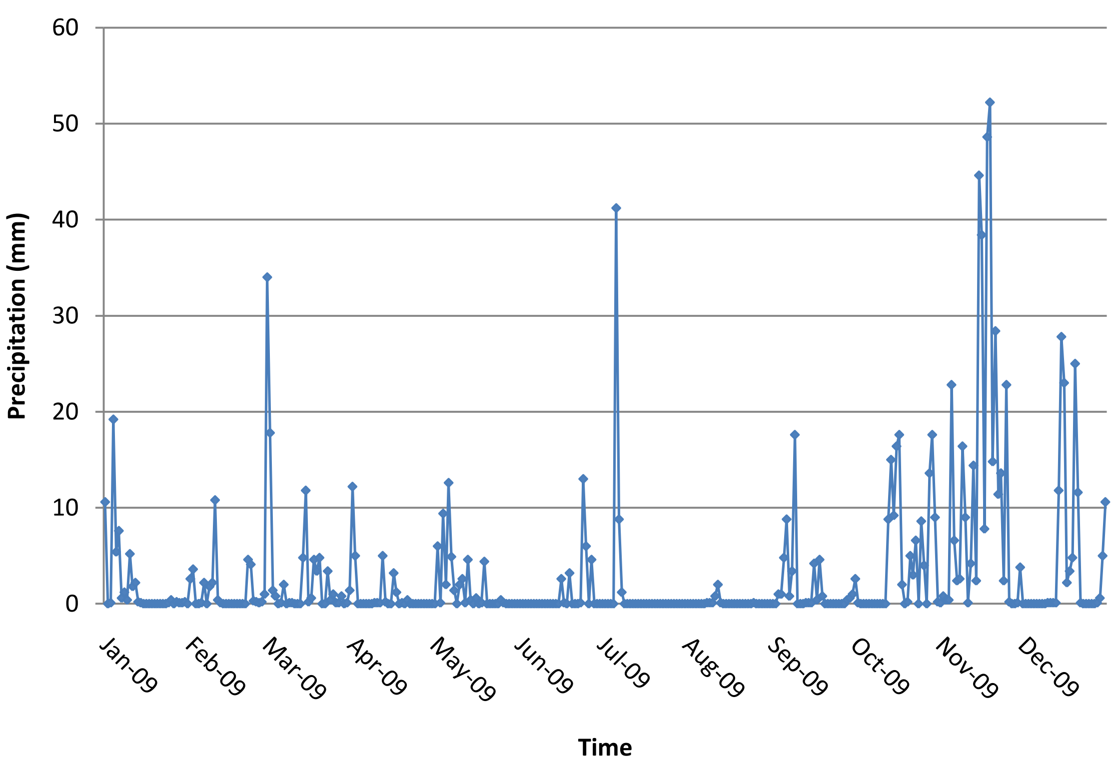

Figure 2. Hyetograph of 2009 precipitation quantities for Comox, BC.

Source: Environment Canada (2010)

5.2.1 Land-use

The land-use composition of the watershed is 42% rural lots and 55% suburban lots (Table 2). The headwaters of Brooklyn Creek have been largely impacted by urban and agriculture development. Beyond residential developments, a substantial portion of the suburban development includes two golf courses: Crown Isle and Longlands; both of which are situated around the headwaters of the creek. There have been some efforts made by both golf courses to manage the storm water runoff by creating a series of storm water retention ponds (Photo 2).

Photo 2: Crown Isle retention pond, spring 2010.

Table 2: Brooklyn Creek watershed land use and vegetation coverage.

Land Use		Vegetation Coverage	
Rural Lots	276.3ha (42%)	Forested	147.3ha (22%)
Suburban Lots	361.3ha (55%)	Cleared	151.9 (23%)
Park	17.5ha (3%)	Developed	355.8 (55%)
+/- 40% Impervious area			

Source: Adapted from Paul de Greef Copyright Document

5.2.2 Parks

Salish Park and Mack Laing Park make up approximately 3% of the watershed (Table 2). Salish Park is located just upstream of a heavily developed urban area and contains approximately 500 metres of Brooklyn Creek. The relatively dense vegetation within the park augments the quality of salmon habitat by providing bank stability and canopy cover for the creek. Mack Laing Park is located along the furthest downstream reaches of the creek, and stretches from the creek's estuary, where it enters Comox Harbour, to about one kilometre inland. This park is characterized by a well vegetated riparian area which includes both invasive and native species, and a well established canopy cover providing shade for the creek.

5.2.3 Impervious Surfaces

Brooklyn Creek's urbanized flow patterns are considered a limiting factor for fish productivity because of poor base flow, low summer flows, and elevated peak storm flows (Wong, R. 2009). Studies show that approximately 40% of the Brooklyn Creek watershed is made up of impervious surfaces (Table 2). In addition to anthropogenic surface types, naturally occurring soils present in most “of the watershed are primarily poorly drained and highly erodible silts or silty sands” that allow very slow infiltration of water into the ground; therefore, encouraging surface water runoff or pooling (Cousens, B. & Lee, C. 1999).

Based on research relating the effects of urbanization on aquatic ecosystems, the Brooklyn Creek watershed falls directly within the category of a non-supporting stream (Figure 3). A stream within a watershed with more than 25% impervious surface, by area, is classified as a non-supporting stream. A stream in this category shifts from being moderately supportive of aquatic life to being poorly supportive. This classification is qualified by diminishing water quality, habitat quality, and aquatic diversity.

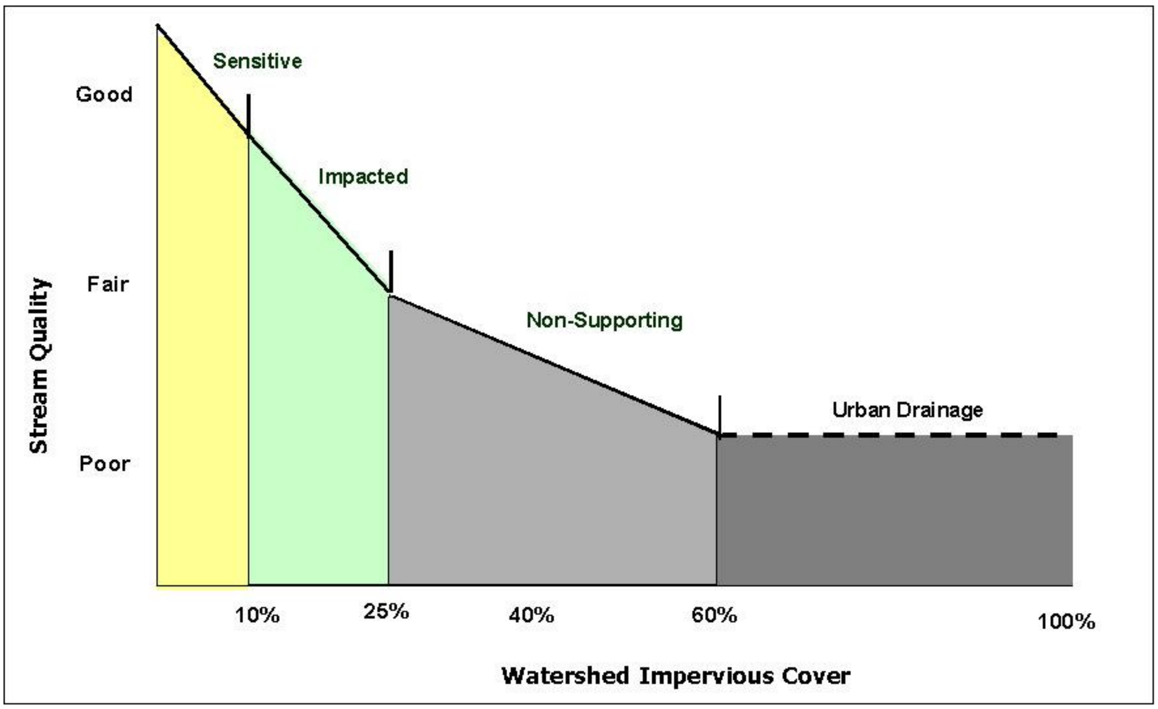

Figure 3: Classification relating watershed impervious cover with stream quality and the ability to support aquatic life. Source: Storm Water Center (2010)

5.3 Stream Characteristics

The creek can be divided into three categories based on predominant land use: upper reaches, mid-reaches, and lower reaches. Additional information describing the creek’s character includes sediment structure, and past habitat restoration projects.

5.3.1 Upper reaches

The upper reaches of Brooklyn Creek are largely developed into golf courses, which may in some ways be beneficial to the creek considering Crown Isle Golf course has large retention ponds which regulate summer flows to a certain degree, and low summer flows are stated to be the main limiting factor to salmonid production (Photo 2) (Bainbridge, G. & Kuta, C. 2000). Conversely, local knowledge from longtime residents, suggests that flows in the upper reaches of the creek were historically ephemeral (Bainbridge, G. & Kuta, C. 2000). Additionally, the upper areas of Brooklyn Creek that are not encompassed by golf courses have been channelized during urban development into a series of low gradient ditches which have limited canopy cover to shade the creek (Bainbridge, G. & Kuta, C. 2000). The negative effects of channelization include; increased erosion, reduction in the richness of species in riparian areas, reduced bank stability, increased downstream flooding, loss of large woody debris, and sedimentation of streams, all of which have been observed in Brooklyn Creek and may negatively affect salmon populations (Brooker, M. 1985). The upper reaches maintain poor salmon spawning and rearing habitat due to the lack of spawning gravel, large woody debris (LWD), vegetation; and a flashy water regime (Photo 3). The sediment is composed of sands or fine gravels and in some places is only 20-30 cm thick above the hardpan (Cousens, B. & Lee, C. 1999).

Photo 3: Example of an upper reach in Brooklyn Creek near Crown Isle, spring 2010.

5.3.2 Mid-reaches

The mid reaches of Brooklyn Creek have been largely subjected to urban and agricultural development, and are currently the receiving body for a portion of storm water. In a portion of these reaches the creek meanders through a ravine with steep banks that are un-vegetated and subject to erosion. The soil character is composed of rich peaty organics (Cousens, B. & Lee, C. 1999). There is one case where the mouth of a storm water drain cascades from approximately 6 m, causing the lower bank to erode, resulting in further decreases of slope stability. The channelization and storm water inputs have had damaging effects on the stream and have increased the flashiness of Brooklyn Creek.

5.3.3 Lower Reaches

The lower reaches of the stream are largely contained within a system of parks and are in a more natural state than the upstream areas. Mack Laing Park hosts excellent fish habitat in the lower reaches of the creek, and further upstream, Salish Park has high-quality rearing habitat with good bank and crown cover (Cousens, B. & Lee, C. 1999). This section contains a relatively complex channel and is where the most extensive salmon rearing habitat exists (Bainbridge, G. & Kuta, C. 2000). However, there is some bank erosion and loss of channel structure from storm water surges. This has decreased the spawning habitat due to the influx of sediment being washed downstream and covering spawning gravel. There is a distinct riffle-pool pattern in much of this region of Brooklyn Creek, however some segments do seem unnaturally straight, which suggests possible anthropogenic alterations have been made. An engineered wetland was constructed in Salish Park in 2007, with the intention of alleviating the damage caused by storm water surcharges (Wong, R. 2009). The wetland was engineered to divert storm water into, and then allow for slow infiltration back into Brooklyn Creek. Mack Laing Park has been the site of several salmon spawning and rearing habitat enhancements projects, discussed in greater detail in Section 5.3.5, including; increasing the riffle-pool structure, reintroducing LWD, and planting native species in riparian areas.

5.3.4 In-stream Sediment Structure

The sediment structure in the creek varies from silty pools to cobbly riffles. The hardpan underlying the in-stream sediment is invariably composed of clay or clay/glacial till (Cousens, B. & Lee, C. 1999). This hardpan is effectively impermeable to water and erodes very slowly. In some exposed areas the hardpan shows evidence of anthropogenic interference such as excavator claw marks.[4]

5.3.5 Habitat Restoration Projects

A number of restoration projects have been undertaken in the lower reaches of Brooklyn Creek. The primary objective of these projects has been to improve fish habitat and rearing grounds, and secondarily to prevent sediment from erosion entering the creek. According to Wong, R. (2009) beyond sediment and erosion, some of the "limiting factors to fish production in Brooklyn Creek include poor base flows and elevated peak flows due to the increasing effects of urbanization and alterations to watercourses and wetlands."

An enhancement strategy for Brooklyn Creek began in 2005 and is planned to continue through 2011. The restoration works have included the installation of a fish ladder under Balmoral Ave.; mitigation of storm water inputs; installation of large woody debris (LWD) and boulder matrices; riffle, pool, and spawning platform construction; removal of obstructions to fish passage; and riparian vegetation planting (Photo 4). The majority of these works have taken place in the lower reaches of the creek, especially within Mack Laing Park.

Photo 4: Habitat enhancement project that includes installation of LWD, 2009.

Source: Brooklyn Creek Watershed Society

[4] Pers. Com. Dave Davies, Community Advisor, DFO. April, 2010.

5.3.6 Historical Fish Inventory

Past fish enumeration has largely been the by-product of fish exclusion efforts from in-stream restoration projects. When habitat restoration work is done in-stream, such as the installation of LWD and boulder matrices, the creek's flow must be diverted around the work site and any fish residing therein moved to another reach above or below the work area. This type of work is undertaken during the general fisheries work window from June 15 to September 15, so as to minimize the impact on salmon.[5] At this time of year the fish that are excluded from in-stream restoration projects are predominately recently emerged Coho fry. These fish are caught using gee-traps, and by electrofishing. The fish that are caught for exclusion are enumerated and speciated. This data has been collected on a number of occasions.

Beyond this empirically collected data, information regarding the historical presence of salmon in the creek is available from the online Fisheries Information Summary System (FISS)[6] the results of this query are available in Appendix A. In summary, the historically present species of salmon according to the FISS query is limited to Coho. There is mention of both chum (*Oncorhynchus keta*) and pink salmon (*Oncorhynchus gorbuscha*) as "Escapements"; however, they are not included in "Fish Distributions" (Appendix A).

5.4 Water Flow and Water Quality

The following section outlines Brooklyn Creek's flow regime and discusses the relationships between water quality and salmon.

5.4.1 Water Flow

The flow in Brooklyn Creek varies greatly throughout the year, and can fluctuate to a great extent over the course of one day based on a rain event. There are two main reasons for this: (1) the impermeable silt hardpan common in this region promotes sheet-flow runoff, (2) the creek is an integral part of the ToC's storm water infrastructure. This rapid runoff decreases water quality due to increased sedimentation from bank erosion, and since this is a largely urban area, increases contaminants being washed into the creek. The mean annual discharge of the creek "is estimated at 0.29 m^3/s based on a unit discharge of 44.5 L/s per km^2 and a watershed area of 650 hectares" (Chilibeck, B. 2005).

5.4.2 Water Quality

The following water quality parameters were taken because of their known effect on salmon development and survival. These include; dissolved oxygen (DO), % saturation, water temperature, total dissolved solids (TDS), pH, and conductivity.

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[5] The window for Cutthroat Trout is shorter, ranging form August 15- September 15. Accessed from <http://www.pac.dfo-mpo.gc.ca/habitat/timing-periodes/index-eng.htm> on June 13, 2010.

[6] Accessed from <http://a100.gov.bc.ca/pub/fidq/main.do> on June 13, 2010.

5.4.2.1 Dissolved Oxygen

Various studies have been done on egg to fry emergence with respect to DO levels. One such study by Shumway, D. et al. (1964) found that "fry from embryos reared at low and intermediate oxygen concentrations hatched later and were smaller in size at hatching than fry from embryos reared at concentrations near the air-saturation level." During their freshwater motile lifecycle, fish demonstrate "behavioral response to reduced external availability of dissolved oxygen" these responses according to Kramer, D. (1986) "are (1) changes in activity, (2) increased use of air breathing, (3) increased use of aquatic surface respiration, and (4) vertical or horizontal habitat changes."

According to McMahon, T. (1983), "growth rate and food conversion efficiency of coho fry is optimum at DO concentrations above 5mg/L. Below 4.5 mg/L, growth and food conversion rapidly decreases to the point where growth ceases or is negative (below 3 mg/L)."

5.4.2.2 Water Temperature

Seaward migration often follows periods of rapid temperature warming (Shapovalov, L. & Taft, A. 1954). When water temperatures rise and insect derived food is abundant a rapid growth phase may occur for smolts in preparation for their seaward journey (Shapovalov, L. & Taft, A. 1954). Along the west coast of North America Coho migration is shown to occur according to regional temperature ranges, in several Alaskan streams Coho migration occurred between 5.0 - 13.3°C (Drucker, B. 1972) and 6.7 - 11.1°C with its peak at 8.0°C (Logan, S. 1967); another migration began at 2.5°C, peaked at 8.1°C, and ended at 9.7°C (McHenry, E. 1981). Moving southerly from Alaska to California the Coho smolt migration timing begins earlier (Sandercock, F. 1991f). It should be noted that the upper lethal temperature for juvenile Coho is 25°C and can be reached during low summer flows and high air temperatures (Sandercock, F. 1991g).

5.4.2.3 Total Dissolved Solids (TDS)

TDS is a measure of all of the solids, usually mineral salts, dissolved in a water body. By measuring TDS in conjunction with habitat type and mean annual temperatures, parr production can be quantified (Lirette, M. et al. 1985). For example, using this method a river with a TDS of 250 would have 10 times the production of a river with a TDS of 25. The parr capability of a river is dependent on finding it's percentages of habitat type, once these are found, the estimate is adjusted according to TDS and temperature, and smolts per unit area can be found (Lirette, M. et al. 1985).

5.4.2.4 pH

The measurement of pH has not been correlated to the timing of Coho migration; however it is a common method of assessing the suitability of a water body for salmon habitat and reproductive capacity. The natural pH range for most freshwater systems is 6 - 9. When the pH falls below 6 many harmful effects on aquatic ecosystems may result. Fish die-off begins to occur at a pH below 6 and is essentially inhospitable to any fish life below 4.5 (Lenntech 2009). The harmful range of pH on fish depends on a number of other factors, including pH acclimatization, water temperature, dissolved oxygen concentration, and the ratios of some cations and anions (Robertson – Bryan 2004). Research done by McKee, J. & Wolf, J. (1963) found that the lower pH limit for salmonids is 4.5 and the upper limit is 9.5. Other issues that may occur as a result of low pH include the release of aluminum ions (Al^{3+}) from streambank soils that can kill fish by causing excessive mucus production leading to asphyxiation (Lenntech 2009). Lenntech also suggested that low pH can cause calcium levels in adult female fish to decrease to a point where egg production is no longer possible or the eggs/larvae develop abnormally (2009).

5.4.2.5 Conductivity

There is a close connection between TDS and conductivity; the more salts dissolved in water, the higher the measure of conductivity. As a result, the method described in the TDS section above could theoretically instead be used with conductivity to find the productivity of a stream.

5.5 Life History of Coho salmon (*Oncorhynchus kisutch*)

For the purposes of this study it is important to understand the lifecycle of Coho salmon in order to relate back our observations and conclusions, and attempt an explanation at survival between the various stages of salmon development including egg, fry, smolt, and returning spawners. The majority of information known about salmon comes from their life stages spent in freshwater and near shore coastal areas; relatively little is known about their time in the open-ocean environment.

According to McMahon, T. (1983) the different stages of development in a Coho salmon's lifecycle can be defined as:

- Adult: Sexually mature Coho migrating from the ocean to natal stream to spawn.
- Spawning/embryo/alevin: From period of egg deposition to hatching and emergence of fry from redds (Alevins = yolk-sac fry).
- Parr: Fry (age 0) and juvenile (age 1+) Coho residing in rearing streams.
- Smolt: Seaward migrant juveniles undergoing parr-smolt transformation.

Based on the information gathered in this section we will be able to predict the number of returning adults and retrodict the number of spawners based on our observed number of migrating smolts. As survival rates are essential to these pre- and retrodictions, many of the following life-stages include an attempt to quantify and explain survival at a given stage.

5.5.1 Distribution

The known distribution of Coho salmon territory reaches from the coastal areas of California, north along the West Coast of the U.S. and British Columbia, and across the Bearing Sea to Kamchatka and

Northern Japan (Figure 4). Coho are found in most salmon bearing coastal streams in British Columbia. In the larger rivers of the province, such as the Fraser and Skeena, Coho typically migrate to the smaller upstream tributaries for spawning. According to Sandercock, F. (1991a), "it was estimated by Aro, K. & Shepard, M. (1967) that Coho spawned in 970 of 1500 known salmon bearing streams in British Columbia. Coho is the most widespread of the five salmon species of Pacific Salmon and no one area of the province is the dominant producer (Milne 1964)" (Figure 5). Following approximately six months incubation, up to fifteen months rearing in fresh water, and sixteen months at sea, Coho typically reach sexually maturity in their third year (Sandercock, F. 1991b).

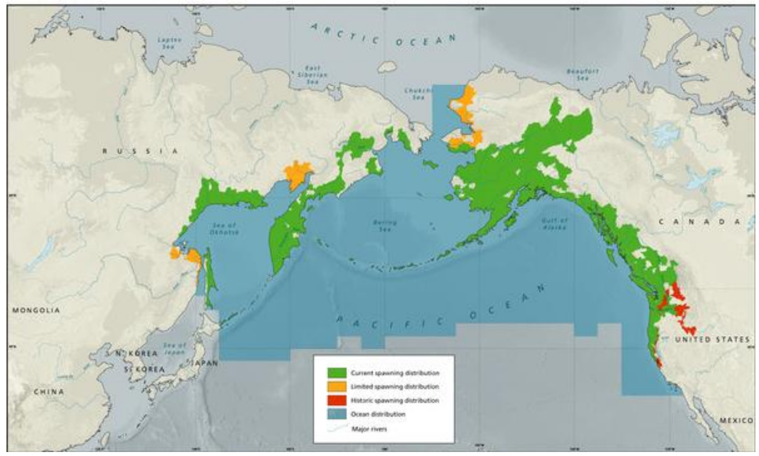

Figure 4: Current and historical distribution of Coho salmon in the North Pacific Ocean, circa 2004.

Source: Steinback, C. & Fuller, A. (2004)

5.5.2 Spawning

Coho begin to return to their rivers of origin in late summer and fall, in British Columbia they usually arrive in September/October, following approximately 1.5 years at sea (Sandercock, F. 1991b). The spawning adult's journey may be relatively short along coastal routes, or as long as hundreds of kilometres, and "for most stocks the duration of the spawning migration appears to be 3 months or more" (Sandercock, F. 1991b).

It is apparent that spawning adults gather at the mouths of shallow coastal streams, such as Brooklyn Creek, and begin to move upstream when the water levels reach a sufficient depth to allow passage. If autumn precipitation freshets do not occur for a sustained duration and are instead infrequent, the upstream migration will be pulsed. In general, the spawners are most likely to begin their migration upstream when the stream experiences a large flow in conjunction with a high tide (Fraser, F. et al. 1983), temperatures between 7.2 - 15.6°C, depth at a minimum of 18 cm, and the water velocity at a maximum of 2.44 m/s (Reiser, D. & Bjorn, T. 1979). It is believed that the aforementioned conditions at the mouth of streams are conducive to allowing fish passage to "small headwater tributaries where good

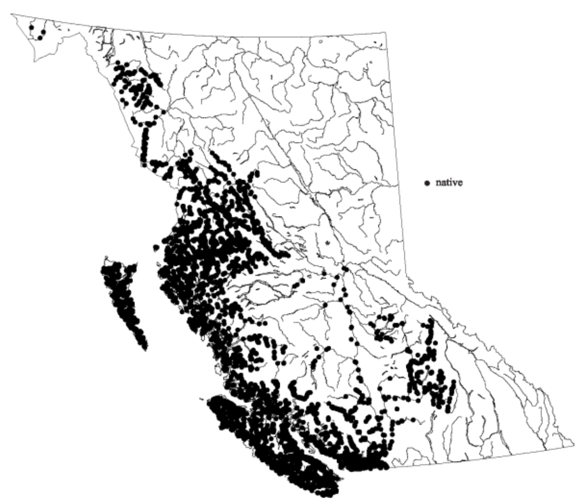

Figure 5: Distribution of native Coho salmon in the freshwaters of British Columbia.

Source: McPhail, D. (2009)

spawning and rearing conditions may be found" further upstream (Sandercock, F. 1991b).

5.5.3 Fecundity

According to Sandercock, F. (1991c) "the number of eggs carried by ripe Coho females varies with the region and with the size of fish." Regionally speaking there appears to be a definite increase in egg number over increasing latitude from California towards Alaska. Drucker, B. (1972) discovered a positive correlation between egg number and the length of spawning female. Neave, F. (1948) found that the mean number of eggs per female from several stocks in British Columbia was 2699. Bradford, M. et al. (2000) report a mean fecundity of 2000-2500 eggs per female.

5.5.4 Incubation and Emergence

Water temperature is the dominant factor affecting the length of time required for egg incubation (Sandercock, F. 1991d). The lower the temperature, the longer the period of incubation required before emergence. For North American stocks it has been observed that in Alaska the range of incubation time is 42 - 56 days (McPhail, J. & Lindsay, C. 1970), in California the range is 48 days at 9.8°C and 38 days at 10.7°C (Shapovalov, L. & Taft, A. 1954). In their study of the Big Qualicum River on Vancouver Island, Fraser, F. et al. (1983) found that Coho in their egg and alevin stages spent an accumulated average time in the gravel of 167 days. During the alevin stage, Coho remain in the gravel where they were deposited as eggs and continue to feed off the embryonic yolk sac until it is depleted.

5.5.5 Parr/Fry

Coho emerging from their gravel incubation are called fry and measure approximately 30 mm in length. According to Mason, J. & Chapman, D. (1965), the fry that emerge from their gravel incubation first are on average larger than those that emerge later. This early emergence may result in "an early growth advantage related to their larger size and better feeding opportunities [the early emerging fry] tend to remain larger and ultimately make up a greater proportion of the fingerling [smolt] population" (Sandercock, F. 1991e).

According to Neave, F. (1949), Coho fry may migrate upstream or downstream where they are capable of inhabiting areas inaccessible to adults. The fry will distribute themselves throughout the stream where they will setup territories for extended periods. This behaviour has the beneficial result of creating a relatively low density of fry in any one area and reduces competition for food resources. However, territorial tendencies can have some negative results, for example the size disparity between late emerging fry and their larger, early emergent relatives, may be compounded by smaller fry being chased out of prime feeding grounds to less favourable sites, consequently, the later emergent fry grow more slowly (Chapman, D. 1962).

Regarding out-migration, Hartman et al. (1982) found "most Coho fry move out of river systems with freshets. However, even during periods of stable flow, fry continue to migrate. The numbers of fry moving do not correlate well with the water discharge rate because the first freshet may move most fish, whereas the second freshet, a few days later, may move only the few that are still left in the stream."

5.5.6 Smolt

In general, it has been found that the timing of smolt out-migration depends on a number of factors including the size of fish, flow conditions, water temperature, dissolved oxygen levels, amount of daylight, and food availability (Shapovalov, L. and Taft, A. 1954). According to Steve Baillie (DFO)[7], there is also some evidence to support a connection between the timing of migration with DO levels, and productivity of Coho per unit area with conductivity. However, in the end it is the annual variations within a single river system that dictate the timing of smolt out-migration.

In many cases the length and weight of Coho can be representative of their age. According to Rounsefell, G. & Kelez, G. (1940) "with moderate water temperatures and an abundant food supply, Coho fry will grow from 30 mm at emergence in March to 60 -70 mm in September, to 80-95 mm by March of their second year, and to 100-130 mm by May." Armstrong, R. & Argue, A. (1977) in their study of the Cowichan River found that one-year-old smolts measured 88-98 mm and two-year-olds were 98-105 mm. In their long-term study of the Big Qualicum River, Fraser, F. et al. (1983) summarized 15 years of data to find the average smolt size was 98.5 +- 58.0 mm, and 11 years of data showed their average weight was 11.18 +- 2.44 g.

Flow conditions leading to migration have been outlined by Lawson, P. et al. (2004) where "correlates for the Oregon Coast stocks were the date of first fall freshets and flow during smolt outmigration. Air temperature is correlated with sea surface temperature and timing of the spring transition so that good freshwater conditions are typically associated with good marine conditions", and where "annual air temperatures and second winter flows correlated strongly with smolt production."

5.5.7 Survival

In a comparison of salmon survival rates, Bradford, M. (1995) found that the "average egg–fry survival of Coho salmon was 19%, and egg–smolt survival was 1-2%." These rates depend on instream conditions such as winter flooding, causing the disruption of gravel, low flows, freezing of gravel, heavy silt loads, predation from birds and insects, and infections; under very harsh conditions, no eggs will survive (Sandercock, F. 1991d). However, Neave, F. (1949) compared Coho against other salmon species in the Cowichan River and found that Coho show relatively high egg-fry survival; possibly due to their selection of spawning sites with conducive flow stability and less egg density.

Emergence occurs near the end of the incubation period when the alevins have nearly exhausted the nutrients in their yolk sack. The alevins begin upward migration, in a direction against the flow of current,

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[7] Pers. Comm. Steve Baillie, Program Head of the Georgia Basin Salmon Stock Assessment DFO. Email correspondence. June 4 2010.

through the gravel. If the gravel above is compacted or loaded with sediment, emergence may not be possible. According to Phillips, R. et al. (1975), where the gravel/sand mixture was 70% sand (particle diameter <3.3 mm), survival to emergence was only 8%. A possible explanation of these low survival rates comes from Tagart, J. (1984), where it was found that when fine sediment filled the interstitial spaces of gravel low DO concentrations resulted. Access to DO is a requirement for salmon survival.

In their analysis of out migrant fry data, Bradford, M. et al. (2000) suggest that "most fry leave the natal stream soon after emergence from spawning areas. Coho salmon egg-to-fry survival has been estimated to range from about 20 to 30% (Sandercock, F. 1991; Bradford, M. 1995); based on a mean fecundity of 2000–2500 eggs, the average rate of fry outmigration that we observed (413 fry per spawner) means that 60 to >90% of the emergent fry could leave the stream in their first spring (Mason, J. 1974)." According to Bradford, M. et al. (2000), "factors such as in-stream habitat complexity, flow stability, and stream morphology will help to reduce fry outmigration rates, which might result in increased smolt production." As a measure of egg-to-smolt productivity, Bradford, M. et al. (2000) found that "on average, about 85 smolts per female spawner will be produced in coastal Coho salmon streams." Wild smolts currently survive to adulthood at a rate of 3.5% for returning spawners.[8]

Weisbart, M. (1968) stated "that salinity tolerance was not a function of age but of size. Coho fry up to 5-6cm in length and five months of age do not survive in sea water. The threshold size for survival seems to be about 7-8cm." Crone, R. & Bond, C. (1976) found "from the study of scales, it has been concluded that Coho that enter the sea in the first spring or summer of life do not generally survive to the adult stage."

5.5.8 Nomads

Fry that move downstream between emergence and the following October are referred to as nomads (Chapman, D. 1962). The Coho that move downstream from November onward are called smolts. According to Sandercock, F. (1991), "in addition to factors such as size, level of aggressive behaviour, and food availability, there may be an innate tendency on the part of nomads to migrate. The fact that some Coho fry migrate downstream early in the spring, even when rearing space is available, would support this suggestion."

5.5.9 Migration in Groups

According to Shapovalov, L. & Taft, A. (1954), smolts often migrate downstream with like-sized individuals, in groups of about 10-50. This schooling behaviour is "generally considered an anti-predator defence" (Major, P.F. 1978). This general consideration is backed up by Petersen, J. & DeAngelis, D. (2000), who found that "mortality of prey depends strongly on the number of prey in the patch." The aggregation of salmon smolts when migrating can be explained by Trites, A. (2002) who states that schooling behaviour creates confusion, due to the amount of activity created by the fleeing school, which makes it difficult for a predator to choose and pursue a single individual.

[8] Pers. Comm. Steve Baillie, Program Head of the Georgia Basin Salmon Stock Assessment DFO, Email correspondence. June 4, 2010.

5.5.10 Sclerochronology

Microscopic examination of fish scales can relate an extensive story about the history and survival conditions of salmon. As a fish ages, the scales develop, and this development can be seen as concentric rings called ‘circuli’. The growth of these rings begins immediately after the fish’s formation (Shapovalov, L. & Taft, A. 1954). Similar to tree rings, the circuli grow at different rates depending on the conditions and lifecycle patterns. The circuli are more widely spaced during rapid growth and more narrowly spaced during slow growth (Shapovalov, L. & Taft, A. 1954). Generally, during the spring and summer the scale’s growth is more widely spaced and during the winter and fall closer together. This enables lab technicians to count the growth patterns of the circuli and determine the age of the fish. If the environmental conditions are not ideal, the circuli will exhibit a brief interruption or irregular pattern which is usually identified by circuli growth that is abnormally close together (Shapovalov, L. & Taft, A. 1954).

5.6 Objectives

The primary objective of this study is to successfully install and monitor a smolt fence within Brooklyn Creek. Several secondary objectives include:

- Carrying out a species inventory of Brooklyn Creek;
- Obtaining a precise count of the number of Coho Salmon (*Oncorhynchus kisutch*) smolts and Cutthroat Trout (*Oncorhynchus clarki*) migrating out of Brooklyn Creek throughout the spring of 2010;
- Obtaining water quality data for the sample period;
- Using statistical analyses to infer correlations between the number of Coho migrating out of the creek and various water quality parameters including dissolved oxygen (DO), total dissolved solids (TDS), pH, conductivity, stage (water height), water temperature, air temperature, and precipitation;
- Describing the age structure of salmonids based on their length, weight, and scale morphology;
- Using stock assessment formulas to back-calculate the number of spawning females from 2008;
- Predicting the number of salmonids that will return to spawn as mature adults in fall 2011;
- Providing a high quality dataset and formal report to the Department of Fisheries and Oceans, Town of Comox, and Brooklyn Creek Watershed Society to stimulate the continuation of habitat restoration projects for juvenile salmon and cutthroat trout in Brooklyn Creek;

6.0 Methods

6.1 Site Selection

The smolt fence was installed in the Brooklyn Creek mainstem approximately 200 meters upstream of the creek's estuary in Comox Harbour, and 600 meters downstream from the intersection of Brooklyn Creek and Balmoral Ave (Figure 6). The specific location for installation of the fence was based on compliance from the ToC, as the desired site is in part on ToC property. Once the ToC accepted the proposed location, the local residences were informed of the project via a letter handed out door to door (Appendix B). The selected location proved ideal due to channel width, shape, and close proximity to a pool needed for placement of the collection box. The location for the fence was easily accessible for installation and disassembling procedures by vehicle and by foot via a driveway at the intersection of Baybrook Drive and Orchard Park Drive. The driveway leads down to a property that was recently procured by the ToC, and contains four or five small houses, a large expanse of maintained lawns and a high density of both native and fruit trees. To access this property, there is a small concrete bridge, wide enough for the passage of one vehicle. The fence was erected immediately upstream of this bridge.

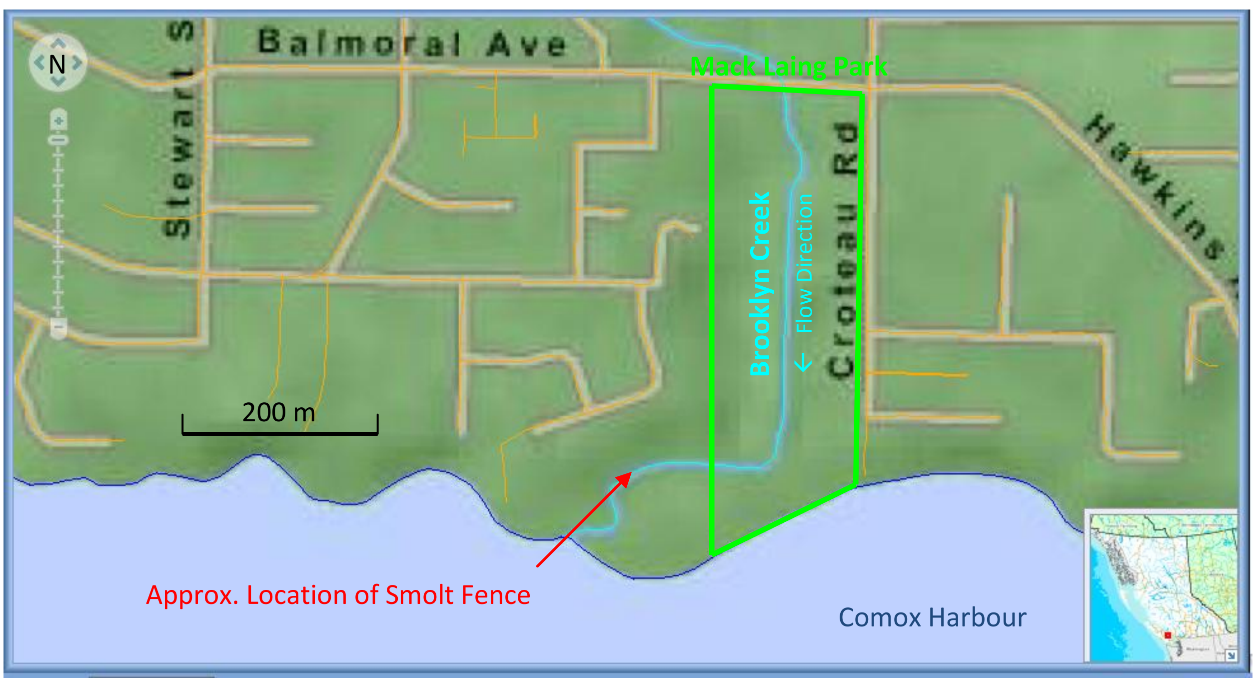


Figure 6: Map showing the approximate boundary of Mack Laing Park including Brooklyn Creek and the proposed location of the smolt fence described in this proposal. Source: Adapted from CDC[9]

[9] CDC, Conservation Data Centre <http://www.env.gov.bc.ca/cdc/>.

This project had the support of the Brooklyn Creek Watershed Society (BCWS), an active group of local volunteers who work to maintain the health of the creek. The relationship between the BCWS and this project has successfully included local residents who participated in the installation, disassembling, maintenance, and data collection. The fence location allowed ease of access for volunteers, yet it was a sufficient distance from public trails so as not to attract vandalism. The local residents were helpful in assisting with monitoring the fence to ensure vandalism was not incurred.

A standard smolt fence, which was previously used in a 2009 out-migration study of Morrison Creek, Courtenay, BC, was available for use in this project. This type of fence was suggested by Dave Davies, Community Advisor, DFO to be ideal for Brooklyn Creek because of the creek's width, flow, depth, morphology, and availability. Furthermore, the same type of smolt fence was being used concurrently in several other streams in the vicinity, and has historically proven to be a reliable design for the intended project. The fence, which had incurred some minor vandalism in 2009, was stored at the DFO office in Comox over the winter. The local DFO supplied the materials necessary for fence repairs, installation and, with the help of Dave Davies, Ian Moul, and John Cavanaugh (BCWS member), the fence was mended and erected on April 16, 2010, and it was completely removed on June 20, 2010.

6.2 Operating Window

Through our communications with Jim Palmer, experienced field biologist and Morrisson Creek streamkeeper; Warren Fleenor and Rupert Wong, professional biologists; and Dave Davies, DFO Community Advisor; we determined that the ideal timing for operation of the fence in Brooklyn Creek would be April 15 to June 15. This decision was based on local knowledge with regard for the out-migration timing of smolts in the Comox Valley region of Vancouver Island. A similar timing window was used by Salo, E. & Bayliff, W. (1958) in their study of Minter Creek, Washington, where the smolt migration occurred between April 15 and June 1, with the peak numbers observed in May. Elsewhere on Vancouver Island, Fraser, F. et al. (1983) observed the migration in Big Qualicum River lasted for a duration of 119 +- 28 days, with the midpoint being May 26 +- 5 days.

6.3 Fence Installation & Monitoring

At the fence site, the dominant creek sediment type is cobbles, the stream width at the top of the fence is 4.4 m wide, and the canopy cover is an estimated 90%, except where the fence and bridge stand and the cover is closer to 5% and 100% respectively. The fence is composed of a number of 1.2 x 2.4 m framed panels covered with 6.3 mm hardware cloth. There were two panels used on either side of the creek in conjunction with ~100 sand bags and a poly liner to insure that the fence

Photo 5: Brooklyn Creek smolt fence.

was “fish tight”. The morphology of the stream banks was conducive to the fence installation, and very limited excavation was necessary to “key-in” the fence (Photo 5).

Photo 6: Upstream view of the smolt fence most ‘V’ point; shows the sediment that accumulated on the sand bags and plastic on the inside of the fence.

Due to the size of the channel, it was determined that four panels needed to be installed in a “V” formation, two on each side, pointing downstream. To install the panels, wooden 2x4 planks were laid on clear plastic which lined the bottom of the creek. The plastic lining functioned to minimize scouring erosion of the creek bed both up- and downstream of the fence, and to help obstruct fish from finding alternative routes around the fence. Sand bags were used under the plastic on the left bank to even out the eroded creek bed. The plastic was covered with creek substrate and over time sediment accumulation created a natural creek appearance (Photo 6). Lateral stabilizing 2x4 planks were added to support the fence panels. The fence panels were secured down with 1 cm re-bar staked about 1 m into the stream bed. Sandbags were used to maintain the structure of the fence and seal any gaps. Additional 2x4 planks were used as braces to further secure the fence to the creek banks in case of a large flow. Furthermore, a stage meter was installed on the upstream side of the bridge to measure the height of water.

Photo 7: Black PVC pipe which leads to the holding box that was located in a calm pool downstream of the smolt fence.

This style of fence funnels fish into the point of the “V” while allowing water to pass through the fence. At the notch of the “V” there is a pipe with a diameter of 20.3 cm and a length of 10.15 meters that leads both water and fish, into a holding box located downstream (Photo 7). The box used to hold the salmonids measures ~1m^3 and is constructed of 1.25 cm plywood and 6.3 mm hardware cloth. The box has a removable lid for easy access to the fish by the monitors. The water level inside the box is approximately 17.6 cm deep, and the excess water exits the holding box though hardware cloth on both sides of the box while the fish remain contained within it. The box was dug down into the creek bed to increase the water level, secured with 1 cm re-bar staked and tied to the trunk of a tree for extra support.

6.3.1 Fence Maintenance

Dave Davies, DFO, suggested that we allow the natural accumulation of organic debris on the upstream side of the fence to increase the head. The purpose of increasing the head is to insure the flow of water has an adequate velocity though the pipe and into the holding box, to direct fish therein and keep captive fish healthy until they are measured and released. However, we found the organic matter buildup did not provide enough head to keep the salmonids from coming back up the pipe at low flows, so landscape fabric was installed on May 14, 2010 from the base of fence, up about 20 cm, to ensure adequate head was achieved.

6.3.2 Fence Monitoring and Operation

The Project Team was the primary operator of the fence, with substantial volunteer assistance from the BCWS, local DFO and volunteers. Dave Davies and Ian Moul agreed to share the responsibility for Monday and Tuesday fence monitoring; these were the days that the project team would not be available. Occasionally they would be assisted by volunteers, which included interested neighbors and a Royal Bank green initiative group (Photo 8).

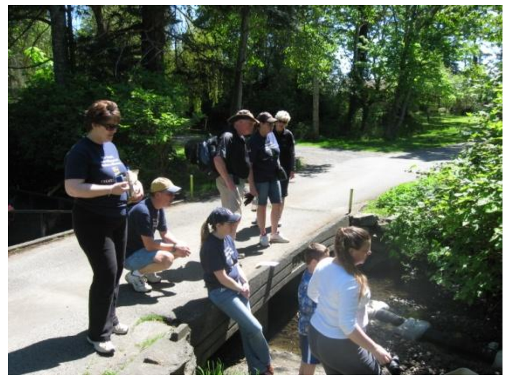


Photo 8: Royal Bank green initiative group, spring 2010

Daily tasks were identified and prioritized by the Camosun monitoring team. A detailed daily task list was added to the field clipboard to ensure sampling protocol remained consistent (Appendix C). Training sessions were offered on a number of Fridays at the beginning of the monitoring period to bring volunteers up to speed on fence maintenance and fish ID techniques. In addition reference material on proper species identification was available to volunteers to ensure accurate identification. With the assistance of the following experienced personnel and regular communication between all individuals involved in monitoring the fence the quality of the data was assured. Dave Davies was available for technical assistance and any species identification clarification that was needed. Jim Palmer of the Morrison Creek Streamkeepers, and Warren Fleenor & Rupert Wong of Current Environmental also offered technical and advisory assistance when needed.

6.3.2.1 Data Collection

The box was checked once daily primarily in the morning around 0830. The first step in collection was to identify species and count numbers of fish in the smolt box. Following data collection, the fish were released downstream of the fence where there was no possibility of re-catching them. There were several days that required a second visit for varying reasons; high migratory numbers in the morning, increased flow and debris blocking the passage for fish, and acquiring water quality data.

Fish length and weight data was collected once per week on Fridays (which was chosen based on convenience and availability of assistance). A maximum of 30 fish were randomly selected for measurement and were then anaesthetized in approximately 4 L of water using 1 tablet of Alka-Seltzer dissolved therein. The number of fish measured was based on time constraints and satisfying the requirements of the statistical Central Limit Thoerem (Statsoft 2010). The fish were measured according to Resource Inventory Standards Committee guidelines from the end of their snouts to the fork of the caudal fin using a measuring board (RISC 1997) (Photo 9). The fish were weighed using a battery powered digital scale which was tare'd with a four cup plastic measuring cup filled with water. During the transfer of fish from the measuring board to the scale caution was used to minimize the addition of water to the measuring cup and stress on the fish. Post-weighing, the fish were placed in a recovery bucket which had oxygen bubbling through it for approximately five minutes and then released downstream.

Photo 9: Measurement method; snout to fork of the caudal fin.

On days that the Project Team was running the fence, daily readings of water temperature, dissolved oxygen (DO), % saturation were measured with the OxyGuard Hand Polaris. Total dissolved solids (TDS), pH, and conductivity were taken using the Hanna Instruments (HI98129) Combo meter. Air temperature was recorded using a field thermometer. The stage was measured with a staff gauge, the height is a relative value; zero stage does not mean zero flow. When volunteers were monitoring, only water temperature, air temperature, weather conditions, and stage were recorded.

Upon completion of the migration study the fence was disassembled and any damage incurred to the fence was fixed to ensure that it was returned to the lender in good working condition.

6.3.2.2 Data Sheet

The data sheets that were used were a revised version of the Morrison Creek Streamkeepers (MCS) data sheet. The MCS provided us with the data sheets in an excel file format. The project team revised sections to customize it to Brooklyn Creek's sampling needs (Appendix D). Dave Davies offered to printout the data sheets on "Rite in the Rain" paper, which was then added to the plastic clipboard and stored in a large plastic tote at the fence. It was important to have a standard data sheet that all the monitoring personnel were familiar with in order to maintain the quality assurance and quality control of data collection.

6.3.2.3 Fish Identification

The ability to identify one fish species from another is a key component of the enumeration process. Field identification is accomplished by placing a specimen into a transparent plastic viewing box, where its key features can be easily seen (Photo 10). This method limits stress on the specimen by avoiding complete removal from the water and over-handling. The method used to differentiate species of juvenile salmon is a dichotomous key style flow chart (Pollard et al. 2006). Once species identification characteristics were easily recognized the smolts and fry were caught and identified in a D-net to further minimize handling time. The ability to positively identify species was confirmed by working with Jim Palmer and Dave Davies; and receiving guidance from Warren Fleenor and Rupert Wong.[10] Other information used to confirm field identification includes matching the species distribution (Section 5.5.1), behaviour (Pollard et al. 2006), and historical presence (Section 5.3.6) with the sample site. The basic features used to identify Coho fry and smolts, Cutthroat Trout, Sculpins, and Stickleback are detailed below.

Photo 10: Coho fry showing identification characteristics, spring 2010.

6.3.2.3.1 Coho fry

The following example is the path taken in the key outlined in Pollard et al. (2006) to arrive at a positive identification for a Coho fry (Photo 10):

- Parr marks present;
- Parr mark length greater than the vertical diameter of eye;
- Adipose fin uniformly pigmented;
- Anal fin sickle-shaped with leading edge longer than base;
- Anal and dorsal fins with white leading edge followed by a black stripe;
- Fins are red to orange;
- Measure approximately 30 – 40.5mm in length.

6.3.2.3.2 Coho smolt

Many of the characteristics from the fry stage are changed or non-existent in smolts. For example, in smolts, the dorsal-lateral parr marks and white leading edge of the anal and dorsal fins are much less obvious. The colouration is distinctively more “silver” and the orange tint of the fry stage is unnoticeable in most specimens. The following example is the path taken in the key outlined in Pollard et al. (2006) to arrive at a positive identification for a Coho smolt (Photo 11):

- Length of base of anal fin greater than dorsal base;
- No spots on fins;
- Parr marks present;
- Parr mark length greater than the vertical diameter of eye;
- First three anal fin rays elongated;

[10] Jim Palmer, experienced field biologist and Morrisson Creek streamkeeper; Dave Davies, DFO Community Advisor; and Warren Fleenor and Rupert Wong, professional biologists.

- Spaces between parr marks wider than width of marks;
- Measure 40.5 – 156.5 mm in length (Fraser, F. et al. 1983).

Photo 11: Coho smolt showing some identifying characteristics.
Photo by Jim Palmer (May 7 2010).

6.3.2.3.3 Cutthroat Trout/Sculpin/Three-spined Stickleback

For the purposes of this study the species described in this section are considered by-catch; that is they were all enumerated but their numbers have not been treated statistically or related to past or future population trends. Cutthroat Trout are given particular attention in this region and are commonly quantified along with other salmonid species wherever they are present (Wong, R. 2009). The following example is the path taken in the key outlined in Pollard et al. (2006) to arrive at a positive identification for a Cutthroat Trout (Photo 12):

- Length of base of anal fin less than dorsal base;
- Parr marks regular in shape and position, distinct dark spots (once fish length > 8 cm);
- Adipose fin not orange, distinct dark pigment on lower part of first dorsal fin ray (when fish length < 4 cm);
- Adipose may have 1-2 breaks in pigment on rim and often spotted on parr;
- Maxillary reaches past the posterior margin of the eye (once fish length > 8 cm).

Photo 12: Cutthroat trout showing some identification characteristics, spring 2010.

Sculpin (*Cotus spp.*) and Three-spined Stickleback (*Gasterosteus aculeatus*) are easily differentiated from salmonids as their morphologies are both distinct. According to Environment Canada (2010) are "characterized by a bony stay extending from below the eye to the cheekbone generally scaleless, and small (5-20 cm)" (Photo 13), and according to Fishbase (2010)

Photo 13: Resident Sculpin from Brooklyn Creek.
Photo by Jim Palmer (May 7 2010)

Stickleback have three sharp spines before the dorsal fin, “the pelvic fin reduced to a sharp spine and a small ray, and the series of plates along the sides of the body.”

6.3.2.3.4 Freshwater Crayfish

Although not a fish, crayfish were caught on a number of occasions. The freshwater crayfish species that occurs in British Columbia is *Pacifasticus leniusculus*, there are three sub-species found in freshwater environments in BC; however, Brooklyn Creek’s crayfish was not keyed out to subspecies (Photo 14).

Photo 14: Resident crayfish Brooklyn Creek, spring 2010.

6.3.2.4 Sclerochronology

It was decided that scale samples, to determine fish age, would be collected on Friday, May 28 2010 along with identifying species, weighing, and measuring. Dave Davies advised and assisted on the process of taking scale samples during this one sampling session. Sixteen fish were anaesthetized with Alka-Seltzer then held with their lateral-anterior half exposed. A scalpel was used in the opposite direction of the scales to remove a few samples. Scales were removed from both sides of the fish to insure that there were enough measurable scales. The ideal region to take scale samples is between the lateral line and the anterior portion of the dorsal fin (Shapovalov, L. & Taft, A. 1954). The samples were placed within a scale sample book on a designated square; each salmonid had two squares, one for each side of the fish. The square numbers were recorded next to each salmonid’s species, length, and weight information. The samples were sent to the Sclerochronology Lab in Nanaimo, BC, to be examined microscopically. The purpose of collecting these samples is, in part, to identify the ages of the migrating Coho and relate it back to their observed lengths; thereby, creating an understanding of the length-to-age relationship particular to Brooklyn Creek. It is hoped that the lab results will allow us to get a better understanding of the lifecycle of Coho specific to Brooklyn Creek. At the time of writing these results were not yet available to us.

6.4 Statistical Treatment

Statistical analyses were used to infer correlations between the number of Coho migrating out of the creek and various water quality parameters including dissolved oxygen (DO), total dissolved solids (TDS), pH, conductivity, stage (water height), water temperature, air temperature, and precipitation. All of the statistical tests done in this study used Minitab v. 15 Statistical Software (2007). See Sections 7.1.4 & 8.3 for a detailed discussion of the statistical tests used in this study, and the conclusions derived from them.

The most commonly used statistical test for correlation is the Pearson correlation coefficient (Statsoft 2010). Pearson is a parametric analysis that assumes linearity, normality, and homoscedascity in the data (Cruise Scientific 2010). These assumptions were tested using a 4-in-1 graphical plot and the data proved non-parametric for every assumption (Figure 12; Section 7.1.4).

Because the assumptions for the Pearson parametric test were not met, the closest equivalent non-parametric test was used: the Spearman ρ rank correlation coefficient (Statsoft 2010). Spearman ρ requires that the data be organized in rank order (ordinal scale). We used Spearman ρ to test for a positive or negative correlation between total Coho number and water quality perameters.

Beyond the requirements of Spearman ρ, using rank order to scale the data rather than organizing it for treatment by another method such as physiological time, expressed as degree days (°D), is explained by a study by McCormick et al. (1998) where they found “the timing of smolt descent was controlled by a combination of temperature and temperature increase during spring rather than by a specific water temperature or by degree-days”.

6.5 Materials

The materials required for the repairs, and installation of the fence, were donated by Morrison Creek Streamkeepers (MCS) and the DFO. The materials required in the monitoring stage were lent in kind by the BCWS, MCS, Camosun College, or Current Environmental. The following is a list of the materials that were required to repair, install, and monitor the smolt fence in Brooklyn Creek (Table 3):

Table 3: List of materials required for the repair, installation, and monitoring of a smolt fence in Brooklyn Creek.

Procedure	Item	Quantity	Dimension
Repair/Installation	Fence Panel	7	1.2 x 2.4 m
	Capture Box	1	1.0 x 1.0 m
	Hardware Cloth	1 roll	6.3 mm
	Pipe	1	20.3 cm x 2.5 m
	Fyke Net	1	-
	Re-bar	20	1.0 cm x 1.2 m
	2 x 4 Lumber	8	2.5 m
	Sandbags	20	-
	Plastic Sheeting	2	1.0 x 14.0 m
	Hammer	3	-
	Stapler	1	-
Monitoring	Salmonid ID Literature	2	-
	Scoop Net	1	-
	Plastic Bucket	2	20 L
	Caliper	1	-
	Alka-Seltzer	1 box	-
	Hip or Chest Waiter	1	Per person
	Push Broom	1	-
	Plastic Viewing Box	1	-
	Clip Board	1	-
	Throw Line	1	-
	D-Net	1	-
	Water Quality Meter	2	-
	Waterproof Data Sheets	1 book	-
	Thermometer	1	-

7.0 Results

Our primary result is the successful installation, and maintenance of the smolt fence on a daily basis for the desired time period. Subsequently, a complete inventory of the number and species of fish caught, as well as a comprehensive water quality dataset, within Brooklyn Creek was acquired. The following section includes descriptive statistics, graphs and statistical analysis of the baseline data set.

7.1 Inventory of Fish Species

The species inventory within Brooklyn creek include; Coho (*Oncorhynchus kisutch*), Cutthroat trout (*Oncorhynchus clarki*), Sculpin (*Cottus spp.*), Three-Spined Stickleback (*Gasterostreus aculeatus*) and Freshwater Crayfish (*Pacificastacus leniusculus*). The data was collected over 51 days from April 17 to June 6. The primary species caught by the fence was Coho; there were a total of 3680 Coho smolts and 620 Coho fry (Table 4), these totals do not include eight smolt mortalities. Seventeen Cutthroat trout were caught throughout the sampling period, and 59 sculpins were caught predominantly within the first two weeks (Appendix E). Six crayfish and 13 Stickleback were collected within the study period (Table 4).

Table 4: Total fish caught by species within Brooklyn Creek's Smolt Fence from April 17th to June 6th for a total of 51 days, Spring 2010.

Coho Smolt (Oncorhynchus *kisutch*)	Coho Fry (Oncorhynchus *kisutch*)	Cutthroat Trout (Oncorhynchus clarki)	Sculpin (Cottus *spp.*)	Crayfish (Pacificastacus *leniusculus*)	Stickleback (Gasterostreus *aculeatus*)
3680	620	17	59	6	13

7.1.1 Descriptive Statistics on Coho Smolt

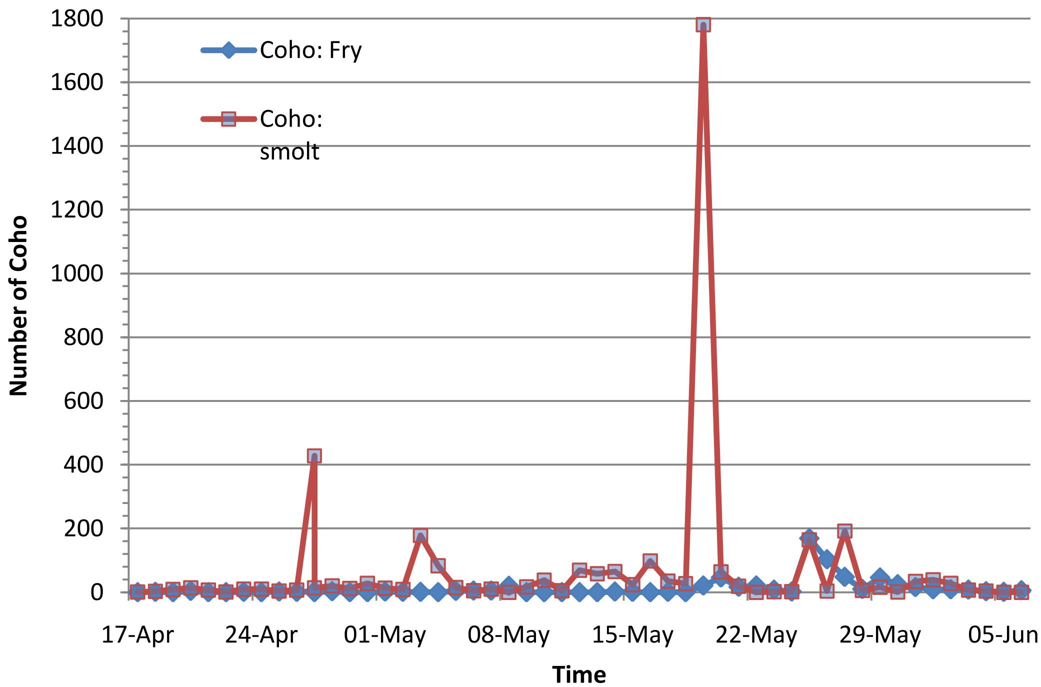
The daily number of Coho smolts ranged from 0 to 1781, with a mean of 72 and a median of 13 per day (Table 5). On April 17, the first fence monitoring day, 1 Coho smolt was caught. There were two migration spikes within the sample period; the first on April 27 when 442 smolts were caught, the second on May 19 when 1781 smolts were caught (Figure 7). June 6 was the final day of fence monitoring, zero Coho smolts were caught.

7.1.2 Descriptive Statistics on Coho Fry

The daily number of Coho fry range from 0 to 169, with a mean of 12 and a median of 2 (Table 5). On April 17, the first fence monitoring day, 0 Coho fry were caught. There was one spike within the sample period, on May 25 when 169 fry were caught (Figure 7). June 6, the last day there were 6 fry caught (Appendix E). Starting on May 25 it was noticed that there were a large number a Coho which ranged from 5.0 - 7.0 cm. It was unclear to which category they belonged, fry or smolt. Most often they were recorded under fry, however, the larger specimens were classified as smolt.

Table 5: Descriptive Statistics on Coho Smolt and Fry Caught within Brooklyn Creek Smolt Fence from April 17th to June 6th for a total of 51 days, Spring 2010.			
Statistics	**Coho: smolt**	**Coho: fry**	**Total Coho**
Mean	72	12	42
Median	13	2	7
Standard Deviation	255	29	183
Minimum	0	0	0
Maximum	1781	169	1781

Figure 7. Coho smolt and fry count from Brooklyn Creek, April 17 to June 6, 2010



7.1.2.1 Descriptive Statistics on Length and Weight of Coho

The descriptive statistics data on weekly length (cm) and weight (g) of Coho is based on seven sampling days collected once per week from April 24 to June 4 (Appendix F). The Coho were randomly collected from the holding box with a maximum daily sample size of 30. There were several sample days were 30 Coho were not available within the box. The total sample size for the seven weeks is 124. The mean length is 10.0 cm and median is 10.8 cm (Table 6). The longest Coho measured was 13.8 cm and the shortest 5.5 cm. The mean weight was 11.8 g with a standard deviation of 6.56 g and median of 12.7 g. The heaviest Coho weighed was 26.9 g and the lightest 1.2 g (Table 6).

Table 6: Descriptive Statistics on weekly Length (cm) and Weight (g) of Coho, within Brooklyn Creek smolt Fence, Spring 2010		
Statistics	**Length (cm)**	**Weight (g)**
Mean	10.0	11.8
Median	10.8	12.7
Standard Deviation	2.42	6.56
Maximum	13.8	26.9
Minimum	5.3	1.2

7.1.2.2 Retrodictions and Predictions of Coho Numbers

Smolts are expected to reside in the creek system for about 1 year before migrating seaward (Section 5.5.6). Through simple calculations, using known survival rates, it was calculated that, at an egg to smolt survival rate of 1.5%, in 2008 there were approximately 245334 eggs (Table 7). Since a female Coho salmon, on average produces 2699 eggs, it was calculated that, based on the number of eggs, there were 91 spawning female salmon in Brooklyn Creek in 2008.

Using a different technique, and the approximation that 85 age 1+ smolts per female spawner are produced, it was calculated that, based on the 3680 smolts counted in the 2010 study, there were 43 spawning females in 2008 (Table 7).

Table 7: Retrodiction of 2008 Coho numbers within Brooklyn Creek		
Parameter	**Method of Calculation**	**Result**
Number of eggs	smolts (3680)/ egg-smolt survival (0.015)	245334 eggs
Number of female spawners based on number of eggs	eggs (245334)/avg eggs per female (2699)	91 female spawners
Number of female spawners based on 85 smolts per female	smolts (3680)/smolts per female spawner (85)	43 female spawners

The accepted return rate for wild Coho salmon is 3.5%. Based on this, it was calculated that from the 3680 smolts 129 adult Coho salmon will return in 2011 (Table 8). It is assumed that approximately half of these will be female spawners.

Table 8: Prediction of Coho adult returning to Brooklyn Creek in 2011		
Parameter	**Method of Calculation**	**Result**
Number of adult Coho salmon expected to return	Smolts (3680) x Rate of survival to return (0.035)	129 Adult Returns

7.1.3 Descriptive Statistics of Water Quality Data

The water quality data was collected from April 16 to June 6. Fifty-one consecutive days worth of data was collected for stage, air, and water temperature. Data was collected for 35 days for total dissolved solids (TDS), pH, conductivity, and dissolved oxygen (DO). The precipitation data was acquired from Environment Canada's, historical weather for Comox, BC (Environment Canada 2010).

7.1.3.1 Air & Water Temperatures

Mean air temperature at Brooklyn Creek over the study period was 11.3°C with a standard deviation of 3.1°C and median of 11.0°C (Table 9). The maximum and minimum temperatures were 20.0°C and 6.5°C, respectively. The mean water temperature of Brooklyn Creek at the fence was 10.2°C with a standard deviation of 1.6 and median of 10.1°C. The maximum and minimum water temperatures were 13.6° and 7.6°C, respectively (Table 9).

Table 9: Descriptive Statistics of Water Quality Data Collected within Brooklyn creek, Spring 2010									
Statistics	**Air temp (°c)**	**Water temp (°c)**	**Stage (m)**	**TDS (ppm)**	**pH**	**Cond. (µS)**	**% Sat.**	**DO (mg/L)**	**Preip. (mm)**
Mean	11.3	10.2	0.363	73.7	7.05	174.8	93.7	10.5	2.53
Median	11.0	10.1	0.354	75.0	7.07	150.0	94.0	10.7	0.10
Standard Deviation	3.1	1.6	0.038	51.65	0.18	14.5	2.35	0.08	0.57
Maximum	20.0	13.6	0.510	87.0	7.46	174.0	98.0	11.4	16.40
Minimum	6.5	7.6	0.320	54.0	6.78	109.0	90.0	9.6	0.00

7.1.3.2 Water Temperatures & Migration Trends

As seen in Figure 8, there is a visible trend of increasing water temperature before the high smolt migration day, May 19. From May 9 to 19 temperatures were consistently above 10 degrees Celsius. On May 20 and 21, water temperatures dropped by over one degree to 8.9, and 8.6 degrees respectively, and out-migrating fish numbers decreased steadily.

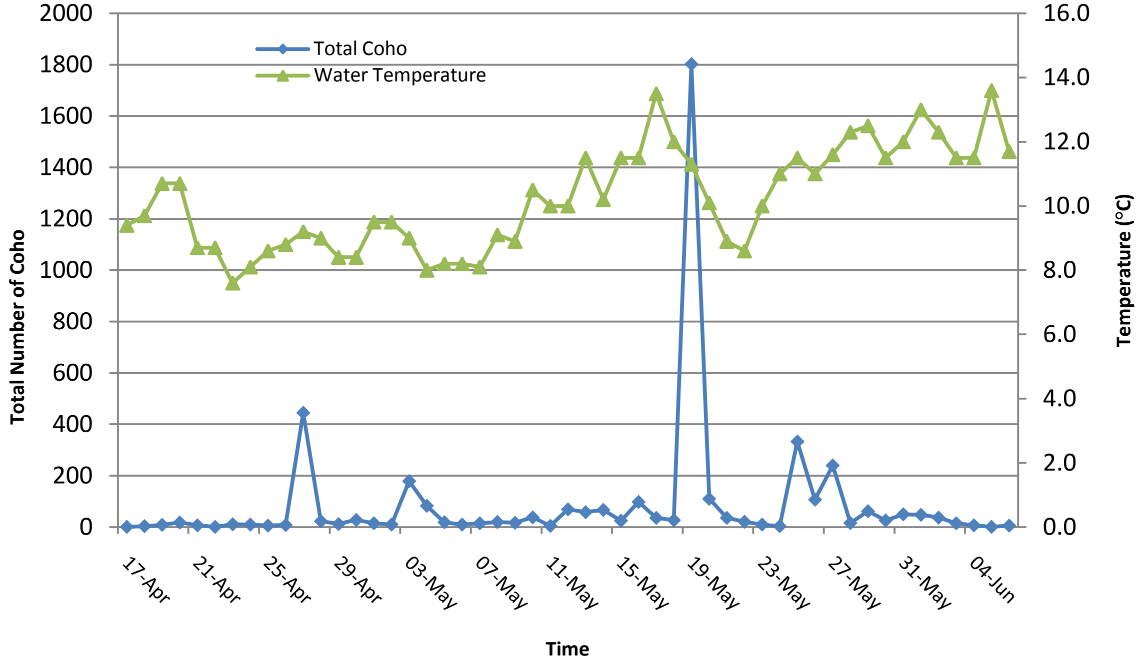
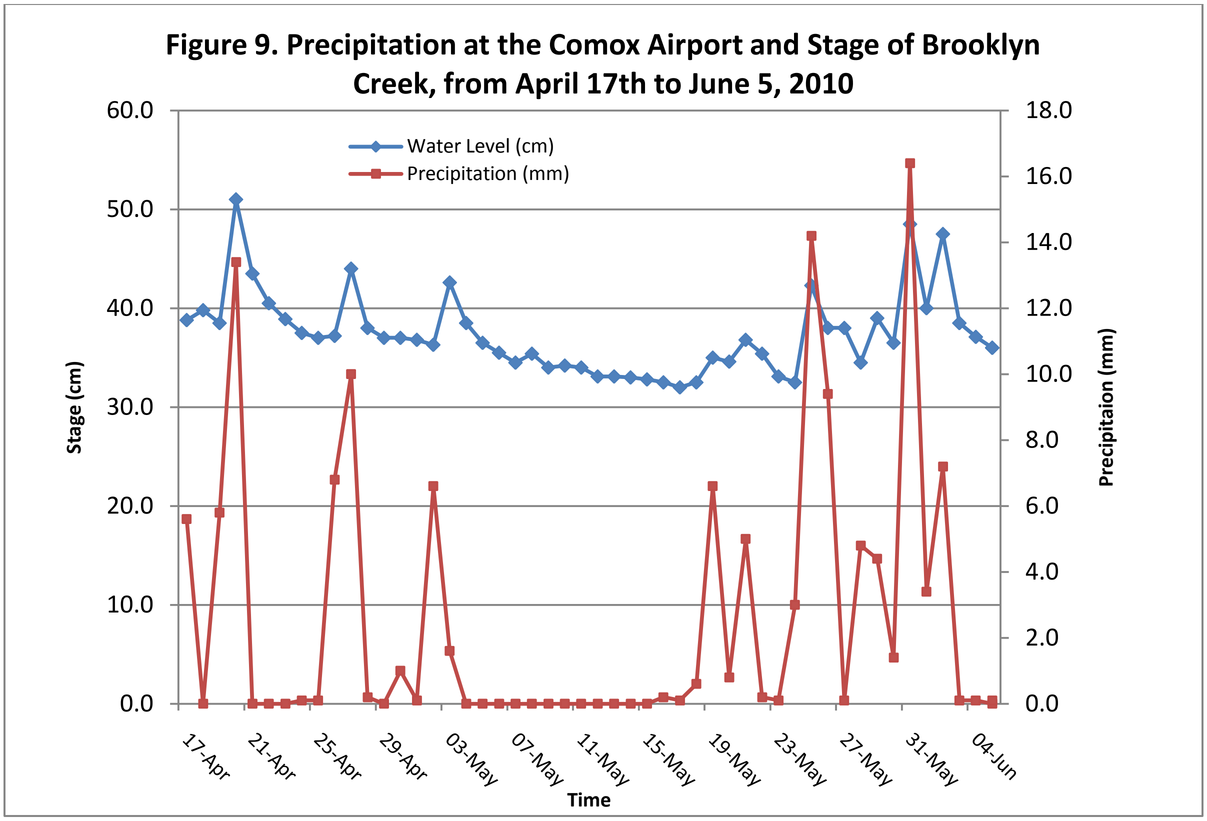


Figure 8. Total Number of Coho Smolts and Water Temperature for the Period of April 17th to June 6th, 2010

7.1.3.3 Stage and Precipitation

The mean precipitation for Comox, over the study period, was 2.53 mm with a standard deviation of 0.57mm and median of 0.10mm, (Table 9). Figure 9, graphically shows the trends in precipitation and stage over the study period. On June, 31st the maximum rainfall occurred at 16.40 mm. There were several days were there was no precipitation. The staff gauge, located just downstream of the smolt fence; had a mean height of 0.363 m with a standard deviation of 0.038 m and a median of 0.354 m. The maximum stage reading was 0.510 m on April 20th and the lowest reading of 0.320 m was on May 17th (Table 9).



7.1.3.4 Total Dissolved Solids (TDS), pH, Conductivity, % Saturation and Dissolved Oxygen(DO)

The water quality sampling site was slightly downstream, but in close proximity, of the smolt fence. The mean TDS was 73.68 ppm with a standard deviation of 51.7 ppm and median of 75.0 ppm. The maximum and minimum TDS were 87.0 ppm and 54.0 ppm, respectively. The pH within the creek had a mean of 7.05 with a standard deviation of 0.18 and a median of 7.07. The maximum and minimum pHs were 7.46 and 6.78, respectively. The mean conductivity was 174.8 µS with a standard deviation of 14.5 µS and median of 150.0 µS. The maximum and minimum was 174.0 µS and 109.0 µS, respectively (Table 9). The pH, TDS and conductivity are visually shown in Figure 10. The mean % saturation was 93.7 with a standard deviation of 2.35 and median of 94.0. The mean Dissolved Oxygen (DO) was 10.56mg/L with a standard deviation of 0.08 and median of 10.7mg/L. The maximum and minimum DO were 11.4mg/L and 9.6mg/L, respectively (Table 9). The trends for water temperature, % saturation and DO can be seen in Figure 11.

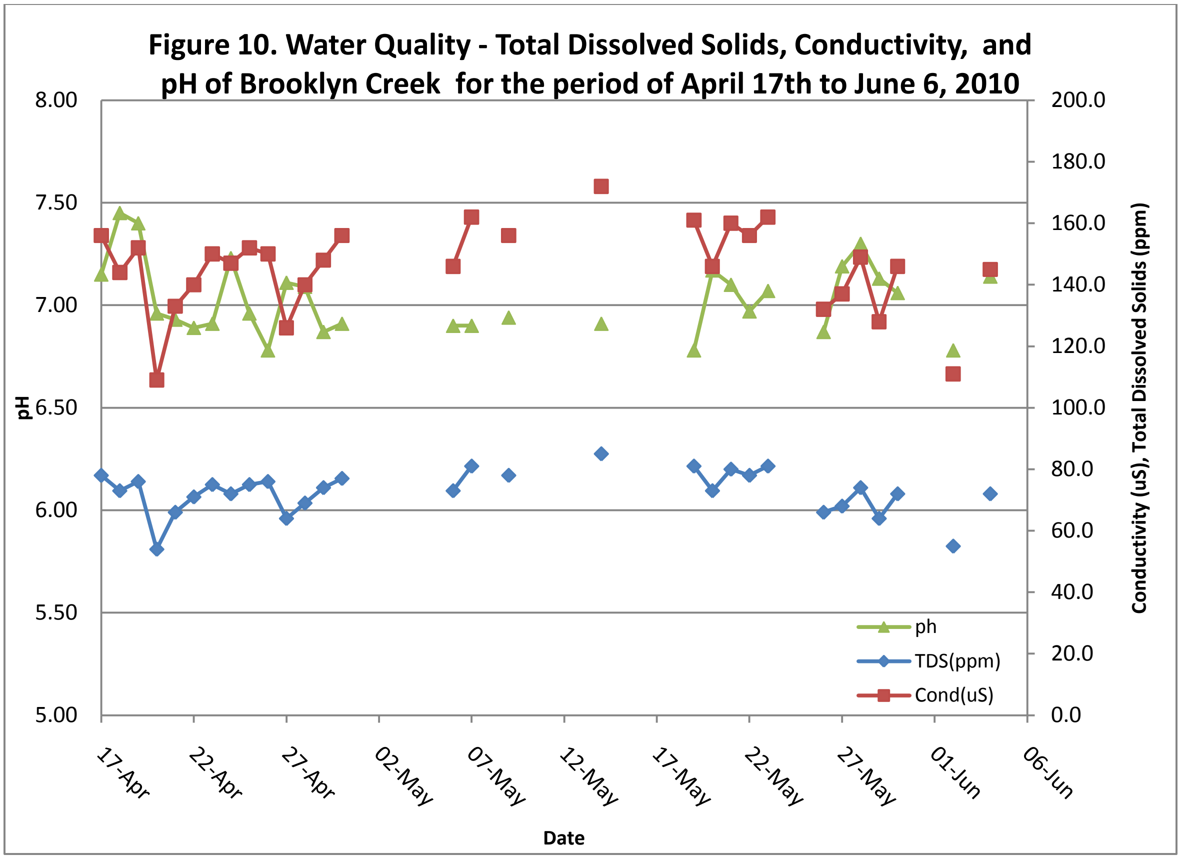


Figure 10. Water Quality - Total Dissolved Solids, Conductivity, and pH of Brooklyn Creek for the period of April 17th to June 6, 2010
pH
Conductivity (uS), Total Dissolved Solids (ppm)
Date
ph
TDS(ppm)
Cond(uS)
8.00
7.50
7.00
6.50
6.00
5.50
5.00
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
17-Apr
22-Apr
27-Apr
02-May
07-May
12-May
17-May
22-May
27-May
01-Jun
06-Jun

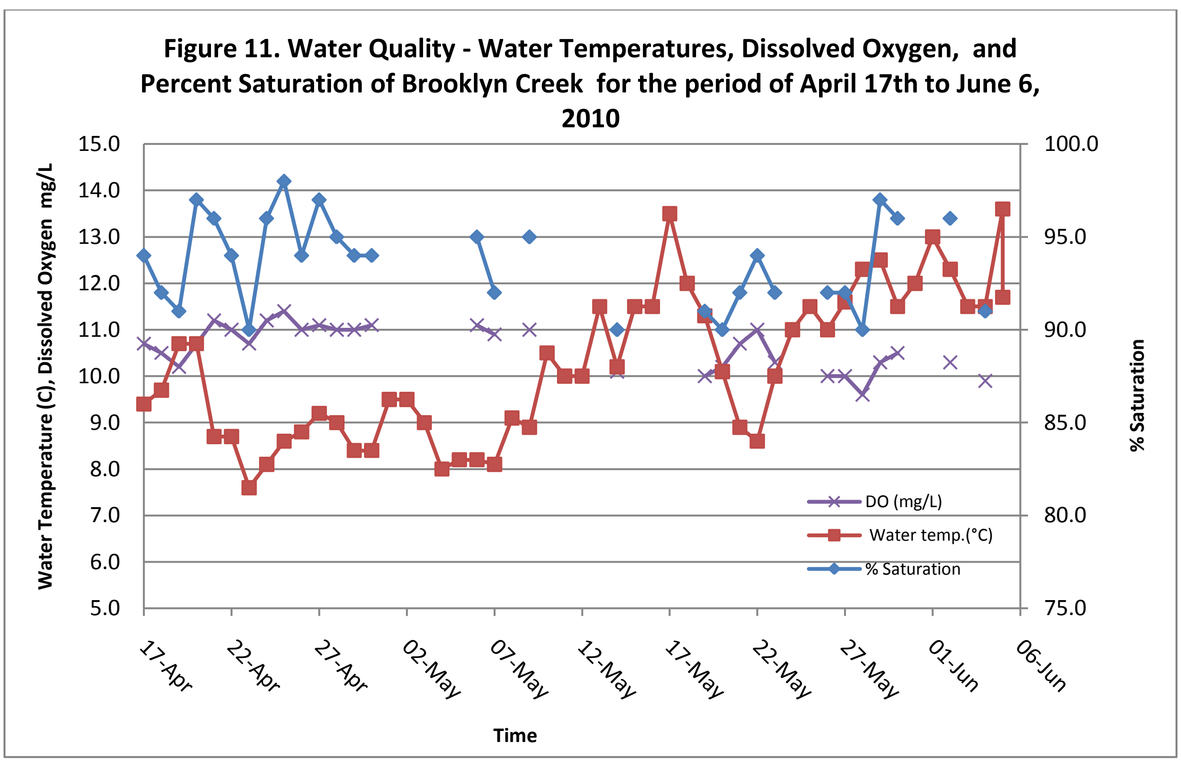


Figure 11. Water Quality - Water Temperatures, Dissolved Oxygen, and Percent Saturation of Brooklyn Creek for the period of April 17th to June 6, 2010
Water Temperature (C), Dissolved Oxygen mg/L
% Saturation
Time
DO (mg/L)
Water temp.(°C)
% Saturation
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
100.0
95.0
90.0
85.0
80.0
75.0
17-Apr
22-Apr
27-Apr
02-May
07-May
12-May
17-May
22-May
27-May
01-Jun
06-Jun

7.1.4 Inferential Statistics

In order to infer a correlation between the measured values of this study, a statistical examination of the total number of Coho salmon against all of the water quality parameters was done. The water quality measurements include dissolved oxygen, % saturation, water temperature, total dissolved solids, pH, and conductivity.

A four-in-one residual plot of the raw data shows the total number of Coho (Appendix E) does not meet the parametric assumptions of a Pearson product-moment coefficient of correlation (Figure 12). These assumptions are linearity, normality, and homoscedascity (Cruise Scientific (2010). As shown in Figure 12 the normal probability plot (upper left) exhibits a lone point on the right, the histogram (bottom left) shows a distinctively skewed tail towards the right, the residuals versus fitted values (top right) indicates a fanned shape with a lone point to the upper right; all of which are the result of 1,802 Coho caught on May 19, 2010 (Appendix E) effectively acting as an outlier. The residuals versus order (bottom right) shows there is some dependence (i.e., adjacent points below the line); it too is influenced by the May 19 Coho data acting as an outlier.

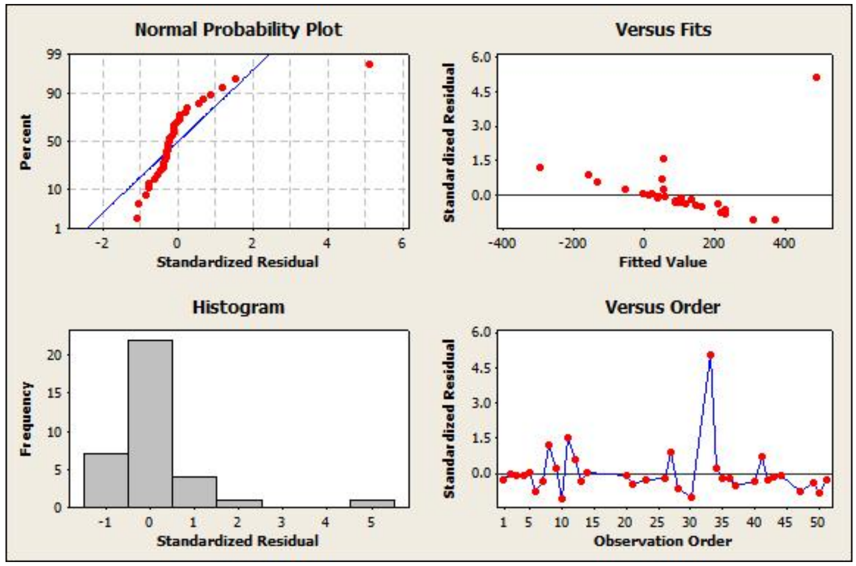


Figure 12. Residual plots for Total Coho numbers caught in Brooklyn Creek smolt fence.

Because the assumptions for the Pearson parametric test were not met, the closest equivalent non-parametric test was used: the Spearman ρ rank correlation coefficient (Statsoft 2010). Spearman ρ is used to “estimate strength and direction of association between two ordinal level variables” (AcaStat 2007). Spearman ρ is considered equivalent to Pearson in terms of accounting for proportion of variability (Statsoft 2010). The Spearman ρ rank correlation coefficient assumes a value between -1 and +1. If one variable increases while the other decreases the correlation coefficient is negative, and if they both increase/decrease together the coefficient is positive.

Spearman ρ requires that the data be organized in rank order (ordinal scale). According to Statsoft (2010) “the ordinal scale of measurement represents the ranks of a variable's values. Values measured on an ordinal scale contain information about their relationship to other values only in terms of whether they are ‘greater than’ or ‘less than’ other values but not in terms of ‘how much greater’ or ‘how much smaller’ Statsoft (2010).”

The hypotheses tested in the Spearman ρ are between any two variables. For example, when testing for a correlation between total Coho number and water temperature (°C) the following hypothesis was tested:

$$H_o: \rho = 0$$

$$H_A: \rho \neq 0$$

The calculation used in Spearman ρ, because there were no tied ranks, is:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}.$$

The results of the Spearman ρ test where all of the other variables were tested against total Coho number showed the greatest positive correlation with water temperature (ρ = 0.269) (Table 10).

Table 10: Results of Spearman ρ statistical test of ranked Total Coho Number (n = 51) against temperature and water quality parameters (α = 0.05-0.10).

	Stage (m)	TDS (ppm)	pH	Cond. (µS)	% Sat.	DO (mg/L)	Water T. (°C)
Total. Coho	0.004	0.022	-0.037	0.025	-0.097	-0.097	0.269

In order to assess the significance of this correlation the calculated value of ρ = 0.269 and degrees of freedom (df = n - 2) of 49 are compared to a Spearman ρ Table of critical values for α = 0.10 – 0.05 with a critical value of 0.238 (Appendix G). The correlation between total Coho number and water temperature is also supported in Figure 8.

8.0 Discussion

The primary objective of constructing and maintaining a smolt fence within Brooklyn Creek for the defined period of April 17 to June 6, 2010 was completed successfully. There were a number of concerns going into the project including vandalism, consistency in the quality of volunteer assistance, ensuring a complete data set, and water overflowing the fence. Fortunately, the fence was left untouched by vandals, volunteer assistance was of the highest quality, and the data set was complete except for the days when the project team was not on-site to collect water quality data. On two occasions following periods of high precipitation, water was able to pass around one of the upstream corners; this problem was quickly remediated with additional sandbags. In general, the results of the project include the most comprehensive data acquisition effort to date in Brooklyn Creek. The following sections outline our project findings including a species inventory of the creek, the age structure of Coho salmon particular to Brooklyn, salmon migration, predictions and retrodictions of spawners, and water quality data.

8.1 Species Inventory of Brooklyn Creek

The presence of Coho Salmon, Cutthroat Trout, Three-Spined Sticklebacks, Sculpins, and Crayfish within Brooklyn Creek were observed during this study. Chum Salmon, Pink Salmon, Chinook Salmon, Rainbow Trout, and Lampreys are found in other freshwater bodies in the Comox Valley; although initially their presence in Brooklyn was considered a possibility they were not observed. 3,680 Coho smolts migrated out of Brooklyn Creek in the spring of 2010 (Table 4). Eight smolt mortalities were observed during the sampling period, these deaths may have been the result of many factors including high flows, natural predation, or natural causes. This is a substantially higher quantity than estimates from previous years. In the spring of 2008 and 2009 an estimated 473 and 870 Coho smolts migrated from Brooklyn Creek respectively (Table 1; Wong, R. 2009). This could be attributed to the significant restoration efforts that have been ongoing since 2007. Another potential reason observed smolt abundance estimates are higher than calculations from previous years, is because the previous estimate techniques are not as reliable as a smolt fence counts.

8.2 Coho Age Structure Specific to Brooklyn Creek

According to daily species identification and weekly weight and length data, we found there may be a number of separate age classes of Coho fry and smolts migrating from Brooklyn Creek. We observed a number of Coho with identifiable characteristics and lengths that made it difficult to definitively categorize them as smolts or fry; this is especially true for the period following the peak of out-migrants on May 21. For example, we observed Coho that fit the identifiable feature category for smolts (Section 6.3.2.3.2) but had the length of a fry (Section 6.3.2.3.1). We began to label these fish "mini-smolts" and categorized them based on our best estimates for features and length. In general, newly emerged fry measure approximately 30 – 40.5 mm and year old smolts measure 40.5 – 156.5 mm (Fraser, F. et al. 1983). Therefore; it is unclear whether the mini-smolts and fry that were caught by the fence were migrating out of the creek, or simply moving within the creek.

Possible causes for the synchronous migration of morphologically distinct Coho include the time of emergence from egg/alevin to the fry stage, ability to compete for resources, quality of rearing grounds, and migration as nomads or in groups. Late emergence may translate to being out-competed for the most productive and desireable territories by the earlier, and now larger emergers. Upon emergence fry will demonstrate territorial tendencies by establishing and defending a particular area of the creek. The late emergers and/or less fit individuals will be forced to take up residence in less desireable/productive areas. The relegation to less desirable habitats can mean that the fry will continue to receive less nourishment and remain small compared to other fish of the same generation (Section 5.5.5). Nomads are fry that migrate in the spring due to factors such as size, level of aggressive behaviour, and food availability; if they are below the threshold size they do not tend to survive once they reach the ocean (Section 5.5.8). The herd-mentality of migrating in groups has the positive effect of predator-swamping but could also have the negative effect of drawing undeveloped fry along with the group out to sea (Section 8.3.1).

In an attempt to categorize these fish by age class we obtained sclerochronological data by taking scale samples along with length, weight, and species data on May 28 The samples were sent to the Sclerochronology Lab in Nanaimo, BC. At the time of writing we had not received the results of the analysis from the lab. Refer to Recommendations (Section 9.2) for future treatment of this information once it becomes available. In order to avoid miscategorization during statistical analysis we treated the fish by species rather than age class.

8.3 Migration

The timing of Coho migration occurred within the timeframe suggested by DFO, local filed biologists, and a literature review of the Coho lifecycle (Section 6.2). Monitoring efforts began on April 17 while Coho smolt and fry numbered less the 15 per day for the first 11 days. It was anticipated that an increase in precipitation, and the consequential increased flow, would result in larger migration numbers. The first spike in numbers of out-migrating smolts occurred after a night of heavy rainfall on April 27 where 10.0 mm of precipitation was recorded. Total Coho numbers were statistically tested against precipitation and no correlation was found. It should be noted that although no correlation between Coho migration and precipitation was found in this study, the largest outmigration occurred after a rainfall where 6.0 mm of precipitation was recorded.

On May 19 the peak of Coho numbers occurred after 10 days of water temperatures reaching levels over 10°C. This is consistent with the premise that migration often follows periods of rapid temperature warming (Shapovalov, L. & Taft, A. 1954). This is further supported by our statistical calculations where we have been able to conclude that because $\rho_{calc} > \rho_{crit}$ (df = 49; α = 0.10 – 0.05) we reject Ho that there is no correlation between total Coho number and water temperature (Section 7.1.4). Therefore, in the spring of 2010 in Brooklyn Creek there was a positive correlation between water temperature and the migration of total Coho Salmon. There was no other significant correlation between the total number of migrating Coho and any other water quality parameter (Table 10).

The Coho migration began to slow around June 3, suggesting that Brooklyn Creek's migration timing is similar to other documented creeks including Minter Creek in Washington and the Big Qualicum River on Vancouver Island (Section 6.2). June 6 was the final day of counting by the Camosun monitoring team.

8.3.1 Migration in Groups

The two peak migrations occurred over short periods of time (one day) and in relatively large numbers (Figure 8). Dave Davies commented that the increase in migration numbers has a positive correlation to survival from predators. This is called predator swamping and has been documented by Trites, A. (2002) who states that schooling behavior confuses the predators and makes it difficult for an individual smolt to be pursued.

8.3.2 Past/Future Spawners

Based on the number of Coho smolts observed in the 2010 study, assuming the smolts were age 1+, retrodictions of the number of previous spawners were made. Using two different methods we found that in 2008 there were either 90 or 43 successful female spawners, but it is possible that the actual number lies somewhere in between (Table 7). In addition, based on survival estimates (Section 7.1.2.2) we were able to predict that 129 female Coho would return to spawn in 2011.

8.4 Water Quality

Water quality measurements were collected just downstream of the fence site and were used to help characterize Brooklyn Creek in this reach for the sampling period. There are certain water quality requirements for the survival and prosperity of salmon that our measurements can be compared to in order to assess the general ability of Brooklyn to support fish. Of the measured parameters, special consideration is given to DO, water temperature, and pH as they are considered to have the greatest affect on salmon health. The volume of water flow is also given consideration.

The mean DO concentration was 10.56 mg/L with a standard deviation of 0.08 and median of 10.7 mg/L. The maximum and minimum DO were 11.4 mg/L and 9.6 mg/L, respectively (Table 9); while the minimum DO concentration for a salmon bearing creek is 5.0 mg/L. The mean water temperature was 10.2°C with a standard deviation of 1.6 and median of 10.1°C. The maximum and minimum water temperatures were 13.6° and 7.6°C, respectively (Table 9); while the upper lethal temperature for juvenile Coho is 25°C. The pH within the creek had a mean of 7.05 with a standard deviation of 0.18 and a median of 7.07. The maximum and minimum pHs were 7.46 and 6.78, respectively (Table 9). The natural pH range for most freshwater systems is 6 - 9. When the pH falls below 6 many harmful effects on aquatic ecosystems may result. Fish die-off begins to occur at a pH below 6 and is essentially inhospitable to any fish life below 4.5.

Considering that all of the above water quality parameters are above their minimum threshold values for salmon health we can conclude that Brooklyn Creek contains healthy conditions for supporting salmonid health and productivity.

The volume of water flowing in the creek is another important consideration for salmonid health. Shown in Section 5.4.1 intermittent water flow is a limiting factor for salmon production within Brooklyn Creek. It became evident by falling water levels observed during the sampling period how quickly this creek might dry without precipitation. Consistently high rainfall during the sampling period allowed water to continuously flow through the subject reach without obstructing the ability of fish to migrate out of the creek.

9.0 Recommendations

The following recommendations are intended to help improve the methods of future fence installation and monitoring efforts, and to suggest possible directions for future management initiatives.

9.1 Fence Installation/Design

On two occasions during the highest flows experienced during the sampling period, water and assumedly fish were able to pass around the upstream end of the fence on the left bank. Debris accumulation on the fence causing increased head was partially responsible for this situation, as was a lack of sandbags at the breach. In order to avoid this situation from occurring in the future, we recommend that enough sandbags be installed and keyed into the bank on both upstream ends of the fence to achieve the same height as the fence.

The period of lowest flow experienced during the sampling period caused concern for continued fish passage into the box. It became evident that one point along the length of the pipe may have been higher than the water surface. In order to correct this situation before the water levels dropped further it was necessary to excavate a small amount of sediment out from under the path of the pipe so that it sat lower than the water surface. We recommend that the depth of the pipe be considered during installation. We did however ensure the depth of the box was sufficient that it remain wetted even at the lowest flows.

9.2 Fence Monitoring/Data acquisition

In order to maintain consistency in data acquisition we recommend sampling at the same time in the morning every day. Reasons for this include less time in the box for fish leading to potential harm reduction, and consistent water quality levels for comparison over time. Samples taken later in the day were subject to heating that may affect levels of air temperature, water temperature, DO, and % saturation.

The DO, % Saturation, TDS, Conductivity, and pH water quality parameters were only measured on days where the Camosun monitors were responsible for sampling because of equipment access issues. In future monitoring efforts, it is recommended that the monitoring team have access to and measure all of the parameters of interest daily. Data continuity makes for more robust statistical inference.

During lower flows, or when the box was full, many fish would reside in the pipe rather than the box, making removal difficult. We would entice the fish in the pipe to move towards the box by tapping along the length of the pipe; however, once in the box there was nothing to stop them from moving back up the pipe. We attempted to obstruct their travel out of the box by placing a net over the pipe outlet. This functioned to allow water to continuing flowing in and keep the fish from swimming out; however, the net was not ideally suited to this task as it was not the same shape as the outlet. We recommend that a small net be constructed to fit snugly over the pipe outlet, perhaps with a loop of elastic cord that would ensure fish could not leave the box during sampling.

As mentioned above in Section 7.1.2, we observed a number of Coho with identifying characteristics and lengths that made it difficult to definitively categorize them as smolts or fry, especially in the period following the peak of out-migrants on May 21. In an attempt to categorize these fish by age class we obtained sclerochronological data by taking scale samples along with length, weight, and species data on May 28. The samples were sent to the Sclerochronology Lab in Nanaimo, BC. At the time of writing we had not received the results of the analysis from the lab. As a result, the age classes based on size and morphology remain somewhat as a mystery. To avoid categorizing these fish incorrectly we treated the fish by species rather than age class during statistical analysis. We recommend that when the lab results become available they be used to compare or add to similar sampling efforts during a future fence monitoring study. It is useful to conclude age classes based on physical characteristics in order to increase the accuracy of annual abundance estimates, survival and return predictions, and back-calculated number of spawners.

9.3 Future Management

Based on the results of the species inventory and amount of salmonids caught within Brooklyn Creek we recommend that the creek be continually managed as being a productive fish bearing stream and the following projects be implemented to educate local people, and restore and enhance fish habitat;

- Re-install the smolt fence in the spring of 2011. To provide a second baseline data set for the species and population numbers within Brooklyn. This will allow restoration projects to be quantified.
- Present the results from the spring 2010 smolt fence to the local residents within the Brooklyn watershed. This education will help with community involvement, funding and the overall awareness of Brooklyn Creek as a salmon bearing stream.
- Continue with fall fry and spawner assessment to be able to predict returns, survival rates and quantify restoration projects.
- Install a low flow monitoring system during the summer and fall. To quantify flow limitations for fish migration within Brooklyn Creek.

10.0 Conclusion

The primary objective of installing and monitoring the Brooklyn Creek smolt fence from April 17 to June 6 was realized and will provide the most accurate baseline data set of fish species and abundance in Brooklyn Creek to date. Through daily data collection, it was determined that 3680 Coho smolts (*Oncorhynchus kisutch)* migrated out of the creek. Other specimens collected included 620 Coho fry, 17 Cutthroat Trout (*Oncorhynchus clarki*), 59 Sculpin (*Cottus spp*.), 13 Stickleback (*Gasterostreus aculeatus*), and 6 Crayfish (*Pacificastacus leniusculus*). The most significant day for out-migrating salmon was May 19, when 1781 Coho smolts and 179 Coho fry were caught, which was significantly higher than the median daily out-migrating smolts and fry which were 13 and 2, respectively. This extreme spike in Coho smolts followed a 10 day period where water temperatures were consistently over 10°C, and was also the day after relatively high precipitation (6.0 mm).

Based on the number of Coho smolts migrating out of Brooklyn Creek in 2010, we were able to make predictions about past and future spawning Coho numbers. Using two different techniques, retrodictions on spawning salmon in 2008 were carried out. The first method used the egg to smolt survival rate of 1.5% to calculate that there were approximately 245,334 eggs in 2008. Since, on average, a female Coho salmon produces 2,699 eggs, it was estimated that there were 91 spawning salmon in Brooklyn Creek in 2008. The second method was based on the approximation that 85 smolts per female spawner are produced, therefore, in 2008 there were 43 spawning salmon. The actual count is assumed to be somewhere in this range. To predict how many spawning salmon will return, an average return rate for wild Coho salmon of 3.5% was used. Using this percentage, it was calculated that 129 adult Coho salmon will return in 2011, presumably half of these will be female spawners.

A comprehensive water quality data set was also collected during the period of April 17 to June 6. This includes 51 consecutive days worth of data for stage, air, and water temperature and 35 days for total dissolved solids (TDS), pH, conductivity, and dissolved oxygen (DO). Statistical analyses were carried out to determine if there was a correlation between the individual daily water quality parameters and out-migrating Coho salmon. A Spearman ρ rank correlation coefficient test was completed, and it proved there is a positive correlation between water temperature and out-migrating Coho salmon. There was no other significant correlation between the total number of migrating Coho and any other water quality parameter.

We hope that the results of this study may be used to help direct and support future stewardship initiatives and continue to improve the health and productivity of salmonids in Brooklyn Creek. As the Comox Valley continues to be developed it is imperative that a holistic management strategy be implemented that includes considerations for ecosystem integrity within an increasingly urbanized setting. The acquisition of baseline data is a first step towards understanding how this creek fits into the mosaic of regional salmon production.

11.0 Works Cited

AcaStat. (2007). Spearman Rho Coefficient. Applied Statistics Handbook. Retrieved on June 17, 2010 from <http://www.acastat.com/Statbook/spearman.htm>.

Armstrong, R. & Argue, A. (1977). Trapping and coded-wire tagging of wild coho and Chinook juveniles from the Cowichan River system, 1975. Fisheries and Marine Service. Canada Pacific Region Technical Report Service. PAC/T-77-14. pp 58.

Aro, K. & Shepard, M. (1967). Salmon of the North Pacific Ocean. Pacific Salmon in Canada. International North Pacific Fisheries Commission Bulletin. No. 23. pp 225-327.

Bainbridge, G. & Kuta, C. (2000). Brooklyn Creek Mapping and Inventory Project: Sensitive Habitat Inventory and Mapping (SHIM) Survey. Unpublished. Comox Valley, BC.

Bradford, M. (1995). Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 52(6): pp 1327–1338.

Bradford, M., Myers, R., & Irvine, J. (2000). Reference points for coho salmon (*Oncorhynchus kisutch*) harvest rates and escapement goals based on freshwater production. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 57: pp. 677–686.

Brooker, M.P. 1985. The Ecological Effects of Channelization (The Impact of River Channelization)."*The Geographical Journal.* The Royal Geographical Society (with the Institute of British Geographers). 151, 1, pp 63-69.

Chapman, D. (1962). Aggressive behaviour in juvenile coho salomn as a cause of emigration. Journal of Fisheries Resource Board of Canada. Vol. 19. pp 1047-1080.

Chilibeck, B. (2005). Brooklyn Creek Intake and Fish Screen Design Memo. Unpublished. Northwest Hydraulic Consultants. North Vancouver, BC.

Cousens, B. & Lee, C. (1999). Preliminary Fisheries Resource, Habitat and Development Impact Assessment of Brooklyn Creek in Comox-Courtenay, BC. Unpublished. J.C. Lee and Associates Ltd. Biological Consultants, Nanaimo BC. Pp 6 -8

Crone, R. & Bond, C. (1976). Life history of coho salmon *Oncorhynchus kisutch*, in Sashin Creek, sotheastern Alaska. U.S. Fisheries Bulletin. Vol. 74. pp 897-923.

Cruise Scientific. (2010). Correlation: Assumptions and Limitations. Visual Statistics with Multimedia. Retrieved on June 17, 2010 from <http://www.visualstatistics.net/Visual%20Statistics%20Multimedia/correlation_assumtions.htm>.

Drucker, B. (1972). Some life history characteristics of coho salmon of Karluk River system, Kodiak Island, Alaska. U.S. Fisheries Bulletin. No. 70. pp 79-94.

Environment Canada. (2010) National Climate Data and Information Archive. Retrieved June 15, 2010 from <http://www.climate.weatheroffice.gc.ca>

Fraser, F., Perry, E., & Lightly, D. (1983). Big Qualicum River salmon development project. Volume 1: a biological assessment 1959-1972. *Canadian Technical Report* of Fisheries and Aquatic Sciences. No. 1189. pp 198.

Hartman, G., Anderson, B., & Scrivener, J. (1982). Seaward movement of coho salmon (*Oncorhynchus kisutch*) fry in Carnation Creek, an unstable coastal stream in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 39. pp 588-597.

Lawson, P., Logerwell, E., Mantua, N., Francis, R., & Agostini, V. (2004). Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. Vol. 61: pp. 360–373.

Lenntech. (2009). Effects of Changes in pH on Freshwater Ecosystems. Acids & Alkalis in Freshwater. Online. Retrieved from <http://www.lenntech.com/aquatic/acids-alkalis.htm>.

Lirette, M., Hooton, R., & Olmstead, W. (1985). A summary of wild steelhead smolt enumeration and habitat productivity studies at Quinsam River, 1976-1984. Ministry of Environment. Fisheries Branch. Nanaimo, BC. pp 12-13.

Logan, S. (1967). Silver salmon studies in the Resurrection Bay area. Program Report Alaska Department of Fish and Game. Sport Fish Division. Vol. 8. (1966-1967). pp 83-102.

Major, P.F. 1978. Predator- prey interactions in two schooling fishes (Caranx ignobilis) and (Stolephorus purpureus). Anim. Bhav. 26, pp 760-777.

Mason, J. & Chapman, D. (1965). Significance of early emergence, environmental rearing capacity and behavioural ecology of juvenile coho salmon in stream channels. Journal of Fisheries Restoration Board of Canada. Vol. 22. pp 173-190.

Mason, J. (1974). Aspects of the ecology of juvenile coho salmon (*Oncorhynchus kisutch*) in Great Central Lake, B.C. Fisheries Resource Board of Canada. Technical Report. Vol. 438. pp 7.

McCormick, S., Hansen, L., Quinn, T., & Saunders, R. (1998). Movement, migration, and smolting of Atlantic salmon (Salmo salar). Canadian Journal of Fisheries and Aquatic Sciences. Vol. 55. Supplemental 1. pp 77–92.

McHenry, E. (1981). Coho salmon studies in the Resurrection Bay area. Annual Progress Report of Alaska Department of Fish and Game Federal Aid Fish Restoration. Vol. 81. pp 1-52.

McKee, J. & Wolf, J. (1963). Water Quality Criteria. 2nd Edition. State Water Quality Control Board. Sacramento, CA. Pub. No. 3-A.

McMahon, T. (1983). Habitat suitability index models: Coho salmon. U.S. Department of the Interior. Fish and Wildlife Service. FWS/OBS-82/10.49. pp 29.

McPhail, J. & Lindsey, C. (1970). Freshwater fishes of northwestern Canada and Alaska. Bulletin of the Fisheries Resource Board of Canada. No. 173. pp 381.

Milne, D. (1964). The chinook and coho salmon fisheries of British Columbia. Bulletin of the Fisheries Resource Board of Canada. No. 142. pp 46.

Minitab 15 Statistical Software. (2007). [Computer software]. State College, PA: Minitab, Inc. <www.minitab.com>.

Neave, F. (1948). Fecundity and mortality in Pacific salmon. Proceedings and transactions of the Royal Society of Canada. Ser. 3. 42(5). pp 99-105.

------------ (1949). Game fish populations of the Cowicahn River. Bulletin of the Fisheries Resource Board of Canada. No. 84. pp *1-32.*

Petersen, J.H. & DeAngelis, D.L. 2000. Dynamics of prey moving through a predator field: a model of migrating juvenile salmon. Mathematical Biosciences. Volume 165, Issue 2, pp 97-114.

Phillips, R., Lantz, R., Claire, E. & Moring, J. (1975). Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society. No. 104. pp 461-466.

Pollard, W., Hartman, G., Groot, C., & Edgell, P. (2006). Field Identification of Coastal Juvenile Salmonids. Harbour Publishing. Madeira Park, BC. Identification Chart: Five species of juvenile Pacific Salmon. pp 8. Detailed Species Information. Coho Salmon. pp 24-25.

Reiser, D. & Bjorn,T. (1979). Influence of forest and rangeland management on anadramous fish habitat in the Western United states and Canada. Habitat Requirements of anadramous salmonids. U.S. Forest Service General Technical Report. PNW-96. pp 54.

Resources Information Standards Committee. (1997). Fish Collection Methods and Standards. 6.1 Length. Fork Length. Retrieved June 16 2010 from <http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/fishcol/assets/table-4.gif>.

Robertson – Bryan, Inc. (2004). pH Requirements of Freshwater Aquatic Life. Technical Memorandum. Direct Effect of pH on Aquatic Life. pp. 3. Online. Retrieved from <http://www.swrbc.ca.gov/rwqcb5/water_issues/basin_plans/ph_turbidity/ph_turbidity_04phreq.pdf>.

Rounsefell, G. & Kelez, G. (1940). The salmon and salmon fisheries of Swiftsure Bank, Puget Sound and the Fraser River. Bulletin of the Bureau of Fisheries. US Department of Fisheries. Vol. 48. Pp. 693-462.

Salo, E. & Bayliff, W. (1958). Artificial and natural production of silver salmon (*Oncorhynchus kisutch*) at Minter Creek, Washington. Resource Bulletin. Washington Department of Fisheries. Vol. 4. pp 76.

Sandercock, F. (1991a). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Spawning populations. Life History. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 400.

------------------- (1991b). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Spawning Migration. Seasonal Timing. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 402-403 & 405.

------------------- (1991c). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Fecundity. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 408.

------------------- (1991d). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Incubation, Survival, and Emergence. Incubation and Hatching; Survival during incubation. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 414.

------------------- (1991e). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Freshwater Residence. Fry Behaviour in Streams. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 408.

------------------- (1991f). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Smolt migration. Seasonal Timing. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 422.

------------------- (1991g). Life History of Coho Salmon (*Oncorhynchus kisutch*). Pacific Salmon Life Histories. Fry and Fingerling Survival. Groot, C. & Marcolis, L. (Editor). UBC Press. University of British Columbia. Vancouver, BC. pp 420.

Shapovalov, L. & Taft, A. (1954). The life histories of the steelhead rainbow trout (*Salmo gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game's Fish Bulletin. No. 98. pp 375.

Shumway, D., Warren, C., & Doudoroff, P. (1964). Influence of Oxygen Concentration and Water Movement on the Growth of Steelhead Trout and Coho Salmon Embryos. Transactions of the American Fisheries Society. Vol. 93. Issue 4. pp 342-356.

Statsoft. (2010). Non-parametric Statistics. Nonparametric correlations. Retrieved on June 17, 2010 from <http://www.statsoft.com/textbook/nonparametric-statistics>.

Storm Water Center. The Impervious Cover Model. (Retrieved June 13, 2010) <http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm>

Tagart, J. (1984). Coho salmon survival from egg deposition to fry emergence. Walton, J. & Houston, D. (Editors). Proceedings of the Olympic Wild Fish Conference, March 23-25 1983. Fisheries Technology Program, Peninsula College. Port Angeles, Wash. pp 173-181.

Trites, A. W. ND. Predator-Prey Relationships. University of British Columbia, Vancouver, Canada. W.F. Perrin, B. Wursig and H.G.M. Thewissen (eds), *Encyclopedia of Marine Mammals*. Academic Press, San Diego. pp. 994-997.

Weisbart, M. (1968). Osmotic and ionic regulation in embryos, alevins and fry of the five species of Pacific Salmon. Canadian Journal of Zoology. Vol. 46. pp 385-397.

Wong, R. (2009). Brooklyn Creek Channel Enhancement Compendium Report. Submitted to Department of Fisheries and Oceans & The Brooklyn Creek Watershed Society. Unpublished. pp. 2.

Appendix A

FISS Report

Gazetted Name :	BROOKLYN CREEK
Watershed Code :	920-558600
Waterbody Identifier :	00000COMX
Region :	1
Alias :	
Type :	**S**
Report created on :	Sun Jun 13 10:04:19 PDT 2010

Water Quality Stations

No records found

Water Survey Stations

No records found

Management Objectives

Habitat Type	Objective 1	Objective 2
Anadromous River		

Enhancement

Activity	Start Year	Finish Year	Species Name	Comments	Reference Number	Geo Ref 1	Geo Ref 2

143 Fishway	9999		Coho Salmon		14-8	P 092F10 9	
151 Stocking/Colonization	1989		Coho Salmon	(COLONIZED WITH 50 ADULTS FROM PUNTLEDGE HATCHERY REF# = 14-8)	14-8	U 092F10 8	D 092F10 9
120 Habitat Enhancement (unspecified)	1983	1983		(SOME MINOR WORK HAS BEEN UNDERTAKEN ON THIS STREAM, HOWEVER HABITAT DEGRADATION IS ADVERSELY AFFECTING SALMON PRODUCTION REF# = 14-2)	14-2	W 308184	
122 Rearing Habitat Enhancement	1998	1998		100 shrubs were planted on south edge of creek to exclude cattle.	DFO243	W 308184	

Harvests and Uses

No records found

Resource Use

No records found

Resource Values

No records found

Resource Sensitivities

No records found

Land Use

No records found

Fisheries Potentials and Constraints

Activity	Impact	Degree of Impact	Comments	Species Name	Reference Number	Geo Ref 1	Geo Ref 2
611 Summer low flows	Describing constraint for increasing fisheries production	Not Specified		Coho Salmon	14-2	U 092F10 10	D 092F10 11
630 Flow fluctuations	Describing constraint for increasing fisheries production	Not Specified		Coho Salmon	14-2	U 092F10 10	D 092F10 11
741 Erosion/sedimentation	Describing constraint for increasing fisheries production	Not Specified			14-2	U 092F10 10	D 092F10 11

Obstructions

Description	Height	Length	Comments	Species Name	Reference Number	Geo Ref 1	Geo Ref 2
Culvert	0	0	(REMOVAL RECOMMENDED IN 1983 REF# = 14-2)		14-2	W 308184	

Escapements

Species Name	Stock	Ten Year Start / End	Ten Year Mean / Max	Max Esc Year	Max. Escapements	Target esc.	Reference Number	Geo Ref 1	Geo Ref 2
Chum Salmon		1990 / 1999	175 / 200	200	200		DFO_ESC	W 308184	
Chum Salmon		1998 / 1999	175 / 200	200	200		NUSEDS-SUM	W 308184	
Coho Salmon		1989 / 1999	65 / 150	150	150		NUSEDS-SUM	W 308184	
Coho Salmon		1990 / 1999	65 / 150	150	150		DFO_ESC	W 308184	
Pink Salmon		1990 / 1999	100 / 100	100	100		DFO_ESC	W 308184	
Pink Salmon		1996 / 1996	100 / 100	100	100		NUSEDS-SUM	W 308184	

Fish Distributions

Species Name	Stock / Stock Type	Stock Char	Management Class	Activity	Comments	Refs And Dates	Geo Ref 1	Geo Ref 2
Coho Salmon	/ NOT SPECIF	Anadromous	Not Specified	OBL Fish observed at this point or zone		(14-2, 01-JAN-1985)	W 308184	
Coho Salmon	/ NOT SPECIF	Anadromous	Not Specified	SPL Spawning location	(SPAWNING TO 2.5 KM. REF#=14-2)	(14-2, 01-JAN-1985)	U 092F108	

Species and Life Phase History

No records found

Appendix B

Dear Brooklyn Creek Watershed Resident,

We, Camosun College Environmental Technology Students, partnering with the Brooklyn Creek Watershed Society and the Department of Fisheries and Oceans, are working on a study of the out-migration of juvenile salmon and cut-throat trout leaving Brooklyn Creek this spring. This study involves the installation of a smolt fence. Which after a preliminary survey of the Creek, it seems the ideal location for the proposed fence is on the downstream side of the small concrete bridge near your property. This site is ideal for a number of reasons;

- The fact that it is on private land minimizes the chance of vandalism to the fence;
- The shape of the Creek is ideal for fence installation;
- The road access allows easy assembly and removal of the fence.

The benefits of this study are that it will:

- Give an accurate count on the number, health, and type of fish migrating out of the Creek;
- Supply information on the productivity of the Creek.

What to expect

- **Weekend of April 16th – Installation of fence**
    - **This is one of two times when a vehicle will be brought down the driveway**
- **April 16th to around the first week of June - Fence monitoring**
    - **Volunteers from the Brooklyn Creek Watershed society or Students from Camosun College will walk down to maintain the fence (this will be done once per day in the morning and should take about half an hour)**
- **May 20-24th – Peak migration of juvenile fish**
    - **Volunteers or Students will walk down twice per day to maintain the fence, count, and identify the fish.**
- **First week of June – Removal of fence.**

We are seeking your permission to access the bridge near your residence for the duration of this study. Your approval to carry out this study would be greatly appreciated,

Sincerely,

Camosun College Environmental Technology Students
Brooklyn Creek Watershed Society
Department of Fisheries and Oceans
If you have any further questions, or are interested in getting involved with the fence monitoring and maintenance please feel free to call Dusty or Desiree at 250-508-4252 or 250-857-5558 email any of the following:
bassett_danielle@hotmail.com, dustyevsky@gmail.com, desiree_lyver@hotmail.com

Appendix C

Brooklyn Creek Volunteer Task Checklist

1) Retrieve the gear bin from the bush (there is a set of waders for a volunteer therein).
2) Record water level from stage to three decimal places.
3) Record air and water temperature using thermometer located inside grey clipboard.
4) Check for any breaches in the fence especially at the upstream corners or along the upstream edge of the submerged 2x6.
    a. Use the shovel stored with the gear box to plug the holes with gravel as necessary.
5) Clean debris away from mink guard at fence inlet.
    a. If the flows are high (e.g. >0.450 m on stage) clear way some debris from fence itself leaving approx. 3-4 inches so as to maintain head at lower flows. There are two brushes with the bin.
6) Open the fish box and remove surface debris, and water calming stones.
7) Tap the pipe from upstream towards downstream to coerce fish into the box.
8) Cover the pipe outlet with the small silver handled net to calm water flow and limit fish egress.
9) Fish with D-net and small guppy net. As an aside I have found it efficient to place the d-net in the downstream corner closest to the right bank. The fish will either swim right into it or you can fish the other corners using the guppy net and they will move into the D-net.
10) Identify fish species using the viewing box and literature from inside the grey clipboard as necessary. Limit the amount of time handling fish and make sure your hands are wet when doing so to limit stress on the fish.
11) Once you feel the box is fished out, tap down the pipe again and feel around the corners of the pipe inside the box for sheltered fish.
12) Replace the water calming stones into the box in a manner that creates areas of calm for the fish and won't have them crash into a rock if they are spit out of the pipe. Close and secure the lid with the latch.
13) Clear the mink guard of debris once again.
14) Replace all of the equipment in the gear box and stow back in bush.

Appendix D

Brooklyn Creek 2010
Smolt Fence Reporting Form

Project Coordinator: Dusty Silvester 508-4252
Date:________________mm/dd/yyyy **Time:**______________
Water Temp:______°C **Air Temp:**______°C **Water Level:** 0._____m
Weather:____
Observers:

Coho: FRY **Total Fry**_________	**Coho:** SMOLTS **Total Smolts** ___________

Chinook **Total**_____	**Pink** **Total**_______	**Chum** **Total**_______

Cutthroat **Total**_____	**Steelhead (RBW)** **Total**_____	**Sculpin** **Total**___	**Stickleback** **Total**____

Lamprey **(no eyes=ammocoetes; eyes = adult)** Note colour & length (cm)	**Water Quality** (Recorded by Camosun) **TDS (ppm)** _____ **Temp. (°C)**______ **pH** _____ **% Sat.** ______ **Cond (μS)** _____ **DO (mg/L)**______

Comments:

Appendix E. BROOKLYN CREEK SMOLT FENCE COUNTS 2010

Date/Time		Species					Water Quality Data										
Date	Time	Coho: Fry	Coho: smolt	Cutthroat	Sculpin	Stickle-back	Air temp (°C)	Water temp (°C)	Water level (m)	Precip-itation (mm)	TDS (ppm)	pH	Cond (uS)	% Sat.	DO (mg/L)	Comments	Weather
17-Apr	am	0	1	1	1	0	11.0	9.4	0.388	5.600	78.0	7.15	156.0	94.0	10.70		light showers
18-Apr	am	1	3	0	7	0	13.0	9.7	0.398	0.000	73.0	7.45	144.0	92.0	10.50		overcast
19-Apr	am	0	9	0	6	2	12.0	10.7	0.385	5.800	76.0	7.40	152.0	91.0	10.20		overcast
20-Apr	am	4	14	0	9	1	12.0	10.7	0.510	13.400	54.0	6.96	109.0	97.0	10.70		overcast
21-Apr	am	0	7	0	5	1	8.0	8.7	0.435	0.000	66.0	6.93	133.0	96.0	11.20		sun
22-Apr	am	0	1	0	0	1	7.5	8.7	0.405	0.000	71.0	6.89	140.0	94.0	11.00		sun
23-Apr	8:30	1	10	0	0	1	10.5	7.6	0.389	0.000	75.0	6.91	150.0	90.0	10.70		overcast
24-Apr	8:30	0	10	0	2	0	9.0	8.1	0.375	0.100	72.0	7.23	147.0	96.0	11.2		sunny/cloudy
25-Apr	9:15	2	4	0	2	0	10.0	8.6	0.370	0.100	75.0	6.96	152.0	98.0	11.4		overcast
26-Apr	8:24	1	7	0	1	1	9.0	8.8	0.372	6.800	76.0	6.78	150.0	94.0	11.0	1 crayfish	overcast
27-Apr	8:20	3	442	3	2	0	9.0	9.2	0.440	10.000	64.0	7.11	126.0	97.0	11.1	large rain night before & 2 mortalities	cloundy
28-Apr	8:00	3	20	0	1	0	7.0	9.0	0.380	0.200	69.0	7.09	140.0	95.0	11.0		sunny/cloudy
29-Apr	8:15	0	12	0	1	0	6.5	8.4	0.370	0.000	74.0	6.87	148.0	94.0	11.0		sun
30-Apr	8:00	0	28	0	1	1	9.0	8.4	0.370	1.000	77.0	6.91	156.0	94.0	11.1	weight/length day	overcast
1-May	9:15	2	13	1	0	0	12.0	9.5	0.368	0.100							overcast
2-May	9:00	1	9	0	0	0	9.8	9.5	0.363	6.600						Debris in mink guard obstructing fish from getting through	cloudy
3-May	8:30	1	178	1	1	0	8.0	9.0	0.426	1.600							overcast
4-May	8:50	0	83	0	3	1	7.0	8.0	0.385	0.000							sunny thin clouds
5-May	8:30	4	15	0	0	0	8.0	8.2	0.365	0.000							sunny/cloudy
6-May	8:30	5	5	0	0	0	6.5	8.2	0.355	0.000	73.0	6.90	146.0	95.0	11.1		sunny/cloudy
7-May	8:30	5	10	0	0	0	9.6	8.1	0.345	0.000	81.0	6.90	162.0	92.0	10.9		sunny/cloudy
8-May	9:00	20	0	0	0	0	9.2	9.1	0.354	0.000							sunny
9-May	9:00	0	17	1	0	0	9.1	8.9	0.340	0.000	78.0	6.94	156.0	95.0	11.0		sunny
10-May	8:30	0	38	0	0	0	11.0	10.5	0.342	0.000							overcast
11-May	8:30	0	5	0	0	0	10.5	10.0	0.340	0.000						1 crayfish	sunny
12-May	1:30	0	69	0	1	0	19.0	11.5	0.331	0.000	79.0	7.23	158.0	94.0	10.2	Dusty came at 1441 and caught 66 fish	sunnny
13-May	1:00	0	58	0	0	1	21.0	11.5	0.331	0.000	80.0	7.46	163.0	97.0	10.7	1 crayfish	sunny
14-May	8:00	2	65	0	1	0	11.0	10.2	0.330	0.000	85.0	6.91	172.0	90.0	10.1	1 little crayfish	sunny
15-May	8:30	1	24	0	0	0	11.0	11.5	0.328	0.000							clear and warm

Date/Time		Species					Water Quality Data										
Date	Time	Coho: Fry	Coho: smolt	Cutthroat	Sculpin	Stickleback	Air temp (°C)	Water temp (°C)	Water level (m)	Precipitation (mm)	TDS (ppm)	pH	Cond (uS)	% Sat.	DO (mg/L)	Comments	Weather
16-May	3:00	0	98	0	0	0	18.5	12.5	0.325	0.200	87.0	7.10	174.0	93.0	9.9		sunny/cloudy
17-May	8:30	1	35	0	1	0	13.0	13.5	0.320	0.100							slight rain
18-May	8:30	0	27	2	0	0	14.5	12.0	0.325	0.600							overcast
19-May	9:20	21	1,781	1	0	0	15.8	11.3	0.350	6.600	81.0	6.78	161.0	91.0	10.0	3 mortalities	overcast/ periods of rain
20-May	8:30	46	64	0	5	0	9.8	10.1	0.346	0.800	73.0	7.17	146.0	90.0	10.2	WQ data taken above fence (many fry were 5-6cm)	stormy/overcast
21-May	8:20	17	19	0	2	0	8.9	8.9	0.368	5.000	80.0	7.10	160.0	92.0	10.7	Had a few fry that were medium size counted them as smolt	rainning
22-May	8:30	21	0	0	1	0	10.9	8.6	0.354	0.200	78.0	6.97	156.0	94.0	11.0		overcast
23-May	8:30	8	2	0	1	0	13.8	10.0	0.331	0.100	81.0	7.07	162.0	92.0	10.3		overcast
24-May	9:00	2	2	0	0	0	12.0	11.0	0.325	3.000							overcast
25-May	8:30	169	164	1	0	0	11.0	11.5	0.423	14.200							overcast and rain
26-May	8:00	103	4	0	2	1	12.0	11.0	0.380	9.400	66.0	6.87	132.0	92.0	10.0		rainning
27-May	8:10	48	192	0	1	1	12.0	11.6	0.380	0.100	68.0	7.19	137.0	92.0	10.0	I crayfish/ 1 smolt mortality	overcast and rainning
28-May	8:00	10	6	0	1	0	13.0	12.3	0.345	4.800	74.0	7.30	149.0	90.0	9.6		overcast
29-May	9:00	46	16	0	0	0	13.0	12.5	0.390	4.400	64.0	7.13	128.0	97.0	10.3	1 smolt mortality	overcast/rain last night
30-May	9:00	25	1	0	1	1	14.0	11.5	0.365	1.400	72.0	7.06	146.0	96.0	10.5	I dead stickle back	overcast
31-May	8:45	16	34	1	0	0	14.0	12.0	0.485	16.400							
1-Jun	8:35	9	39	0	0	0	12.0	13.0	0.400	3.400							
2-Jun	8:30	9	28	3	0	0	13.0	12.3	0.475	7.200	55.0	6.78	111.0	96.0	10.3	I mortality/ Fence overflow	rainning
3-Jun	8:30	8	7	2	0	0	11.0	11.5	0.385	0.100						cloudy/sunny	
4-Jun	8:30	3	4	0	0	0	11.0	11.5	0.371	0.100	72.0	7.14	145.0	91.0	9.9	I crayfish	crayfish
5-Jun	17:00	1	0	0	0	0	15.0	13.6	0.360	0.000	75.0	7.15	151.0	96.0	10.0	Late afternoon monitoring	Sun
6-Jun	11:30	6	0	0	0	0	16.0	11.7	0.360	0.100	77.0	7.17	156.0	94.0	10.2		Cloudy
Season Totals		**625**	**3,680**	**17**	**59**	**13**											

Appendix F. Coho Length and Weight Data Collected Once a Week Over Seven Weeks April 23 - June 4

Species	Length (cm)	Weight (g)
Coho	5.3	1.8
Coho	5.4	1.9
Coho	5.5	1.2
Coho	5.6	2.2
Coho	5.8	2.4
Coho	5.8	2.4
Coho	5.9	2.0
Coho	6.0	2.4
Coho	6.1	2.7
Coho	6.1	2.3
Coho	6.2	2.3
Coho	6.2	2.9
Coho	6.3	2.9
Coho	6.4	3.3
Coho	6.4	3.1
Coho	6.5	3.0
Coho	6.5	3.2
Coho	6.6	2.6
Coho	6.6	5.0
Coho	6.7	2.5
Coho	6.7	3.3
Coho	6.7	3.7
Coho	6.7	3.3
Coho	6.8	3.7
Coho	6.8	3.8
Coho	6.8	4.4
Coho	6.8	3.8
Coho	6.8	3.6
Coho	7.0	4.9
Coho	7.1	4.6
Coho	7.2	4.8
Coho	7.3	4.6
Coho	7.3	4.7
Coho	7.4	4.2
Coho	8.6	6.9
Coho	8.8	7.6
Coho	9.0	6.0
Coho	9.0	8.2
Coho	9.0	8.3
Coho	9.2	8.5
Coho	9.3	8.4
Coho	9.4	9.3
Coho	9.6	9.0
Coho	9.6	9.5
Coho	9.7	10.5
Coho	9.8	9.9
Coho	10.0	10.6
Coho	10.1	11.0
Coho	10.1	11.7
Coho	10.1	11.2
Coho	10.2	9.1
Coho	10.3	9.7
Coho	10.4	10.9
Coho	10.4	11.1
Coho	10.5	12.0
Coho	10.5	12.3
Coho	10.5	11.9
Coho	10.5	12.3
Coho	10.6	13.7
Coho	10.6	15.2
Coho	10.6	11.5
Coho	10.6	11.5
Coho	10.7	13.1
Coho	10.8	12.8
Coho	10.8	12.6
Coho	11.0	16.0
Coho	11.0	15.1
Coho	11.0	14.8
Coho	11.0	14.4
Coho	11.0	13.9
Coho	11.0	14.3
Coho	11.0	12.9
Coho	11.1	13.6
Coho	11.1	14.8
Coho	11.2	14.0
Coho	11.3	16.9
Coho	11.3	15.1
Coho	11.3	15.3
Coho	11.3	13.2
Coho	11.3	15.2
Coho	11.4	13.7
Coho	11.4	12.4
Coho	11.4	15.3
Coho	11.4	14.1
Coho	11.4	14.2
Coho	11.5	14.5
Coho	11.5	16.4
Coho	11.5	14.5
Coho	11.6	21.3
Coho	11.6	16.6
Coho	11.6	15.1
Coho	11.8	16.4
Coho	11.8	17.8
Coho	11.8	11.8
Coho	11.9	15.1
Coho	11.9	16.1
Coho	12.0	16.8
Coho	12.0	17.5
Coho	12.0	17.5
Coho	12.1	18.5
Coho	12.1	16.6
Coho	12.2	18.0
Coho	12.2	16.1
Coho	12.2	16.6
Coho	12.3	18.9
Coho	12.3	21.2
Coho	12.4	20.5
Coho	12.4	18.5
Coho	12.4	17.8
Coho	12.4	17.2
Coho	12.4	18.0
Coho	12.5	18.7
Coho	12.6	20.6
Coho	12.7	20.9
Coho	12.7	22.7
Coho	12.8	22.4
Coho	12.8	20.3
Coho	12.9	21.5
Coho	13.1	21.8
Coho	13.3	21.2
Coho	13.4	25.2
Coho	13.5	26.2
Coho	13.8	26.9
Coho	13.8	21.0
Coho	13.8	20.7

Critical Values of the Spearman's Ranked Correlation Coefficient (r_s)

Taken from Zar, 1984 Table B.19

α(2):	0.50	0.20	0.10	0.05	0.02	0.01	0.005	0.002	0.001
α(1):	0.25	0.10	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
n									
4	0.600	1.000	1.000						
5	0.500	0.800	0.900	1.000	1.000				
6	0.371	0.657	0.829	0.886	0.943	1.000	1.000		
7	0.321	0.571	0.714	0.786	0.893	0.929	0.964	1.000	1.000
8	0.310	0.524	0.643	0.738	0.833	0.881	0.905	0.952	0.976
9	0.267	0.483	0.600	0.700	0.783	0.833	0.867	0.917	0.933
10	0.248	0.455	0.564	0.648	0.745	0.794	0.830	0.879	0.903
11	0.236	0.427	0.536	0.618	0.709	0.755	0.800	0.845	0.873
12	0.217	0.406	0.503	0.587	0.678	0.727	0.769	0.818	0.846
13	0.209	0.385	0.484	0.560	0.648	0.703	0.747	0.791	0.824
14	0.200	0.367	0.464	0.538	0.626	0.679	0.723	0.771	0.802
15	0.189	0.354	0.446	0.521	0.604	0.654	0.700	0.750	0.779
16	0.182	0.341	0.429	0.503	0.582	0.635	0.679	0.729	0.762
17	0.176	0.328	0.414	0.485	0.566	0.615	0.662	0.713	0.748
18	0.170	0.317	0.401	0.472	0.550	0.600	0.643	0.695	0.728
19	0.165	0.309	0.391	0.460	0.535	0.584	0.628	0.677	0.712
20	0.161	0.299	0.380	0.447	0.520	0.570	0.612	0.662	0.696
21	0.156	0.292	0.370	0.435	0.508	0.556	0.599	0.648	0.681
22	0.152	0.284	0.361	0.425	0.496	0.544	0.586	0.634	0.667
23	0.148	0.278	0.353	0.415	0.486	0.532	0.573	0.622	0.654
24	0.144	0.271	0.344	0.406	0.476	0.521	0.562	0.610	0.642
25	0.142	0.265	0.337	0.398	0.466	0.511	0.551	0.598	0.630
26	0.138	0.259	0.331	0.390	0.457	0.501	0.541	0.587	0.619
27	0.136	0.255	0.324	0.382	0.448	0.491	0.531	0.577	0.608
28	0.133	0.250	0.317	0.375	0.440	0.483	0.522	0.567	0.598
29	0.130	0.245	0.312	0.368	0.433	0.475	0.513	0.558	0.589
30	0.128	0.240	0.306	0.362	0.425	0.467	0.504	0.549	0.580
31	0.126	0.236	0.301	0.356	0.418	0.459	0.496	0.541	0.571
32	0.124	0.232	0.296	0.350	0.412	0.452	0.489	0.533	0.563
33	0.121	0.229	0.291	0.345	0.405	0.446	0.482	0.525	0.554
34	0.120	0.225	0.287	0.340	0.399	0.439	0.475	0.517	0.547
35	0.118	0.222	0.283	0.335	0.394	0.433	0.468	0.510	0.539
36	0.116	0.219	0.279	0.330	0.388	0.427	0.462	0.504	0.533
37	0.114	0.216	0.275	0.325	0.383	0.421	0.456	0.497	0.526
38	0.113	0.212	0.271	0.321	0.378	0.415	0.450	0.491	0.519
39	0.111	0.210	0.267	0.317	0.373	0.410	0.444	0.485	0.513
40	0.110	0.207	0.264	0.313	0.368	0.405	0.439	0.479	0.507
41	0.108	0.204	0.261	0.309	0.364	0.400	0.433	0.473	0.501
42	0.107	0.202	0.257	0.305	0.359	0.395	0.428	0.468	0.495
43	0.105	0.199	0.254	0.301	0.355	0.391	0.423	0.463	0.490
44	0.104	0.197	0.251	0.298	0.351	0.386	0.419	0.458	0.484
45	0.103	0.194	0.248	0.294	0.347	0.382	0.414	0.453	0.479
46	0.102	0.192	0.246	0.291	0.343	0.378	0.410	0.448	0.474
47	0.101	0.190	0.243	0.288	0.340	0.374	0.405	0.443	0.469
48	0.100	0.188	0.240	0.285	0.336	0.370	0.401	0.439	0.465
49	0.098	0.186	0.238	0.282	0.333	0.366	0.397	0.434	0.460
50	0.097	0.184	0.235	0.279	0.329	0.363	0.393	0.430	0.456

α(2):	0.50	0.20	0.10	0.05	0.02	0.01	0.005	0.002	0.001
α(1):	0.25	0.10	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
n									
51	0.096	0.182	0.233	0.276	0.326	0.359	0.390	0.426	0.451
52	0.095	0.180	0.231	0.274	0.323	0.356	0.386	0.422	0.447
53	0.095	0.179	0.228	0.271	0.320	0.352	0.382	0.418	0.443
54	0.094	0.177	0.226	0.268	0.317	0.349	0.379	0.414	0.439
55	0.093	0.175	0.224	0.266	0.314	0.346	0.375	0.411	0.435
56	0.092	0.174	0.222	0.264	0.311	0.343	0.372	0.407	0.432
57	0.091	0.172	0.220	0.261	0.308	0.340	0.369	0.404	0.428
58	0.090	0.171	0.218	0.259	0.306	0.337	0.366	0.400	0.424
59	0.089	0.169	0.216	0.257	0.303	0.334	0.363	0.397	0.421
60	0.089	0.168	0.214	0.255	0.300	0.331	0.360	0.394	0.418
61	0.088	0.166	0.213	0.252	0.298	0.329	0.357	0.391	0.414
62	0.087	0.165	0.211	0.250	0.296	0.326	0.354	0.388	0.411
63	0.086	0.163	0.209	0.248	0.293	0.323	0.351	0.385	0.408
64	0.086	0.162	0.207	0.246	0.291	0.321	0.348	0.382	0.405
65	0.085	0.161	0.206	0.244	0.289	0.318	0.346	0.379	0.402
66	0.084	0.160	0.204	0.243	0.287	0.316	0.343	0.376	0.399
67	0.084	0.158	0.203	0.241	0.284	0.314	0.341	0.373	0.396
68	0.083	0.157	0.201	0.239	0.282	0.311	0.338	0.370	0.393
69	0.082	0.156	0.200	0.237	0.280	0.309	0.336	0.368	0.390
70	0.082	0.155	0.198	0.235	0.278	0.307	0.333	0.365	0.388
71	0.081	0.154	0.197	0.234	0.276	0.305	0.331	0.363	0.385
72	0.081	0.153	0.195	0.232	0.274	0.303	0.329	0.360	0.382
73	0.080	0.152	0.194	0.230	0.272	0.301	0.327	0.358	0.380
74	0.080	0.151	0.193	0.229	0.271	0.299	0.324	0.355	0.377
75	0.079	0.150	0.191	0.227	0.269	0.297	0.322	0.353	0.375
76	0.078	0.149	0.190	0.226	0.267	0.295	0.320	0.351	0.372
77	0.078	0.148	0.189	0.224	0.265	0.293	0.318	0.349	0.370
78	0.077	0.147	0.188	0.223	0.264	0.291	0.316	0.346	0.368
79	0.077	0.146	0.186	0.221	0.262	0.289	0.314	0.344	0.365
80	0.076	0.145	0.185	0.220	0.260	0.287	0.312	0.342	0.363
81	0.076	0.144	0.184	0.219	0.259	0.285	0.310	0.340	0.361
82	0.075	0.143	0.183	0.217	0.257	0.284	0.308	0.338	0.359
83	0.075	0.142	0.182	0.216	0.255	0.282	0.306	0.336	0.357
84	0.074	0.141	0.181	0.215	0.254	0.280	0.305	0.334	0.355
85	0.074	0.140	0.180	0.213	0.252	0.279	0.303	0.332	0.353
86	0.074	0.139	0.179	0.212	0.251	0.277	0.301	0.330	0.351
87	0.073	0.139	0.177	0.211	0.250	0.276	0.299	0.328	0.349
88	0.073	0.138	0.176	0.210	0.248	0.274	0.298	0.327	0.347
89	0.072	0.137	0.175	0.209	0.247	0.272	0.296	0.325	0.345
90	0.072	0.136	0.174	0.207	0.245	0.271	0.294	0.323	0.343
91	0.072	0.135	0.173	0.206	0.244	0.269	0.293	0.321	0.341
92	0.071	0.135	0.173	0.205	0.243	0.268	0.291	0.319	0.339
93	0.071	0.134	0.172	0.204	0.241	0.267	0.290	0.318	0.338
94	0.070	0.133	0.171	0.203	0.240	0.265	0.288	0.316	0.336
95	0.070	0.133	0.170	0.202	0.239	0.264	0.287	0.314	0.334
96	0.070	0.132	0.169	0.201	0.238	0.262	0.285	0.313	0.332
97	0.069	0.131	0.168	0.200	0.236	0.261	0.284	0.311	0.331
98	0.069	0.130	0.167	0.199	0.235	0.260	0.282	0.310	0.329
99	0.068	0.130	0.166	0.198	0.234	0.258	0.281	0.308	0.327
100	0.068	0.129	0.165	0.197	0.233	0.257	0.279	0.307	0.326