DATA REPORT

Water Quality and Stream Invertebrate Assessment

for Departure Creek, Nanaimo, BC,

(Fall 2011)

Report prepared by:

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on Departure Creek, Nanaimo, BC, during October-November 2011.

This study was undertaken by 3rd year undergraduate students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU), offered as part of the Bachelor of Natural Resources Protection (Sarah Gordon, Alina Koch and Braeden Lattanzi). Students worked under the supervision of the course instructor, Dr. Eric Demers (Vancouver Island University). This report was compiled by Dr. Eric Demers based on a student group report.

VIU students contributed approximately 100 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 12 hours for project management and report compilation.

Logistical support was provided by Fisheries and Oceans Canada (DFO) and the Harbour City River Stewards. Funding for field expenses and analytical processing of water samples was provided by the Regional District of Nanaimo and Fisheries and Oceans Canada. ALS Laboratory (Burnaby, BC) provided reduced rates on its analytical services for this project.

2. Introduction

Departure Creek is located in the neighborhood of Departure Bay in Nanaimo, BC. It is approximately 3 km in length and it drains an urban watershed area of approximately 3 km² (City of Nanaimo, 1998).

Restoration and habitat enhancement have been conducted within the creek since 1995, especially within Woodstream and Centennial Parks (City of Nanaimo, 1998).

This report documents a water quality and stream invertebrate assessment conducted on Departure Creek, Nanaimo, BC, during October-November 2011.

Specific objectives for this study of Departure Creek included:

- establish 4 water quality sampling stations;
- obtain field measurements of water quality at the 4 sampling stations during two sampling events (31 October and 21 November 2011);
- obtain water samples from each sampling station during two sampling events (31 October and 21 November 2011) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 2 sampling stations during one sampling event (31 October 2011) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Departure Creek which is located in the neighbourhood of Departure Bay in Nanaimo, BC (Figure 1). The creek originates from two tributaries, Joseph Creek and Keighly Creek, and it discharges in the Strait of Georgia at Departure Bay. Water flows through an underground stormwater network in the upstream portion of watershed. The open portion of Departure Creek has an average gradient of 3%.

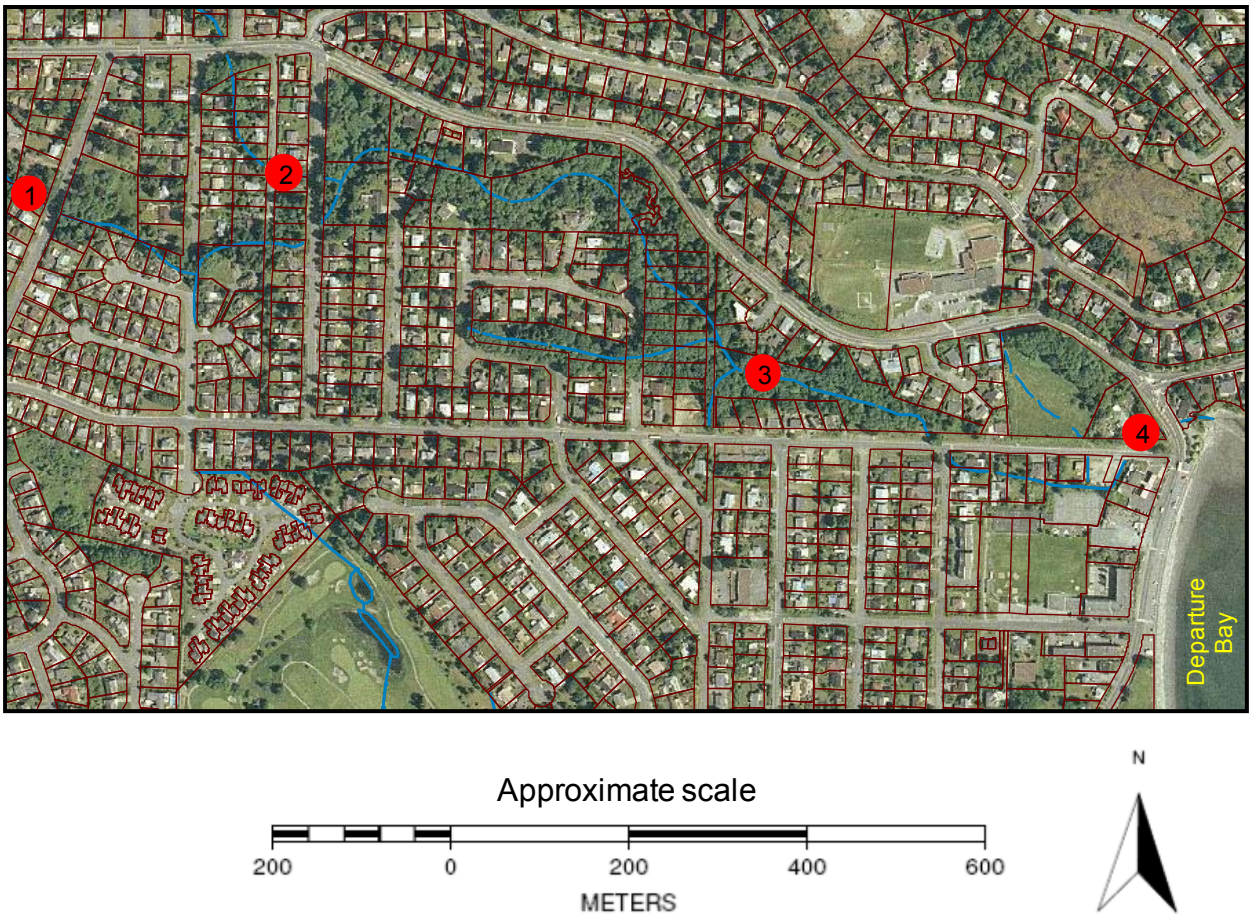

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Departure Creek, during October-November 2011. Departure Creek is outlined in blue. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map and aerial photo (taken in 2003) were obtained from the City of Nanaimo's CityMap. Map scale is approximated.

3.1.1. Sampling Stations

Four stations were established on Departure Creek, during October-November 2011 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of Departure Creek. The locations of stations 1 and 2 differed from a previous study conducted on Departure Creek during Fall 2010 (VIU, 2011) to minimize disturbance of spawning pink salmon. Stations were numbered from the upstream end to the downstream end of the creek. All stations were easily accessed via foot paths or road crossings. Station 1 was located immediately upstream of the Neyland Road crossing. Station 2 was located on Joseph Creek immediately upstream of the Newton Street crossing and approximately 50 m upstream from its confluence with Departure Creek. Station 3 was located within Woodstream Park. Station 4 was located immediately upstream of the Departure Bay Road crossing.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Departure Creek, during October-November 2011.

Station	Northing	Easting	Distance from Departure Bay (m)	General Location
1	5451108	428056	1,700	Immediately upstream of Neyland Rd
2	5451137	428356	1,300	Joseph Creek, immediately upstream of Newton St.
3	5450879	428971	600	In Woodstream Park
4	5450842	429334	70	Immediately upstream Departure Bay Rd

3.1.2. Sampling Schedule

Field sampling was conducted on 31 October and 21 November 2011. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the October event. Photographs showing site conditions and sampling activities are included in Appendix 1.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 31 October and 21 November 2011. At each sampling station, field measurements of water temperature (to the nearest 0.1^{o}C) and dissolved oxygen (to the nearest 0.1 mg/L) were obtained with an Oxyguard Handy Polaris electronic probe. The electronic probe was placed directly in the channel water.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Departure Creek, during October-November 2011. The symbols "A" or "B" indicate whether samples / measurements were taken during the October or November sampling events, respectively.

Station	Water Quality				Stream Invertebrates
	Field Measurements	VIU Analyses	ALS Lab Analyses	Microbiology	
1	A [1], B [1]	A, B	---	---	A
2	A, B	A, B	B	A	A
3	A [1], B [1]	A, B	A, B	A	---
4	A, B	A, B	---	---	---

Note: [1] Basic hydrological measurements were taken at stations 1 and 3 during both sampling events.

Basic hydrological measurements were taken at stations 1 and 3 during both sampling events. Water velocity (in m/s) was measured along a 5-m and 10-m stream length at station 1 and 3, respectively. A float was dropped slightly upstream of the stream length and allowed to float downstream through the stream length. A stopwatch was used to measure the travel time of the ball between the upstream and downstream ends of the stream length. The average travel time from 5 passes was used to calculate average water velocity.

Stream wetted widths were measured with a metered tape to the nearest 0.1 m, and wetted depths were measured (along the same wetted widths) with a meter stick to the nearest 0.01 m. Total cross-sectional areas (in m^2) were calculated as the sum of the areas of cross-section polygons. Stream discharge (in m^3/s) was obtained as the product of mean water column velocity and cross sectional area.

3.2.2. Water Sampling

During each sampling event, two sets of water samples were collected for laboratory analyses: one set was transported for analysis at Vancouver Island University (VIU), and another set was shipped for analysis by ALS Laboratory, in Burnaby, BC.

Water samples for analysis at VIU were collected from all stations (Table 2). At each station, a clean pre-labelled 500-ml plastic bottle was rinsed 3 times and then used to collect a water sample (Table 3). Samples were obtained while standing on the stream bank or within the stream channel by immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. All water samples were kept in a cooler and stored at approximately 4^oC. Laboratory analyses were conducted at VIU within 48 hours of sampling.

Samples for analysis by ALS Laboratory were collected at station 3 on 31 October 2011 and at stations 2 and 3 on 21 November 2011 (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank or within the stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 48 hours for laboratory analyses at ALS Laboratory.

Table 3. Sampling containers and preservatives used for water quality samples taken at Departure Creek during October-November 2011. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Burnaby, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total alkalinity, turbidity	500 ml plastic	None	VIU
Conductivity, pH, total hardness	1 L plastic	None	ALS Laboratory
Nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratory
Total metals	250 ml plastic	Nitric acid	ALS Laboratory

3.2.3. VIU Laboratory Analyses

Water samples transported to Vancouver Island University were analysed for conductivity, pH, total alkalinity and turbidity. Conductivity (to the nearest 1 µSiemens/cm) and pH (to the nearest 0.01 pH unit) were obtained with a YSI 556 MPS electronic probe. Total alkalinity (as $CaCO_3$) was measured to the nearest 1 mg/L using the HACH AL-DT digital titration method. Turbidity was measured to the nearest 0.01 NTU (Nephelometric Turbidity Units) using a HACH 2100 Potable Turbidimeter.

3.2.4. ALS Laboratory Analyses

Water samples submitted for external analyses were processed as per ALS Laboratory standard analytical procedures. The analytes were: conductivity, total hardness, pH, nutrients (ammonia, nitrite, nitrate, orthophosphate and total phosphorus), and total metals (31 metals).

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers.

3.2.6. Data Analyses – Comparison with Applicable Guidelines

Water quality results were compared with the applicable provincial water quality guidelines for the protection of freshwater life. The BC Water Quality Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential chronic effects). All guidelines were obtained from the BC Ministry of Environment, Water Protection Division (http://www.env.gov.bc.ca/wat/wq/).

It is important to note that for some metal parameters, analytical detection limits were above applicable guidelines. These include aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, thallium and vanadium. For these metals, measured values reported to be below method detection limits cannot be assumed to be below the applicable guidelines.

3.3. Microbiology

3.3.1. Field Sampling

Water samples for total and fecal coliform enumeration were collected from each sampling station on 31 October 2011 (Table 2). At each station, a sterile pre-labelled 120-ml Whirl-Pak® bag was used to collect a 100-ml water sample by directly immersing the bag by hand just below the water surface while facing upstream. All samples were stored in a cooler with ice packs and transported within 48 hours to Vancouver Island University for laboratory analysis.

3.3.2. Laboratory Analyses

In the laboratory, water samples were tested for total coliform and fecal coliform (*Escherichia coli* or *E. coli*) using the m-coliBlue24 membrane filtration method (Millipore Corporation). A 25-ml volume of sample water was filtered through a 47-µm membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. A filtration blank was also completed with 25 ml of sterile water using the same filtration procedures. Each membrane filter (including the blank) was then transferred to a Petri plate containing an absorbent pad saturated with m-ColiBlue24 broth. All membrane filters were incubated at 37°C for 20 hours (until bacterial colonies were visible).

Table 4. Possible outcomes of the m-coliBlue24 membrane filtration method.

Bacteria Type	Positive Result	Negative Result
Total coliform	Red or blue colony	Clear or white colony No colony
E. coli	Blue colony only	Non-blue colony

Upon completion of the incubation period, membrane filters were then examined for bacterial colonies under a dissection microscope (16X magnification). A red or blue colony represents a total coliform "positive" result (Table 4). A blue colony specifically represents an *E. coli* "positive" result. A clear or white colony represents a total coliform negative result.

All colonies present on a membrane filter were counted and expressed as CFU (colony forming units) per 100-ml of sample water.

3.4. Stream Invertebrates

3.4.1. Sampling Stations

Stream invertebrate samples were collected from stations 1 and 2 on 31 October 2011 (Table 1; Figure 1). The location of stations 1 and 2 differed from a previous study conducted on Departure Creek during Fall 2010 (VIU, 2011) to minimize disturbance of spawning pink salmon. The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples, safety and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-15 cm), with water velocity of ~0.10-0.25 m/s, and primarily sand and gravel substrate.

3.4.2. Invertebrate Sampling

At each station, two replicate samples (duplicates) were obtained using a dipnet and procedures as per the Pacific Streamkeepers procedures (Taccogna and Munro, 1995). Each site was approached by walking from downstream. The 30-cm wide dipnet was pressed into the substrate and a 0.09-m^2 sampling area (30 cm x 30 cm) in front of the net was hand-disturbed to dislodge invertebrates towards the dipnet. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the net was then transferred in a 125-ml plastic sample jar. The net was carefully inspected to ensure all content was transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 24 hours of sampling.

3.4.3. VIU Laboratory Analyses

Laboratory procedures and identification also followed the Pacific Streamkeepers procedures (Taccogna and Munro, 1995). The triplicate samples from each station were combined into a single composite sample per station. The contents of all invertebrate sample jars from a station were poured into a shallow white tray. Invertebrates were sorted into apparent taxonomic groups. Identification to the appropriate taxonomic level (as prescribed by the Pacific Streamkeepers procedures) was confirmed using a dissecting microscope. The number of invertebrates and the number of distinguishable subgroups within each broad taxonomic group were recorded on a Pacific Streamkeeper Invertebrate Survey Field Data Sheet. From these records, various useful metrics were calculated for each station, including: total density (number per m^2), total number of taxonomic groups, predominant taxonomic group, Pollution Tolerance Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

4. Results

The discharge measurement (Table 5) and field observations for Departure Creek suggest that water level was not at bankfull during both sampling events (0.044-0.203 m^3/s). On 21 November 2011, a strong rain shower started within 20 minutes of sampling at station 1 (last station sampled on that date). Highly turbid stormwater runoff from nearby impervious surfaces was observed entering Departure Creek at this location. This resulted in the high discharge measurement obtained at that station (0.203 m^3/s).

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from four stations on Departure Creek during October-November 2011. Discharge measurements were collected at stations 1 and 3 during both sampling events.

		Field Measurements				VIU Laboratory	
Station	Discharge (m^3/s)	Temperature (^oC)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Total Alkalinity (mg/L $CaCO_3$)	Turbidity (NTU)
			31 October 2011				
1	0.082	10.9	8.9	229	6.59	83	1.53
2		10.5	9.2	278	6.49	82	3.51
3	0.117	9.3	9.9	307	6.48	95	0.55
4		9.2	9.6	309	6.63	86	0.58
			21 November 2011				
1	0.203	7.5	9.4	223	6.79	64	51.60
2		7.4	9.7	190	6.63	69	1.60
3	0.044	7.5	9.4	202	6.53	89	3.80
4		7.8	9.4	270	6.55	41	1.30

Average air temperature during the 10-day period prior to each sampling event was 7.5^{o}C and 2.7 ^{o}C for the October and November sampling events, respectively (data for Nanaimo Airport retrieved from http://climate.weatheroffice.gc.ca). Total rainfall during the 10-day period prior to the October and November sampling events were 27 mm and 31 mm, respectively.

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 10.0°C and 7.6°C during the October and November sampling events, respectively (Table 5). The decrease in water temperature reflected a concurrent decrease in air temperature between sampling events. During both sampling events, all dissolved oxygen levels were near or above the minimum guideline of 9.0 mg/L for early fish life stages (RISC, 1998). Overall, dissolved oxygen concentrations were 78-86% saturation.

Conductivity averaged 281 and 221 µS/cm during the October and November sampling events, respectively (Table 5). There was a general increase in conductivity as expected from upstream to downstream in Departure Creek, except at station 1 during the November sampling event where a higher than expected conductivity was observed as a result of the rain shower. Water pH ranged from 6.48 to 6.76 during this study.

Total alkalinity averaged 87 and 66 mg/L during the October and November sampling events, respectively (Table 5). Total alkalinity was well above 20 mg/L during both sampling events, indicating "low acid sensitivity" as defined by RISC (1998).

Turbidity ranged from 0.55 to 3.80 NTU during this study, except at station 1 during the November sampling event when turbidity reached 51.6 NTU (Table 5). The high turbidity resulted from the watershed flushing action of the high stormflow event. Such a rapid, high turbidity event / pulse may cause transient habitat deterioration through the length of Departure Creek.

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratories were compared to the BC Provincial water quality guidelines for the protection of aquatic life (Table 6).

The conductivity measurements from ALS Laboratories were consistent with the field measurements obtained with the electronic probe during the October sampling event, but were lower by <32% during the second sampling event. This discrepancy may have been caused by improper probe calibration.

Total hardness averaged 110 and 78 mg/L during the October and November sampling events, respectively. Total hardness was between 60 and 120 mg/L during both sampling events, indicating "moderate hardness" as defined by RISC (1998).

Field measurements of pH (range: 6.48-6.79) were generally lower than the ALS Laboratories results (range: 8.01-8.29). This discrepancy possibly reflects differential calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis.

Table 6. Laboratory results (ALS Laboratory) for water samples taken from Departure Creek during 31 October and 21 November 2011. All values are expressed in mg/L unless specified otherwise. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]				
	BC Max	BC 30-day Mean	31 October 2011	21 November 2011	
Variable	mg/L	mg/L	3	2	3
General/Physical					
Conductivity (µS/cm)			300	260	280
Hardness, Total			110.0	71.4	83.6
pH (pH units)	6.5 - 9.0		8.29	8.20	8.01
Nutrients					
Ammonia-N	2.97 [b]	0.57 [b]	<0.0050	<0.0050	0.0088
Nitrate (as N)	31.3	3	0.688	0.612	0.773
Nitrite (as N)	0.06 [c]	0.02 [c]	0.0071	0.0016	0.0027
Ortho Phosphate (as P)			0.0096	0.0014	0.0021
Total Phosphorus			0.0141	0.0095	0.0202
Total Metals					
Aluminum (Al) [m]	0.10 [d]	0.05 [d]	<0.20	0.20	0.29
Antimony (Sb) [m]	0.02		<0.20	<0.20	<0.20
Arsenic (As) [m]	0.005		<0.20	<0.20	<0.20
Barium (Ba)	5	1	0.011	0.012	0.017
Berylium (Be)	0.0053		<0.0050	<0.0050	<0.0050
Bismuth (Bi)			<0.20	<0.20	<0.20
Boron (B)	1.2		<0.10	<0.10	<0.10
Cadmium (Cd) [m]	0.00002 [e]		<0.010	<0.010	<0.010
Calcium (Ca)			28.6	18.9	22.2
Chromium (Cr) [m]	0.001 [f]		<0.010	<0.010	<0.010
Cobalt (Co) [m]	0.11	0.004	<0.010	<0.010	<0.010
Copper (Cu) [m]	0.009 [g]	0.002 [g]	<0.010	<0.010	<0.010
Iron (Fe)	1.0		0.079	0.396	0.512
Lead (Pb) [m]	0.053 [h]	0.005 [h]	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096	<0.010	<0.010	<0.010
Magnesium (Mg)			9.28	5.89	6.85
Manganese (Mn)	1.33 [i]	0.92 [i]	0.005	0.033	0.035
Molybdenum (Mo)	2	1	<0.030	<0.030	<0.030
Nickel (Ni) [m]	0.025 [j]		<0.050	<0.050	<0.050
Phosphorus (P)			<0.30	<0.30	<0.30
Potassium (K)	373		<2.0	2.1	<2.0
Selenium (Se) [m]		0.002	<0.20	<0.20	<0.20
Silicon (Si)			8.81	6.14	6.29
Silver (Ag) [m]	0.0001 [k]	0.00005 [k]	<0.010	<0.010	<0.010
Sodium (Na)			19.7	24.7	25.5
Strontium (Sr)			0.109	0.080	0.095
Thallium (Tl) [m]	0.0003		<0.20	<0.20	<0.20
Tin (Sn)			<0.030	<0.030	<0.030
Titanium (Ti)	2		<0.010	0.017	0.023
Vanadium (V) [m]	0.006		<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [l]	0.0075 [l]	<0.0050	0.007	0.013

Table 6. (Continued)

NOTES:

Results are expressed as mg/L except for pH and conductivity.
"<" means less than the detection limit.

[a] BC Water Quality Guidelines (WQG) compiled from
http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html
http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

[b] Total ammonia guideline is dependent on water temperature and pH of tested water.

[c] Nitrite guideline is for chloride concentration < 2 mg/L.

[d] Aluminum guidelines for pH ≥ 6.5.

[e] The maximum cadmium guideline is $0.001 * 10^{\{0.86 [\log(\text{hardness})] - 3.2\}}$ mg/L.

[f] Chromium guideline is for the more toxic Chromium VI.

[g] The maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L.
The 30-day mean copper guideline is for hardness < 50 mg/L.

[h] The maximum lead guideline is $0.001 * e^{\{1.273 [\ln(\text{hardness})] - 1.46\}}$ mg/L.
The 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273 [\ln(\text{hardness})] - 4.704\}}]$ mg/L.

[i] The maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L.
The 30-day mean manganese guideline is 0.0044 * (hardness) + 0.605 mg/L.

[j] Nickel guideline is for hardness < 60 mg/L.

[k] Silver guidelines are for hardness < 100 mg/L.

[l] Zinc guidelines are for hardness < 90 mg/L.

[m] Analytical detection limits were above applicable guidelines for these metals.

All nutrient levels were below applicable guidelines and/or below detection limits. Total ammonia was below or near detection limit (i.e., 0.009 mg/L or less) during both sampling events. Nitrate concentrations ranged from 0.61 to 0.77 mg/L. Nitrite concentrations ranged from 0.0016 to 0.0071 mg/L.

Orthophosphate ranged from 0.0014 to 0.0096 mg/L during this study, and there was an apparent decrease between sampling events. Total phosphorus ranged from 0.0095 to 0.0202 mg/L during this study. Overall, total phosphorus levels were mainly within or near the moderate range typical of "mesotrophic" waters (0.010-0.025 mg/L) waters as defined by RISC (1998).

All metal concentrations were below the applicable water quality guidelines and/or below detection limits, except for aluminium (stations 2 and 3) and zinc (station 3) concentrations which exceeded the guidelines during the November sampling event. It should be noted that total metal analyses measure the combined amount of metals dissolved in water and bound to particles. In general, dissolved metals are more bio-available (hence toxicologically available) than metals that are bound to particles. The dissolved fraction of total metals in water is often lower than 100%.

4.2. Microbiology

All samples collected from Departure Creek contained some coliform bacteria (Table 7). Total coliform counts increased range from 313 to 470 CFU / 100 ml. The proportion of total coliform made up of *E. coli* bacteria was 38.7% and 3.4% at station 2 and 3, respectively.

The filtration blank completed with sterile water did not produce any bacterial colonies.

Table 7. Total coliform and *E. coli* counts from water samples taken at two stations on Departure Creek on 31 October 2011. All values are expressed as number of bacteria per 100 ml. No samples were collected on 21 November 2011.

Station	Total Coliform	*E. coli*	% *E. coli*
2	313	121	38.7%
3	470	16	3.4%
Filtration blank	0	0	–

4.3. Stream Invertebrates

A total of 231 stream invertebrates representing 7 broad taxonomic groups were counted at two stations on Departure Creek on 31 October 2011 (Table 8; Figure 2; Appendix 2). Animal density ranged from 611-672 animals/m^2. Overall, aquatic worms and stonefly nymphs were the most common taxonomic group encountered.

Site assessment ratings ranged were 2.00 at station 1 and 3.25 at station 2, suggesting "marginal" and "acceptable" invertebrate community diversity, respectively. The low to moderate representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 7-51% of total abundance) indicates generally "marginal" environmental conditions.

Table 8. Abundance and density of stream invertebrates obtained from duplicate samples taken on 31 October 2011 at two stations on Departure Creek. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No samples were collected on 21 November 2011.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2
Category 1 Pollution Intolerant	Caddisfly Larva	1	4
	Mayfly Nymph	0	11
	Stonefly Nymph	7	47
Category 2 Somewhat Pollution Intolerant	Cranefly Larva	1	3
	Scud (Amphipod)	16	12
Category 3 Pollution Tolerant	Aquatic Worm (Oligochaete)	66	31
	Planarian (Flatworm)	19	13
	Total Abundance	110	121
	Density (number / m^2)	611	672
	Site Assessment Rating	2.00	3.25

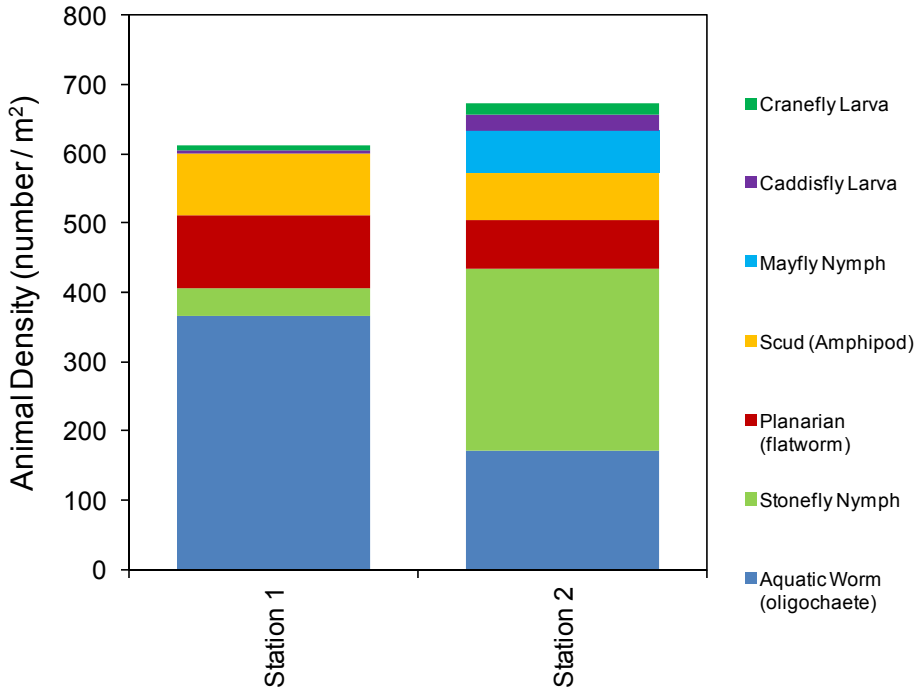

Figure 2. Density of stream invertebrates obtained from duplicate samples taken on 31 October 2011 at two stations on Departure Creek. Data are summarized in Table 8 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

The authors would like to acknowledge Margaret Wright (Fisheries and Oceans Canada) and Joan Michel (Regional District of Nanaimo) for her continued support in facilitating this and other monitoring projects. We also thank Jean-Michel Hanssens, the Harbour City River Stewards, the Departure Bay Neighbourhood Association and the Nanaimo and Area Land Trust for their interest in this project. Additional support was provided by students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University – Nicole Boss, Melissa Dorey, Greg Faasse, Greg Haider, Josiah Klassen, Hayley McCabe, Heather McCubbin, Nik McEwan, Dan McNeill, Jackie Morris, Steph Righi, Clayton Smith, Olivia van Jarrett and Chris White. The Resource Management Officer Technology (RMOT) and Biology Departments at Vancouver Island University provided some laboratory supplies, equipment, vehicle and covered fuel expenses. The Regional District of Nanaimo and Fisheries and Oceans Canada provided funding for analytical processing of water samples. ALS Laboratory provided reduced rates on some of their analytical services for this project and other projects conducted as part of the Environmental Monitoring course.

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7. Appendices

APPENDIX 1. Photographs showing site conditions at each sampling station on Departure Creek.

Photo 1. Downstream view of Departure Creek near station 1 on 31 October 2011.

Photo 2. Downstream view of Departure Creek near station 2 on 31 October 2011.

APPENDIX 1. (Continued)

Photo 3. Downstream view of Departure Creek near station 3 on 31 October 2011.

Photo 4. Downstream view of the Departure Creek near station 4 on 31 October 2011.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for duplicate stream invertebrate samples collected at stations 2 and 3 on Departure Creek during 31 October 2011.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Departure Creek		Date:	31 October 2011
Station Name:	**Station 1**		Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Dipnet	2	0.09 x 2	0.18	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)	1	1
	Mayfly Nymph (EPT)		
	Stonefly Nymph (EPT)	7	1
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		8	2
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	1	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	16	2
	Watersnipe Larva		
Sub-Total		17	3
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	66	4
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)	19	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		85	5
TOTAL		110	10

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 110

DENSITY: Invertebrate density per square metre:

110 ÷ 0.18 = 611

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Aquatic Worm (oligochaete)

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Accpetable	Marginal	Poor
>22	17-22	11-16	<11

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 3 + 5 = 17

EPT INDEX: Total number of EPT taxa.

Good	Accpetable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

1 + 0 + 1 = 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(1 + 0 + 7) / 110 = 0.07

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 10

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

Good	Accpetable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S3 / CT

66 / 110 = 0.60

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	3
EPT Index	2
EPT To Total Ratio	1
Predominant Taxon Ratio	2

Average Rating
2.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Departure Creek		Date:	31 October 2011
Station Name:	**Station 2**		Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Dipnet	2	0.09 x 2	0.18	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	4	1
	Mayfly Nymph (EPT)	11	1
	Stonefly Nymph (EPT)	47	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		62	4
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	3	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	12	2
	Watersnipe Larva		
Sub-Total		15	3
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	31	4
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)	13	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		44	5
TOTAL		121	12

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 121

DENSITY: Invertebrate density per square metre:

121 ÷ 0.18 = 672

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Stonefly Nymph (EPT)

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Accpetable	Marginal	Poor
>22	17-22	11-16	<11

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 3 + 5 = 23

EPT INDEX: Total number of EPT taxa.

Good	Accpetable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

1 + 1 + 2 = 4

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(4 + 11 + 47) / 121 = 0.51

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 12

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

Good	Accpetable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S3 / CT

47 / 121 = 0.39

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	2
EPT To Total Ratio	3
Predominant Taxon Ratio	4

Average Rating
3.25