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Powell River

Environmental Effects Monitoring (EEM) Cycle Six Interpretive Report

March 2013

Prepared for:

Catalyst Paper Corporation
Powell River, British Columbia

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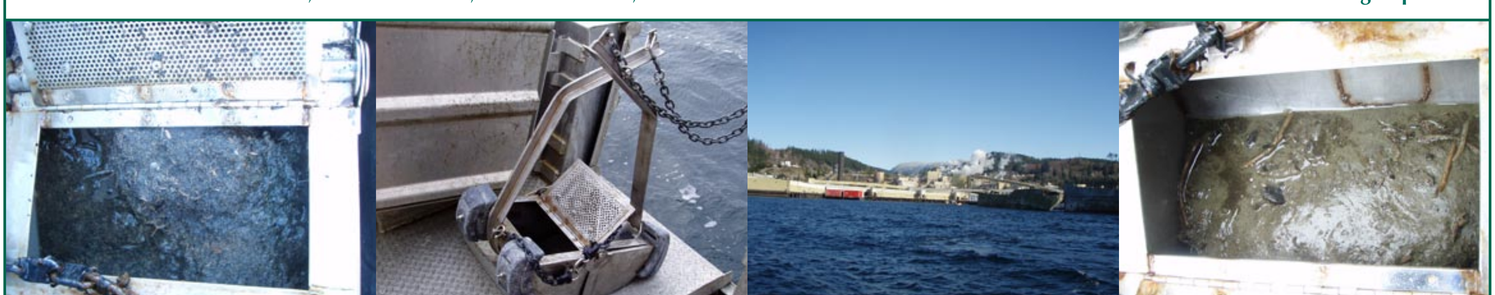

POWELL RIVER

ENVIRONMENTAL EFFECTS MONITORING (EEM) CYCLE SIX INTERPRETIVE REPORT

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LIST OF ACRONYMS

ADt	air-dried tonnes
AOX	adsorbable organic halides
BOD	biochemical oxygen demand
C	Celsius
cm	centimetre
CTMP	chemi-thermomechanical pulp
d	day
EEM	Environmental Effects Monitoring
EPA	Environmental Protection Agency
g	gram
IC25	effluent concentration causing 25% inhibition of a biological function
kg	kilogram
km	kilometre
L	litre
LC50	effluent concentration causing 50% mortality of test organisms
m	metre
µg	microgram
mg	milligram
pg	picogram
ppb	parts per billion
PPER	Pulp and Paper Effluent Regulations
ppm	parts per million
s	second
t	tonne
TMP	thermomechanical pulp
TSS	total suspended solids
v/v	volume/volume
yr	year

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- Ms. Liz Freyman of BC Ministry of Environment; and
- Ms. Sarah Barkowski of Catalyst Paper Corporation.

Contributors to this EEM program at Hatfield included Mr. Colin Schwindt, Mr. Martin Davies, Mr. John Wilcockson, Ms. Jackie Porteous, and Ms. Susan Stanley.

EXECUTIVE SUMMARY

The Environmental Effects Monitoring (EEM) program Cycle Six for Catalyst Paper Ltd., Powell River Division, extended from May 2010 to April 2013, and included studies of the sublethal toxicity of effluent, and a benthic invertebrate community survey, including associated sediment and water quality assessments. Because effluent is diluted to 1% concentrations within 250 m of the outfall, the mill was exempt from fish population surveys in Cycle Six, as per the PPER. The mill was also exempt from a fish-tissue survey due to low or non-detectable concentrations of dioxins/furans previously measured in fish tissue and mill effluent, respectively.

Sublethal toxicity testing was undertaken six times from 2010 to 2012 for the Powell River pulpmill. Algal reproduction was affected at a mean effluent concentration of 4.9%, while invertebrate fertilization was affected at a mean effluent concentration of 64.4%. Because of the rapid diffusion of effluent expected from the multi-port diffuser installed at the Power River Pulpmill, potential effects are expected to be seen to a maximum extent of 24.7 m from the effluent diffuser.

A benthic invertebrate survey was conducted in the vicinity of the Powell River pulpmill in March 2012 using a gradient survey design consisting of 13 stations located northwest and southeast of the mill diffuser. Two samples were collected from each station to assess benthic invertebrate communities and sediment chemistry with a third collected for sediment composition and chlorinated phenolic compounds. Adult invertebrate data were used for statistical analysis and evaluation of impacts for five key effects endpoints as well as describing community composition.

Significant effects were observed for total taxa richness and the Bray-Curtis index with respect to distance from the diffuser and C/N ratio. No effects were observed for density, Simpson's diversity index or evenness when compared to either distance from the diffuser or C/N ratio. Although effects on benthic invertebrates were observed in Cycle Six, sediment conditions improved and benthic densities increased at nearly all sites, relative to previous cycles. In addition, an increase in total taxa richness was observed in Cycle Six largely associated with an increase in the number of epifaunal taxa that inhabit "coarser" substrates, suggestive of improving sediment conditions and reference areas.

Sediment near the diffuser, while improving, remains organically enriched and exhibits reducing conditions to inhabiting biota. Remaining gradient stations exhibited sediment conditions indicative of natural conditions/reference areas. Given continued improvements in effluent quality since Cycle Three and consistent declines in TOC overtime, the cause of the effects is resulting from the historical fibre-mat and not current mill discharge conditions. In addition, a spatially condensed study design, with more stations near the diffuser and fewer distant (far-field) stations, likely contributed to the significant effects observed in Cycle Six.

DISTRIBUTION LIST

The following individuals/firms have received this document:

Name	Firm	Hardcopies	CDs
Sarah Barkowski	Catalyst Paper Corporation, Powell River Division	3	
Janice Boyd	Environment Canada	1	1
Liz Freyman	Ministry of Environment	1	

1.0 INTRODUCTION

Pulpmills in Canada are required by the *Pulp and Paper Effluent Regulations* (PPER) under the federal *Fisheries Act* to conduct Environmental Effects Monitoring (EEM) studies on a regular basis. EEM studies are typically conducted in three-year cycles, each of which includes a study design phase, study implementation, data analysis, and reporting. The required components of an EEM study typically include:

- Sublethal toxicity testing of effluent, to examine the effect of chemicals or chemical mixtures on the reproduction and growth of representative aquatic organisms;
- A biological monitoring program, to assess the potential effects of effluent on fish populations, benthic invertebrate communities, and fish tissue in the receiving environment; and
- Water and sediment quality measurements, to support interpretation of biological monitoring results.

Effluent sublethal toxicity testing is conducted twice per year for mills that discharge effluent over a period of more than 120 days. The fish population and benthic invertebrate surveys and supporting environmental measurements are conducted once per cycle, or once every two cycles (i.e., once every six years) if no effects in these components have been observed in the two most recent EEM cycles. In addition, a mill is exempt from a fish survey and a benthic invertebrate community survey if the concentration of effluent in the exposure area is 1% or less within 250 m or 100 m, respectively, of the effluent outfall. An assessment of dioxin/furan concentrations in the tissue of fish captured from the exposure area is required if the effluent contains measurable concentrations of these chemicals, or if concentrations in fish tissue reported in the most recent interpretive report exceeded Health Canada consumption guidelines (Government of Canada 2008).

Six EEM cycles have been completed since the release of the original PPER in 1992: Cycle One, from 1993 to 1996; Cycle Two, from 1997 to 2000; Cycle Three, from 2001 to 2004; Cycle Four, from 2004 to 2007; Cycle Five, from 2007 to 2010; and Cycle 6, from 2010 to 2012. All components of the Powell River pulpmill EEM programs have been conducted in accordance with applicable regulatory requirements, with implementation guided by the most current and applicable technical guidance documents produced by Environment Canada.

The Powell River pulpmill EEM Cycle Six program was designed in accordance with the 2008 amendments to the PPER (Government of Canada 2008), with guidance from the pulp-and-paper EEM Technical Guidance Document (Environment Canada 2010). The study design is described in Hatfield (2012).

In December 2011, Catalyst Paper Corporation (Catalyst) began to utilize spare boiler and generator capacity to generate electricity at the Powell River mill as part of the G12 Power Increase Project (G12 Project; Hatfield 2013). The implementation of the G12 Project was predicted to result in significant increases in the volume of water/effluent discharged from the mill's outfalls, due to additional non-contact cooling water from the G12 Project. The increased volume through the effluent-carrying outfall (Outfall #1) was predicted from two of the diffuser ports, based on pre-project modeling (Hatfield 2010). The resulting increase in the 1% zone beyond the 100-m distance triggered a requirement for the mill to conduct a benthic invertebrate community survey as part of the Cycle Six program.

Given that the 1% effluent concentration zone of Powell River mill's primary outfall is not projected to exceed 250 m with the implementation of the G12 Project, the mill maintained its exemption from the fish-population survey requirement. An exemption from fish-tissue dioxin/furan monitoring was also maintained, due to low dioxin/furan concentrations in previous fish-tissue evaluations and non-detectable concentrations continually measured in effluent.

2.0 SITE CHARACTERIZATION AND MILL UPDATE

2.1 STUDY AREA

The Catalyst Paper Powell River pulpmill is located at the north end of Malaspina Strait in the northern Strait of Georgia, British Columbia, Canada (Figure 2.1). Malaspina Strait is a deep (>300 m), steep-sided channel separated from the Strait of Georgia by Texada Island. Water temperatures in the area are relatively constant (about 7°C) at depths below approximately 50 m. In 2012, a thermocline developed in summer between about 10 m and 20 m depth, but was largely broken down by early October when surface waters cool (Hatfield 2013). Tides at Powell River are mainly diurnal, with a mean range of 3.35 m; flood tides move north up the strait while ebb tides flow south (Hatfield 1994).

The marine environment in the vicinity of Powell River supports numerous species of aquatic organisms, including fish and benthic invertebrates. The eastern portion of the Strait of Georgia between Texada Island and Desolation Sound and Malaspina Strait are important migratory routes for juvenile salmon. Several areas within the region are important for salmon and herring rearing, as well as Pacific hake, walleye pollock, herring, and Pacific cod spawning. Near-shore marine waters support numerous species of invertebrates, including oysters, prawns, and clams (Hatfield 1994).

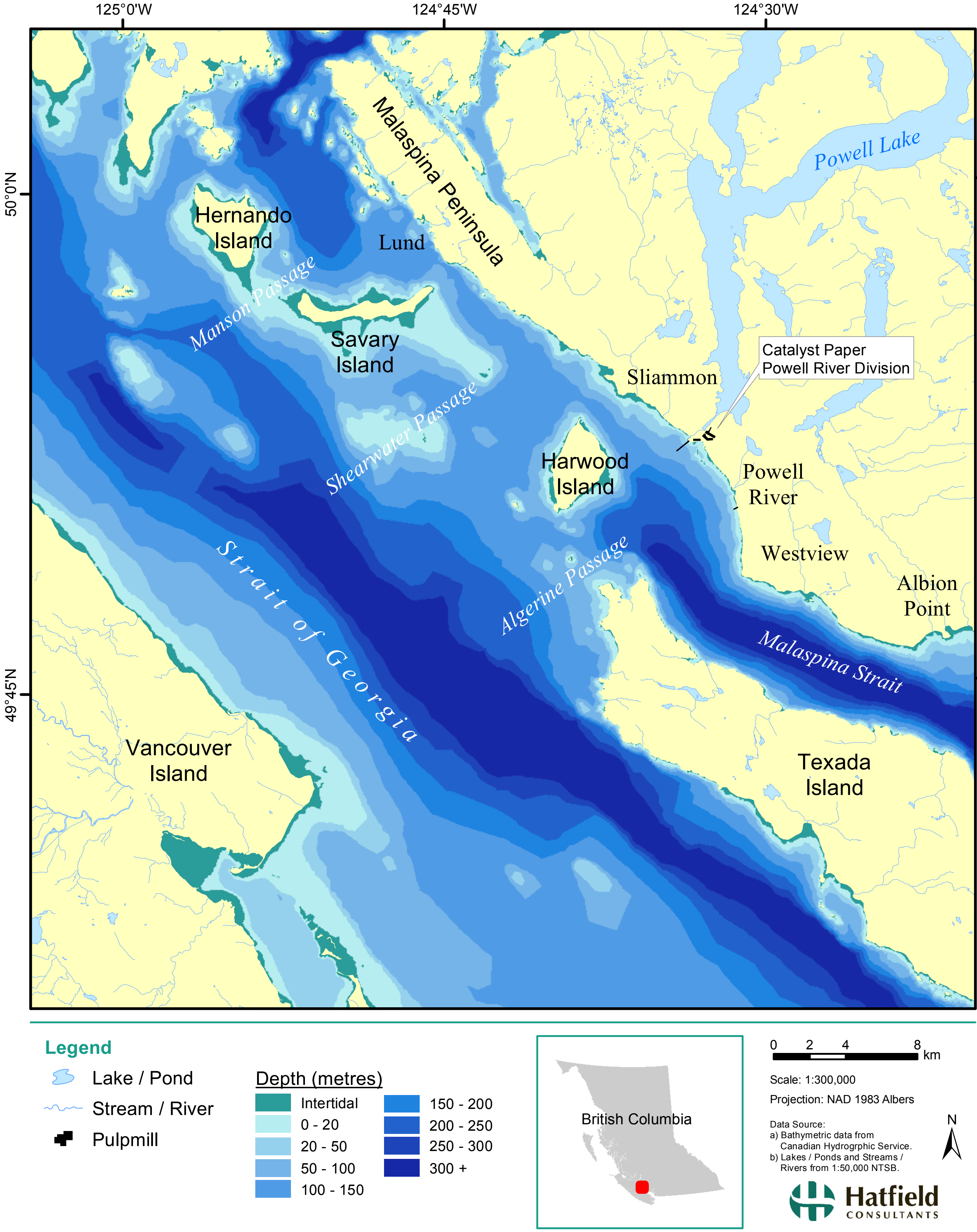
With the exception of the G12 Project, no new large-scale human influences or significant natural changes in the Powell River study area are known to have occurred since the beginning of the EEM program in 1993.

2.2 MILL OPERATIONS

When operations began in 1912, the Powell River mill was the first newsprint mill in western Canada (Catalyst Paper 2009), and used groundwood and sulphite pulping processes. The sulphite mill closed in 1969, and was replaced by a Kraft mill that began production in 1967. A refiner mechanical pulpmill was started in 1969, and used surplus refiners from the sulphite mill; this mill continued operation until 1982. Thermomechanical pulp (TMP) production began in 1975, and was converted to chemi-thermomechanical pulp (CTMP) production over the period 1982 to 1985 by means of sodium sulphite treatment of wood chips (Hatfield 1994). Further details on the operational history of the Powell River pulpmill are available in the pre-design report (Hatfield 1994).

In 1991, elemental chlorine use in the Kraft mill bleach plant was substantially replaced by a chlorine dioxide system; this resulted in the bleaching sequence $DE_{O}D$. Use of elemental chlorine during bleaching was completely eliminated in October 1996. In 2000, the bleaching sequence changed again with the inclusion of peroxide in the alkali extraction process, resulting in the bleaching sequence $DE_{OP}D$ (P=peroxide) (Hatfield 2001). Elimination of elemental chlorine bleaching led to the virtual elimination of dioxins and furans in mill effluent (Hatfield 1994) and greatly reduced effluent adsorbable organic halide (AOX) concentrations (Hatfield 2001).

Figure 2.1 Location of Catalyst Paper, Powell River Division, in Powell River, British Columbia.



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The Powell River pulpmill currently uses an aerobic activated-sludge secondary treatment system, installed in December 1992. This system consists of a three-train bioreactor, two 65.5 m diameter secondary clarifiers, and the submerged effluent diffuser. Installation of the secondary treatment system resulted in a large reduction in effluent BOD (Figure 2.3).

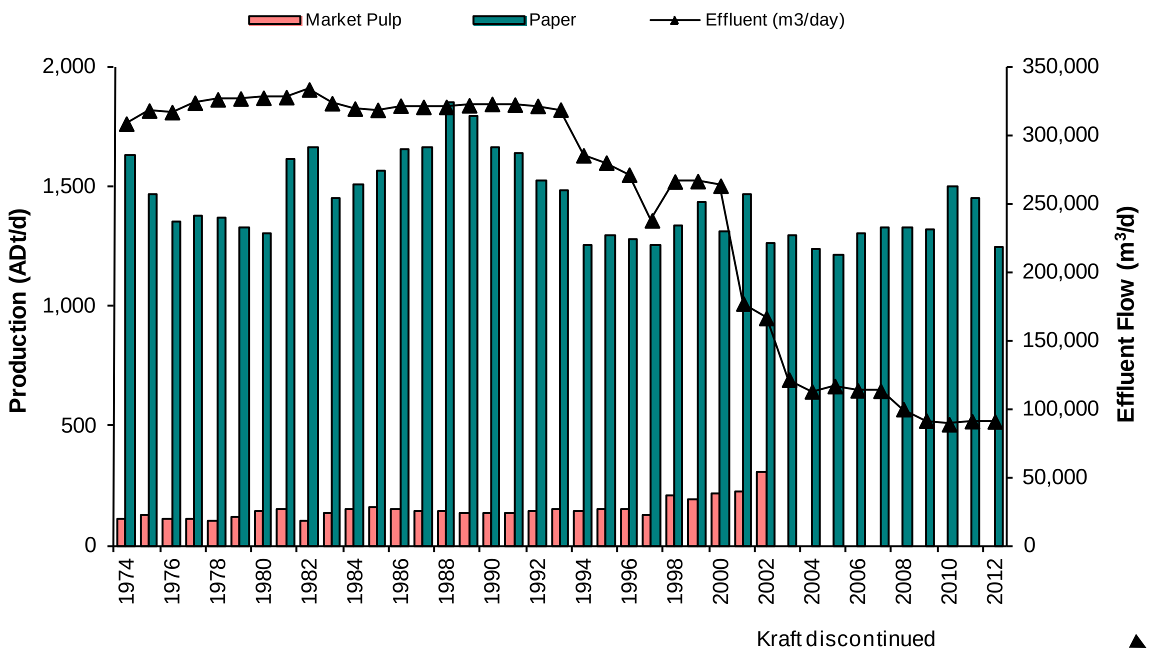
Effluent from the mechanical pulping, woodroom, hog fuel boilers, and paper machines was historically collected in a series of pump stations and transported to a 91 m diameter primary clarifier, installed in 1978, where solids settled out of the effluent and were removed as primary sludge. Effluent TSS concentrations decreased following installation of this primary clarifier (Figure 2.3). During EEM Cycle Four (2004 to 2007), the mill bypassed this existing oversized primary clarifier and converted a much smaller, swing clarifier into a permanent primary clarifier. This modification helped to reduce odour problems related to septicity in the old primary clarifier. In August 1997, liquid ammonia nitrogen (liquid fertilizer) replaced anhydrous ammonia (gas) as the source of nitrogen added to the secondary treatment system (Hatfield 2001). Additional details on the mill's secondary treatment system can be found in the pre-design report (Hatfield 1994).

Since 1993, the combined, treated effluent from all Powell River mill operations has entered the receiving environment through a submarine outfall (Hatfield 1994). This outfall, operational since 1980, extends approximately 820 m into Malaspina Strait. Thirty-six diffuser ports, equally spaced along the length of the outfall starting at the 345 m point, discharge effluent at depths between 57.3 and 72.5 m below low water. Before completion of the outfall in 1980, mill effluent was discharged through a surface tailrace at the mill site. Effluent from the CTMP and groundwood mills, papermill, and woodroom were discharged from this site (after primary treatment) until fall 1992, when the secondary treatment system became operational (Hatfield 1994).

During summer 2001, all paper machines were converted to neutral papermaking processes. In late 2001, the groundwood pulpmill, wood mill operations, and kraft mill operations were discontinued. These changes resulted in a significant reduction in effluent flow (Figure 2.2) and changes in effluent characteristics. Additional discharges from the Powell River pulpmill include cooling and storm waters from the TMP and woodroom areas (Outfall #2, surface discharge to Malaspina Strait); cooling waters from the steam plant and paper machines, and stormwater (Outfall #4, surface discharge to Malaspina Strait); and block flume transport water from Powell Lake, discharged to the Powell River estuary (Outfall #3) (Hatfield 2001).

Currently, Powell River operations include a thermomechanical pulpmill, three repulpers for purchased kraft pulp, and three paper machines. All pulp produced is used for the production of newsprint and groundwood specialties paper. The mill currently produces 32,000 tonnes of newsprint and 434,000 tonnes of specialty papers per year for clients throughout the world. In 2012, average paper production at the Powell River mill was 1,240 ADt/d.

Figure 2.2 Average annual paper and market pulp production and effluent flow, Powell River pulpmill, 1974 to 2012.



The Powell River mill has been owned by several different companies, including MacMillan Bloedel Ltd. and Pacifica Papers. Pacifica Papers and Norske Skog merged in August 2001 to create NorskeCanada. In 2005, NorskeCanada changed its name to Catalyst Paper Corporation.

2.2.1 G12 Power Increase Project

In 2011, Catalyst Paper Ltd. received a permit to utilize spare boiler and generator capacity to generate additional "green" electricity at the Powell River mill (Hatfield 2013). The implementation of the G12 Project has the potential to significantly increase the daily volume of water/effluent discharged from the mill's outfalls. The increase is the result of additional non-contact cooling water from the G12 Project ultimately discharged from the main outfall (Outfall #1). Daily average flow from Outfall #1 (effluent-carrying, sub-surface outfall) is projected to increase from 93,278 m^3/day to 153,425 m^3/day at conservative estimates, and up to the permitted daily maximum of 245,000 m^3/day under the worst-case scenario. Under rare circumstances (e.g., during five hottest days of the year), excess cooling water would be redirected to Outfall #4 (non-effluent carrying surface outfall). During these rare events, maximum daily flow from Outfall #4 may reach up to 90% of the permitted maximum flow of 94,700 m^3/day (i.e., 85,230 m^3/day). In 2012, the G12 Project ran for approximately one month and did not increase overall effluent flow above the range of flows observed in previous years (Figure 2.2).

2.3 EFFLUENT QUALITY

Effluent quality is measured routinely in accordance with provincial permits and federal PPER requirements. All effluent quality variables are based on testing of effluent samples prior to dilution with non-contact cooling water.

Average effluent flow from the mill has decreased from 318,522 m^3/d in 1992, to 87,680 m^3/d (inclusive of the G12 Project) in 2012, a decrease of over 70% (Figure 2.2). Reductions in effluent flow, as well as improvements in effluent quality, have resulted from changes to the Powell River pulpmill facility and operations over this period. Installation of the primary clarifier in 1978 led to a substantial decrease in total suspended solids, while implementation of secondary effluent treatment in 1992 led to a decrease in BOD of approximately 96% (Figure 2.3). With the closure of the kraft mill in November 2001, dioxin/furan and AOX monitoring is no longer required.

Effluent quality variables measured during Cycle Six were generally similar to those reported in Cycle Five (Figure 2.3). Acute toxicity values were greater than 100% effluent in Cycle Six, indicating that effluent was not lethal to fish and invertebrates tested.

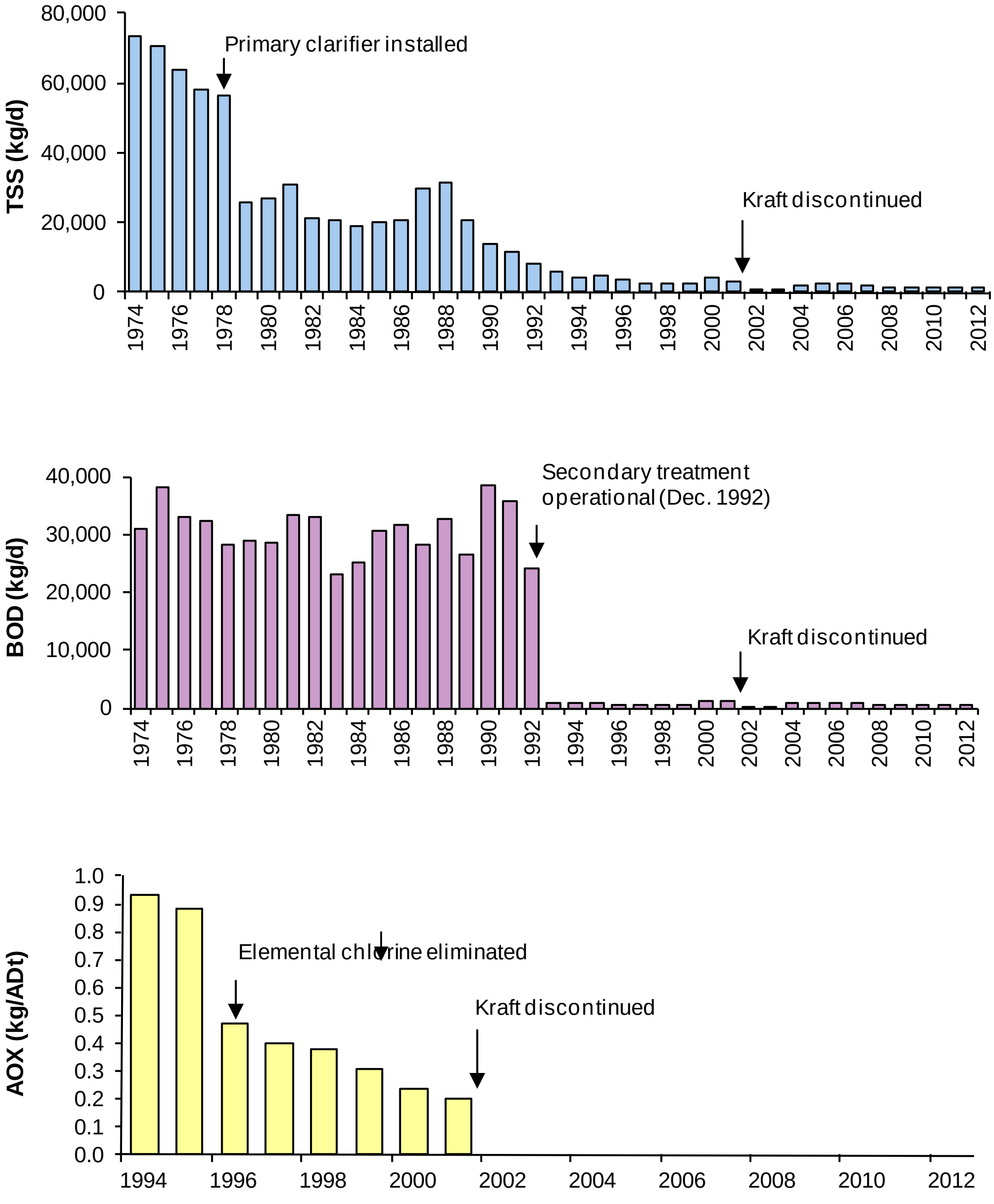
2.3.1 Effluent Chemistry and Acute Toxicity Testing

Effluent quality is routinely measured in accordance with provincial permits and federal PPER requirements. Annual average values for all effluent quality variables measured are presented in Table 2.1.

Implementation of secondary effluent treatment in 1992 and closure of the kraft mill in 2001 have resulted in improved effluent quality, including reductions in total suspended solids (TSS) and biochemical oxygen demand (BOD) and elimination of AOX and dioxin/furans (Table 2.1). With the closing of the kraft mill in November 2001, dioxin/furan and AOX monitoring is no longer required. Effluent quality variables measured most recently during Cycle Six (2010 to 2012) were generally similar to those reported in Cycle Five (2008 to 2010).

In Cycle Six, indicating effluent was not acutely toxic to fish and invertebrates tested. On December 10, 2012, an effluent sample collected for acute toxicity testing from outfall #1 resulted in the mortality of three rainbow trout. While the test was not considered a failure (fewer than 50% of trout died), it was considered a very unusual result. As a result, an investigation into the cause of the mortalities was initiated by Catalyst Paper Corp. No mortalities were reported in the control samples or in samples collected from other outfalls at the same time. The mill is currently monitoring ammonia and ammonium concentrations in effluent from outfall #1 on an ongoing basis in an effort to identify the cause. The effluent sample was subsequently tested for metals, resin acids, and other compounds, but the source of the toxicity was not identified.

Figure 2.3 Effluent quality (annual averages), Catalyst Paper Corporation, Powell River Division, 1974 to 2012.



* AOX not measured after 2001.

2.4 EFFLUENT DISPERSION

2.4.1 1993 to 2001

Since 1993, the combined, treated effluent from all Powell River mill operations has entered Malaspina Strait through the submarine outfall (Hatfield 1994). Given numerous process changes since 1992, average effluent discharge rates from the Powell River pulpmill have steadily decreased over time (Figure 2.2). These lower volumes of effluent continue to be released to the receiving environment via the mill's diffuser, resulting in much more rapid dilution of effluent than occurred previously, when higher flows of effluent were released.

Dispersion of kraft mill effluent from the Powell River pulpmill prior to 1992 was examined through dye dispersion, oceanographic modeling, and water quality studies. These studies indicated that the 1% effluent zone could be delineated as a circle extending 1 km in radius from the outfall diffuser (Hatfield 1994). Effluent flows from the outfall increased in late 1992, when mill effluent flows were combined and released through the submarine outfall rather than the surface tailrace. The various effluent dispersion studies indicated that while patterns of effluent dispersion were expected to remain similar, the effluent 1% zone should be expanded to a circle extending 3 km in radius from the outfall diffuser (Hatfield 1994). Oceanographic modeling suggested that effluent would disperse along two main paths: south along Malaspina Strait to Jervis Inlet, or north to Savary Island and into the Strait of Georgia (Hatfield 1994). Additional information on these early effluent dispersion studies can be found in the pre-design reference document (Hatfield 1994).

2.4.2 2001 to 2012

Following the discontinuation of the Kraft mill in 2001, effluent dispersion flows were re-modeled by Hay and Company (Hayco) using the U.S. EPA PLUMES (UM) model (Hayco 2002). Modeled scenarios included effluent flows of 113,000 m^3/day and 120,000 m^3/day (characteristic of operational conditions at the time; average flow in 2007 was 99,758 m^3/day), and a range of ambient current velocities (data collected by the Canadian Hydrographic Service at a nearby meter). The U.S. EPA PLUMES (UM) model was used to ensure consistency with historical modeling of effluent dispersion. Modeling was conducted at the most shoreward (shallowest) port (#36), as dilution at this port was generally poorest (Hayco 2007) and provided the most conservative approach.

Modeling results indicated that except for short periods of time when ambient currents drop below 3 cm/s, pulpmill effluent is diluted to over 100:1 (i.e., less than 1% of release) immediately above the diffuser (port #36), with the depth of maximum rise estimated to be approximately 30 m. At lower ambient current velocities (at or below 3 cm/s), lower dilution ratios of approximately 87:1 to 98:1 were predicted to occur through vertical rise only. Through mixing upwards to the point of maximum rise, the effluent plume was predicted to spread horizontally to a diameter of approximately 9 to 11 m. Additional dilution associated with horizontal mixing at this final trapping depth would result in dilutions above 100:1 (i.e., concentrations below 1% of release) within 50 m from the diffuser.

2.4.3 Effluent Dispersion Post G12 Power Increase Project (2012)

As part of the G12 Power Increase Project and subsequent release of increased amounts of cooling water into Malaspina Strait, effluent dispersion flows were re-modeled by EBA Engineering (formerly Hayco) in 2010. Modeled scenarios included a pre-project discharge flow rate of 93,278 m^3/day with an effluent temperature of 34.9°C and a post-project discharge flow rate of 153,425 m^3/day (including additional cooling water) with an effluent temperature of 38°C. All discharge scenarios were analyzed for all four seasons (spring, summer, fall and winter) at all ports.

Modeling results indicate that except for ports #1 and #2 in the summer, all ports achieve 100:1 dilution within 100 m for the pre and post-project cases. Ports #1 and #2 are estimated to have a 100:1 dilution plume extent of 120.6 and 105.4 m respectively in summer, with remaining season <100 m from end of pipe. The average horizontal plume extent at 100:1 dilution for the pre and post project (40°C) flows is respectively 6.3 and 10.3 m in spring, 23.2 m and 45.5 m in summer, 8.8 m and 16.4 m in fall, and 12.5 and 34.7 m in winter (Hatfield 2010b). In all four seasons, compared to the lower pre-project flow case, the higher post project flow case causes the dilution ratio at maximum rise to decrease by 15-16% and the trapping depth to decrease by 0.3 to 1%. For the purposes of this study, the 120 m value was assigned as the 1% zone of effluent concentration. This value, while exceeding the 100 m benthic survey trigger, was still <250 m, granting the pulpmill continued exemption from completing a fish tissue survey.

In the summer of 2012, the G12 Project receiving environment monitoring program was conducted to assess potential changes in water quality as a result of the increased discharge from Outfall #1, and potentially, Outfall #4. Results of the monitoring program indicated that the G12 Project did not measurably affect the thermal regime of Malaspina Straight in the vicinity of discharges (Hatfield 2013).

2.5 SPILLS TO THE RECEIVING ENVIRONMENT

- On January 28, 2010, untreated effluent was released from outfall #2, located at the southeast end of the tailrace, due to a failure at pump station H between 10:22 and 10:36 am (Barkowski 2010). Approximately 210 m^3 of untreated effluent was released at a rate of about 250 L/s. The untreated effluent bypassed the primary clarifier, bioreactor, and secondary clarifier, and combined with cooling water before release. The spill was reported to authorities at 14:03, and the problem at pump station H was subsequently investigated by a professional electrical engineer. Data from online water quality meters indicated that the flow from outfall #2 reached a maximum temperature of 27°C and a maximum pH of 8.1, both below permit limits.

- On April 8, 2011, approximately 820 L of untreated effluent was released from outfall #2 while attempting to clear a plugged drain from the discharge line of pump C. The spill was reported to PEP and MOE.

- On June 20, 2011, an unknown volume of hogfuel leachate was released from storm sewer #33. A sample of the leachate was collected for sublethal toxicity analysis which resulted in no mortalities in either rainbow trout or *Daphnia magna.*

- On February 13, 2012, 16.5 m^3 of untreated effluent was released through outfall #2 due to an overflow at pump station C. The incident was reported to PEP and investigated by MOE.

- On September 4, 2012, approximately 3,500 m^3 of untreated effluent, including some dilution water, was released through outfalls #2, 3, and 4 after a total power loss to the pulpmill occurred. The incident was reported to PEP and is currently being investigated by EC.

- On September 18, 2012, approximately 100 m^3 of untreated effluent was released through outfall #2 after a partial power loss to an effluent pump station occurred. The incident was reported and is currently being investigated.

Table 2.1 Annual averages of process effluent quality variables for Catalyst Paper, Powell River Division, 2002 to 2012.

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production (ADt/d)											
Paper	1,260	1,296	1,235	1,215	1,305	1,328	1,330	1,322	1,495	1,453	1,248
Flow (m^3/d)	121,310	112,670	116,600	113,440	113,134	99,758	91,388	88,688	90,967	90,741	87,628
TSS (t/d)	0.4	0.9	2.1	2.4	2.5	2.2	1.5	1.5	1.3	1.5	1.5
BOD (t/d)	0.18	0.3	0.70	1.0	0.78	0.86	0.55	0.65	0.5	0.57	0.63
Conductivity (µS/cm)	680	790	820	854	920	937	834	881	881	NA	NA
AOX (kg/ADt)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,7,8 TCDD +(0.1[2,3,7,8 TCDF]) (pg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rainbow trout 96-hr LC50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
Daphnia 48-hr LC50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100

* Note that the Kraft mill was permanently closed in November 2001.

ND = non-detectable.

NA = not applicable.

2.6 SUMMARY OF PREVIOUS BIOLOGICAL MONITORING

This section summarizes results from previous biological monitoring studies focusing on fish populations, fish tissue, and benthic invertebrate communities, as well as water quality and sediment quality surveys. These summaries are based on information presented in the Powell River pre-design document (Hatfield 1994) and the Cycle One to Five interpretive reports (Hatfield 1997, 2000, 2004, 2007, 2010 respectively) (Table 2.2).

Table 2.2 Summary of environmental monitoring conducted during the Powell River pulpmill EEM Cycles One through Four, 1993-2010.

Study Component		EEM Cycle				
		Cycle One	Cycle Two	Cycle Three	Cycle Four	Cycle Five
		1993 to 1996	1997 to 2000	2001 to 2004	2004 to 2007	2008 to 2010
EEM Component	Sublethal Toxicity Testing	✓	✓	✓	✓	✓
	Fish Populations	✓	✓	✓[1]	-	-
	Fish Tissue	✓	✓	-	-	-
	Benthic Invertebrates	✓	✓	✓	-	-
Supporting Studies	Plume Delineation	-	-	✓[2]	✓[3]	✓[4]
	Water Quality	✓	✓	✓	-	-
	Sediment Quality	✓	✓	✓	✓	-

[1] A 28-day topsmelt survival and growth test was conducted as an alternate fish survey.

[2] Plume modelling study conducted by Hayco in 2002.

[3] Plume modelling study conducted by Hayco in 2007.

[4] Plume modelling study conducted by EBA in 2010.

2.6.1 Receiving Water Quality

Water quality variables analyzed in receiving water at Powell River during Cycle One included chloroform (as an effluent tracer), colour, tannins and lignins, total suspended solids, total phenols, total organic carbon, resin and fatty acids, and chlorinated phenolic compounds. None of these variables indicated the presence of effluent at surface or near-bottom (55 to 80 m) sample locations. Variables related to mill effluent (e.g., chloroform, resin/fatty acids, chlorinated phenolic compounds) were non-detectable in all samples.

Water quality variables (dissolved oxygen, salinity and temperature) were measured in Cycle Two as supporting variables for the oyster and benthic invertebrate surveys; results were generally similar among stations. In Cycle Three, dissolved oxygen, salinity, and temperature were measured as supporting variables for the benthic invertebrate survey. Dissolved oxygen ranged from 8.2 to 9.8 mg/L at depths from 29 m to 41 m, while salinity ranged from 25.7 ppt to 28.0 ppt and temperature ranged from 7.9°C to 8.1°C (Hatfield 2004).

2.6.2 Sediment Quality

Sediment collected in the vicinity of Powell River has consisted predominantly of sand, with smaller fractions of silt, clay and gravel. Total organic carbon concentrations are higher at near-field stations relative to far-field stations, likely due to historical fibre mat deposition near the mill.

Sediment variables measured during Cycle One included physical variables as well as resin/fatty acids and chlorinated phenolics. Sediments collected from the near-field zone exhibited slightly higher levels of resin/fatty acids and chlorinated phenolics relative to far-field and reference stations. Several resin/fatty acids were detected in all sediments; trace levels of chlorinated phenolics were observed in several near- and far-field sediments but not in reference sediments. Phenolic compounds may indicate historical contamination rather than effects from more recent effluent discharge.

Sediments sampled in Cycle Two were analyzed for total organic carbon (TOC), carbon:nitrogen (C/N) ratio, total sulphides, redox potential, chlorinated phenolics, and fecal coliforms. TOC and C/N ratios were highest in sediments near the mill and decreased with distance from the diffuser (Hatfield 2000). Total sulphides indicated greater anaerobic activity from organic material degradation in the near-field and along the northwest gradient relative to the southeast gradient. Redox potential was slightly correlated with distance from the diffuser. Chlorinated phenolic compounds were primarily observed in the near-field and along a northwest gradient. Fecal coliform levels indicated sewage contamination near Westview and along the northwest gradient to Scuttle Bay. Wood fibre and chips were observed in sediments from two near-field stations, which may be the result of the historical fibre mat and present chip barge activity near the mill.

Cycle Three sediments were analyzed for the same variables as in Cycle Two. TOC, total nitrogen, C:N ratio, redox potential, total sulphides and chlorinated phenolics were higher at near-field stations relative to stations along either gradient. All of these variables, except redox, were significantly correlated with distance from the diffuser. TOC and total sulphides values indicated low to gross impacts at near-field stations, based on "impact grades" presented in the *Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring*. Redox potential impacts ranged from low to gross on both gradients. Sediments were primarily composed of sand (70.6 to 98.8%).

In Cycle Four, a sediment quality survey was conducted to provide ongoing monitoring data on bottom sediments in the vicinity of the pulpmill, with samples collected from 280 to 1,800 m from the diffuser in April 2006. Sediments were analyzed for particle size, moisture content, TOC, total nitrogen, redox potential, total sulphides, and chlorinated phenolic compounds. Based on Environment Canada criteria for marine sediments, sediments sampled near the Powell River mill exhibited moderate to gross enrichment. Redox potential values indicated moderate to gross effects; however, total sulphides values indicated no or low impacts at all stations (Hatfield 2007). Based on these criteria, potential impacts of sediments on benthic communities in the vicinity of the mill were similar in Cycles Three and Four.

2.6.3 Benthic Invertebrate Community Surveys

A subtidal benthic invertebrate survey was conducted in the vicinity of Powell River in August 1988, prior to mill upgrades; three subsamples were collected from 14 stations. Mean density of organisms at stations within 1 km of the diffuser ranged from 614 to 9,343 organisms/m^2, while taxonomic richness ranged from 24 to 45 taxa. Mean density of organisms at stations located greater than 1 km from the diffuser ranged from 3,465 to 13,544 organisms/m^2, and taxonomic richness ranged from 38 to 66 taxa. Benthic invertebrate community structure throughout the study area was indicative of stable, unstressed systems. However, some evidence of organic enrichment was evident; especially at a station located near the tailrace (density was 81,918 organisms/m^2). Although density and taxonomic richness were lower near the diffuser, no overt negative impacts of the bleached Kraft mill effluent discharge on benthic invertebrate communities could be detected.

The Cycle One benthic invertebrate survey was conducted in the vicinity of Powell River (three near-field, three far-field and three far-far-field stations) and at Qualicum Beach (two reference stations). Methods in the 1988 and Cycle One surveys differed from those in subsequent cycles in that benthos were screed through a 180-µm screen rather that a 1-mm (1000-µm) screen used in later cycles.

Generally, stations in the vicinity of Powell River exhibited lower densities (but similar taxonomic richness) relative to Qualicum Beach (reference) stations. Mean density at near-field stations was slightly lower relative to far-field and far-far-field stations. Taxonomic richness at near-field stations was most similar to far-far-field stations and reference stations, while far-field stations generally exhibited the highest taxonomic richness. Cluster analysis grouped the near-field stations with various far-field and far-far-field stations; these exposed stations were more similar to each other than to the Qualicum Beach (reference) stations (Hatfield 1997). Discriminant analysis and multivariate statistics indicated that differences between exposed and reference stations for Powell River were not statistically significant.

Benthic invertebrate surveys were also conducted for Cycles Two and Three. Potential effects on benthic invertebrate communities were examined using density and richness endpoints (required EEM endpoints for these Cycles), using a statistical significance level of $p<0.05$ ($\alpha=0.05$, $\beta=0.80$). Critical effects size analysis was used to determine potential effects on evenness and the Bray-Curtis indices in Cycle Three. Cycle Two and Three benthic invertebrate surveys indicated no effects of effluent on benthic invertebrate communities at Powell River, based on correlational and critical-effect-size analyses (Hatfield 2004).

No benthic invertebrate surveys were conducted in Cycle Four or Five, due to the absence of significant impacts observed in Cycles Two and Three and amendments made to the PPER exempting a mill from completing an EEM benthic invertebrate survey if the mill's 1% effluent zone extended less than 100 m from the effluent outfall.

2.6.4 Fish Surveys

Alternative methods have been used for fish population surveys at Powell River given the marine waters and lack of barriers to fish movement. Insufficient numbers of finfish were collected during Cycle One for the adult fish survey; oysters were also collected and analyzed. In Cycle Two, a wild oyster survey was conducted as an alternative to the adult fish survey, given that oysters are sedentary and available along the coastline of Malaspina Strait (Hatfield 2000). Oysters collected in near-field and far-field areas exhibited very similar values for condition and shell density, while reference area oysters exhibited significantly higher condition and lower shell density. However, the effect of pulpmill effluent on oysters was inconclusive, given the very low levels of resin acids measured in oyster tissue (Hatfield 2000).

Cycle Three used an extended sublethal toxicity test (28-day topsmelt), which indicated that effluent effects were not likely in the receiving environment; toxicity testing conducted in Cycle Four indicated that effluent had no effect on topsmelt survival and growth. Fish populations surveys were not conducted during Cycle Four to Cycle Six due to an exemption based on the small extent of the 1% effluent zone (i.e., <250 from diffuser). Given the lack of a finfish sentinel species and viable alternative methods for trapped effluent, EEM fish surveys have been inconclusive.

Fish tissues were analyzed for dioxins and furans in the late 1980s, which resulted in the closure of the crab and oyster fisheries in November 1989. The oyster fishery reopened in February 1995 given low tissue dioxin levels. Consistently low levels of dioxin/furans in crab tissues enabled Fisheries and Oceans Canada to lift the fish consumption advisories. However, sanitary shellfish closures continue from Myrtle Point to Scuttle Bay due to sewage contamination.

No EEM fish tissue surveys were required at Powell River for Cycles Three to Six as concentrations of dioxins/furans in fish tissue were below Health Canada consumption guidelines in previous EEM cycles; fishing closures and consumption advisories related to dioxins and furans were also lifted.

Tiley and Bocking (2009) measured bioaccumulative contaminants in intertidal bivalves, including littleneck clams (*Protothaca staminea*), manila clams (*Venerupis philippinarum*), Nuttall's cockles (*Clinocardium nuttalli*), butter clams (*Saxidomus giganteus*), and Pacific oysters. intertidal bivalves were collected in July 2008 from eleven beaches within Sliammon traditional territory. These beaches included Scuttle Bay, Okeover Inlet, and Harwood Island beaches, Waterfront Beach, and Theodosia Inlet beaches (reference site). The study found only trace concentrations of dioxin and/or furan congeners, but elevated concentrations of four metals (cadmium, zinc, aluminum, and iron) that were sufficiently high that potential health risks could occur in the absence of consumption guidelines.

3.0 SUBLETHAL TOXICITY OF EFFLUENT

Summary of Sublethal Toxicity Testing (Winter 2010 through Summer 2012) for Catalyst Paper, Powell River Division:

- During Cycle Six, six test periods of sublethal toxicity testing were conducted on two species between February 2010 and October 2012;
- Echinoderm fertilization was affected at a mean effluent concentration of 64.4% (IC25);
- Algal reproduction was affected at a mean effluent concentration of 4.9% (IC25); and
- Based on a maximum 1% effluent concentration zone of 120 m from the Powell River outfall, maximum potential zones of sublethal effect from the effluent discharge point were 1.9 m for invertebrate fertilization, and 24.7 m for algal reproduction.

Federal and provincial government regulations require pulp and paper mills to undertake toxicity testing as part of their EEM programs to determine any potential lethality or inhibitory effects of their effluent on fish populations and fish habitat. Current EEM regulations require the use of sublethal toxicity tests to help meet the following objectives (Environment Canada 2010):

- Contribute to the field program as part of a weight-of-evidence approach;
- Compare process effluent quality between mill types and measure changes in effluent quality as a result of effluent treatment and process changes; and
- Contribute to the understanding of relative contributions of the mill to multiple discharge situations.

For Catalyst Paper, Powell River Division, which discharges to a marine receiving environment, Cycle Six sublethal toxicological testing included the following tests, as stipulated in the EEM Technical Guidance Document (Environment Canada 2010):

- Invertebrate fertilization test using an echinoderm (either the sand dollar *Dendraster excentricus*, or the purple sea urchin *Strongylocentrotus purpuratus*); and
- Algal reproduction test, using the marine red alga *Champia parvula*.

Sublethal toxicity testing of echinoderms for Powell River Division was undertaken by Cantest Inc. (Vancouver, BC; Winter 2010), Maxxam Analytics (Burnaby, BC; Summer 2010 to Winter 2011), and Nautilus Environmental (Burnaby, BC; Summer 2011 to Summer 2012). *Champia* tests were sublet to the Saskatchewan Research Council (Saskatoon, SK; Winter 2010) or AquaTox Testing & Consulting Inc (Guelph, ON; Summer 2010 through Summer 2012). A summary of reported endpoints is included with this Cycle Six interpretive report.

3.1 SUBLETHAL TOXICITY TEST METHODS

3.1.1 General Methods and Definitions

During Cycle One, quarterly tests were required for the year field studies were conducted. Since Cycle Two, the *Pulp and Paper EEM Guidance Document* (Environment Canada 2010) stipulates sublethal toxicological testing of process effluent during both winter and summer seasons each year. Testing for Cycle Six was initiated in Winter 2010 and continued until Summer 2012.

In Cycle Six, test seasons assigned were not necessarily representative of the date the test was conducted. The first test period of each year (the "winter" test period) was carried out between March and May. The second test period of each year (the "summer" test period) was carried out in October or November. Figures presented in this section provide both the test season name and actual test date to prevent any confusion. The intent of having two test periods per year is to ensure tests are evenly spaced approximately six months apart.

On each test date, a grab sample of effluent was collected by mill personnel according to the methodology described in the *Pulp and Paper EEM Guidance Document* (Environment Canada 2010) and shipped to the lab for testing; subsamples were shipped by the lab to Saskatchewan Research Council or Aquatox Testing & Consulting for *Champia* testing. Sublethal toxicity testing involved exposure of organisms to a series of effluent dilutions. All sublethal toxicity tests were conducted with controls to assess the background response of test organisms and determine the acceptability of the test using predefined criteria. In addition, in-house cultures were tested with a reference toxicant to monitor the health and sensitivity of the culture.

Algal reproduction and invertebrate fertilization tests provide an IC25 endpoint, which is an estimate of the concentration of effluent that causes 25% inhibition of a quantitative biological function, such as reproduction or growth. Confidence limits are given for each endpoint where possible.

3.1.2 Sublethal Toxicity Test Methods

General procedures for the echinoderm fertilization tests are based on the methodology document *Biological Test Method: Fertilization Assay Using Echinoids (Sea Urchins and Sand Dollars)*, Report EPS 1/RM/27, (December 1992, and November 1997 amendments) (Environment Canada 1997). The test assesses the fertilization success of an echinoderm using the sand dollar *Dendraster excentricus* or the purple sea urchin *Strongylocentrotus purpuratus*. Male and female gametes are exposed to the test effluent for 20 minutes. The percentage of eggs fertilized is compared between the controls and the sample concentrations to determine if any significant inhibition of fertilization is observed. The test result for fertilization (IC25) represents the percent effluent concentration where fertilization is reduced by 25% from control rates.

Procedures for conducting the marine algae (*Champia parvula)* tests are based on *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Marine and Estuarine Organisms*, Third Edition, EPA-821/R/02-014, October 2002 (US EPA 2002). The *Champia* test is a static, non-renewal, marine algal reproduction test where male and female plants are exposed to a test sample for a 48-hour period, followed by a six- to eight-day recovery period. The inhibition of cystocarp reproduction by 25% at the end of the recovery period is the effluent concentration endpoint (reproduction IC25) used to assess toxicity.

3.1.3 Zones of Effluent Concentration

Due to the effects of G12 Power Increase Project, described in Section 2.2.1, on the zones of effluent concentration, two different distances were used based on modeling completed by EBA Engineering (formally Hayco).

Prior to the operation of the G12 Power Increase Project, a zone of effluent mixing was determined through modeling completed in March 2007 based on effluent discharge rates (Hayco 2007). This study determined the maximum extent of effluent concentration of 1% (i.e., 100:1 dilution) or greater, potentially present in the receiving water environment. For the Powell River EEM study, the maximum extent of 1% effluent was defined as a radial distance of approximately 50 m from the pulpmill diffusers.

An additional modeling study was completed by EBA Engineering in 2010 to assess the potential effects of the G12 Power Increase Project and the increases effluent discharge rates on the zone of effluent mixing. Post G12 Power Increase Project, the worst case scenario maximum extent of 1% effluent was defined as a radial distance of approximately 120 m from port #36 of the pulpmill diffuser.

A maximum potential zone of sublethal effect was calculated for each test species from the geometric mean of the IC25 results and the extent of the 1% effluent concentration zones, both pre and post G12 Power Increase Project, as per Environment Canada (2010). The potential zone of sublethal effect is the maximum distance from the effluent discharge where a specified effect may be expressed for a test species and can be used to describe the “downstream” area where the effluent concentration exceeds the geometric mean of the endpoints. These maximum potential zones of sublethal effects were calculated as follows:

$$\text{Zone (m)} = \frac{\text{Extent of 1\% effluent zone(m)}}{\text{Geometric mean of IC25 results}}$$

This model assumes simple, linear dilution of effluent, which is not realistic for this situation, because Catalyst Paper, Powell River Division effluent is discharged through a multi-port diffuser that rapidly dilutes effluent into the marine environment upon release.

3.2 RESULTS AND DISCUSSION

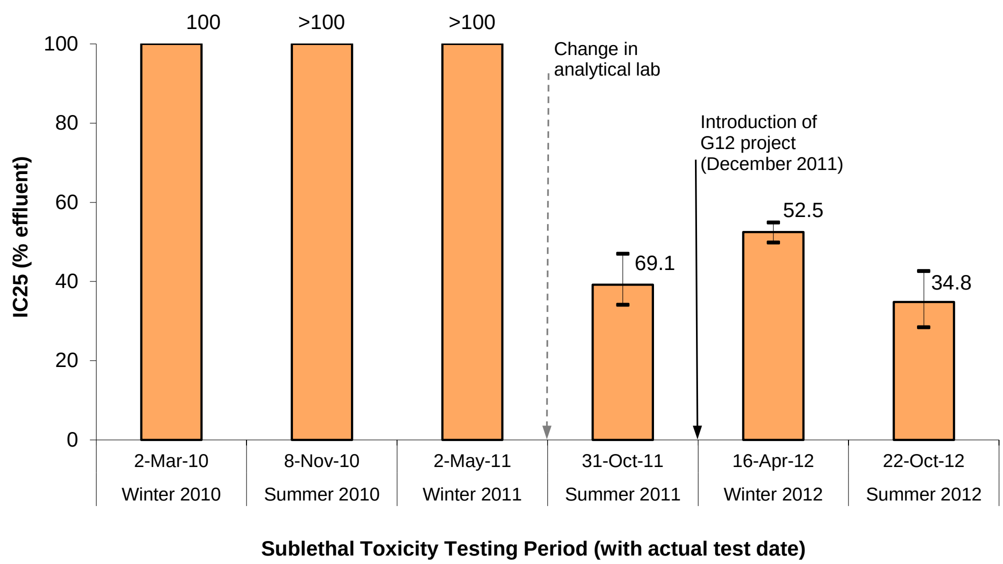
Catalyst Paper, Powell River Division conducted six sublethal toxicity tests from Winter 2010 through Summer 2012 for Cycle Six. Appendix A1 provides a summary of Cycle Six sublethal toxicity test results, including dose-response curves for all tests conducted.

3.2.1 Echinoderm Fertilization Test

Fertilization (IC25) results for Cycle Six echinoderms using purple sea urchins (*Strongylocentrotus purpuratus*) are summarized in Figure 3.1. Results ranged from 26.6% to >100% v/v effluent, for a geometric mean of 64.4%. In the first three test periods of Cycle Five, no effect of effluent on echinoderm fertilization was observed. During the remaining three test periods, effects on echinoderm fertilization were variable. Overall results in Cycle Six suggest slightly reduced effluent quality compared to Cycle Five, but an improvement in effluent quality compared to Cycle One through Cycle Four (Figure 3.3).

Retest sampling was required during both the Summer 2011 and Winter 2012 test periods. In both test events, sand dollars (*Dendraster excentricus*) were used as the initial test species, and sea urchins were used for the retest. During the Summer 2011 test event, sand dollars were at the end of their spawning season and egg and sperm quality was poor, while in Winter 2012, inclement weather conditions prevented the collection of sea urchins for the initial sample date, so sand dollars were instead used for the testing. However, in both cases, echinoderm fertilization tests did not meet the acceptability criteria of 50% fertilization in the control samples. All subsequent testing using sea urchins met all control sample criteria.

Figure 3.1 Effect of exposure to Catalyst Paper, Powell River Division effluent on echinoderm fertilization, expressed as IC25 ±95% confidence limits, EEM Cycle Six.

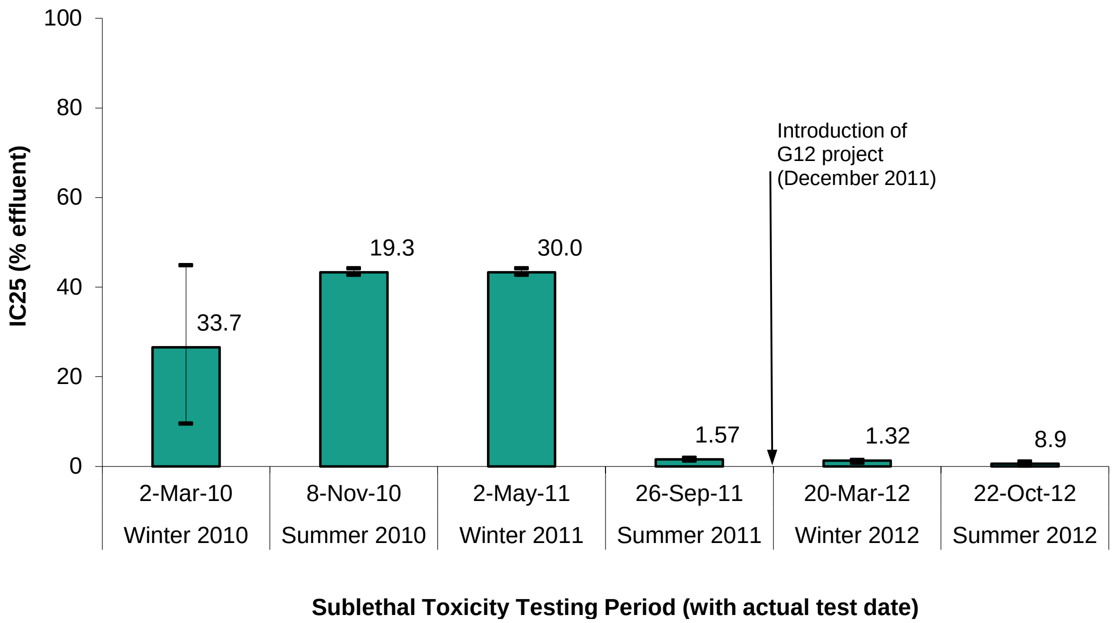


3.2.2 *Champia parvula* Algal Reproduction Test

Champia parvula IC25 reproduction results for Cycle Six are summarized in Figure 3.2.

Algal reproduction was affected by effluent at concentrations ranging from 0.59% to 43.3% v/v effluent with a geometric mean concentration of 4.9%. Effects for Cycle Six were variable, and indicate a trend of increasing toxicity across the cycle, as well as increasing toxicity relative to previous test cycles.

Figure 3.2 Effect of exposure to Catalyst Paper, Powell River Division effluent on algal reproduction, expressed as IC25 ±95% confidence limits, EEM Cycle Six.



3.2.3 Potential Zone of Sublethal Effect

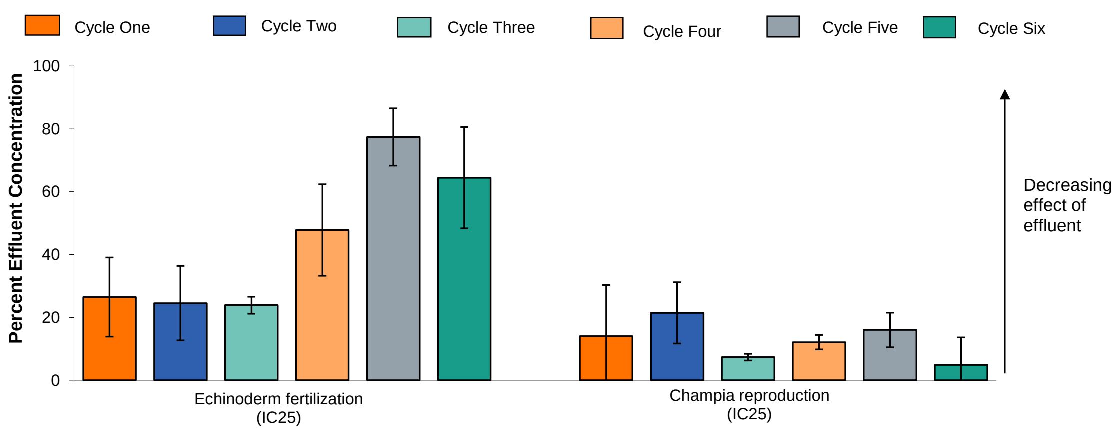
A detail description of the 1% effluent zone for Powell River is presented in 3.1.3. In order to allow direct comparisons across all cycles, the zone of sublethal effect for Cycle One through Cycle Five were recalculated to the defined 1% effluent zone (120 m) for this Cycle Six report. Calculations of geometric means and potential zones of sublethal effect can be found in Appendix A1.

Table 3.1 Geometric mean and potential zone of sublethal effect, Catalyst Paper, Powell River Division, EEM Cycle One through Cycle Six.

	Potential Zone of Sublethal Effect (m)					
	Cycle One	Cycle Two	Cycle Three	Cycle Four	Cycle Five	Cycle Six
Echinoderm Fertilization	4.53 m	4.89 m	5.03 m	2.51 m	1.55 m	1.86 m
Algal Reproduction	8.56 m	5.60 m	16.29 m	9.91 m	7.49 m	24.67 m

The zone of sublethal effect increased for algal reproduction (from 7.49 m to 24.67 m) during the Cycle Six test period, relative to Cycle Five. For echinoderm fertilization, the zone of sublethal effect remained relatively consistent with results for Cycle Five (1.86 m and 1.55 m respectively), although both suggest a slight reduction in effluent quality relative to Cycle One through Cycle Four. Overall results for Cycle Six suggest a reduction in effluent quality relative to previous cycles.

Figure 3.3 Geometric means of IC25 and LC50 results from sublethal toxicity tests of Catalyst Paper, Powell River Division effluent for EEM Cycle One through Cycle Six.



3.3 CONCLUSIONS

The quality of effluent discharged from the Powell River pulpmill, as measured by sublethal toxicity results, was similar to, or slightly decreased relative to effluent quality observed in previous EEM cycles (Table 3.1, Figure 3.3). Algal reproduction was affected at a mean effluent concentration of 4.9% while invertebrate fertilization was affected at a mean effluent concentration of 64.4%. Because of the rapid diffusion of effluent expected from the multi-port diffuser installed at the Power River Pulpmill, high effluent concentrations would not be expected to occur in the receiving environment around Powell River beyond the initial effluent mixing zone, immediately above the effluent diffuser.

The addition of Catalyst Paper, Powell River Division effluent to the marine environment should not have resulted in any observable toxicity during Cycle Six given the extremely small zone of sublethal effect near the diffuser. Potential effects were predicted to be possible up to a maximum extent of 24.7 m from the effluent diffuser.

4.0 BENTHIC INVERTEBRATE SURVEY

Summary of Benthic Invertebrate Community Survey for Powell River EEM Cycle Six, March 2012:

- Gradient sampling design with 13 stations extending northwest and southeast of the mill; two subsamples from each station were analyzed for benthos with a third analyzed for sediment quality;
- Significant effects were observed for taxa richness and the Bray-Curtis index when compared to distance from the diffuser and C/N ratio;
- No effects were observed for density, Simpson's diversity index or evenness when compared to either distance from the diffuser or C/N ratio;
- Sediments near the diffuser, while improving, remain organically enriched and exhibit reducing conditions; remaining stations exhibited sediment conditions indicative of natural conditions/ reference areas;
- Although effects on benthic invertebrates were observed in Cycle Six, sediment conditions improved and benthic densities increased at nearly all stations, relative to previous cycles. In addition, an increase in total taxa richness was observed in Cycle Six largely due to an increase in the number of epifaunal taxa that inhabit "harder" sandy substrates, suggestive of improving sediment conditions and reference type areas; and
- Given the improving state of the sediment quality near the Powell River Pulpmill between Cycle Three and Cycle Six, it is evident that the anoxic conditions and enrichment in the area surrounding the pulpmill diffuser are from historical pulpmill discharges and effects on benthos were likely not from current mill discharges.

4.1 INTRODUCTION

A subtidal benthic invertebrate community survey was undertaken in the vicinity of the Powell River pulpmill in March 2012 to meet federal environmental effects monitoring (EEM) Cycle Six requirements. The objective of the invertebrate community survey is to determine if there is an effect on benthos in relation to effluent discharge from the Powell River pulpmill and, if appropriate, the magnitude and extent of any observed effect. Specifically, the goal of the survey is to determine structural differences (i.e., density, tax richness, diversity, shifts in taxa dominance, etc.), if they exist, in invertebrate communities with increasing distance from the pulpmill diffuser discharge point (Figure 4.1).

This section provides results of the EEM benthic invertebrate community survey conducted in March 2012 for Cycle Six. Data are reported for benthic invertebrates and supporting environmental variables, as well as methodology changes, sieve size, QA/QC and comparisons to historical surveys (Cycles Two and Three). This section follows the reporting guidelines recommended by Environment Canada for EEM Cycle Six interpretive reports (Environment Canada 2010).

4.2 METHODS

4.2.1 Benthic Invertebrate Field Sampling

A radial gradient design survey was conducted in March 2012 similar to the survey undertaken in the EEM Cycle Three program. A total of thirteen stations were sampled in vicinity of pulpmill primary discharge outfall (Outfall #1; Figure 4.1). Due to the small size of the 1% effluent concentration zone and its seasonal variability, the proposed sample sites presented as a radial gradient design with increasing distance from the diffuser in both a northwest and southeast direction.

As per the *Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring* (Environment Canada 2010), two replicate samples were collected at each station for a total of 26 samples (2 replicates x 13 stations).

4.2.1.1 Station Selection

Stations were selected along gradients of exposure from Outfall #1 to a distance of approximately 7 km northwest and 6 km southeast. Locations of proposed sampling stations were consistent with those sampled in Cycle Three with the following changes:

- Removal of stations PRB10, PRB11, PRB9 and PRB7. These stations showed no effects in Cycle Two and Three and are well beyond the current 1% zone; and
- Addition of two stations, PRB100NW and PRB100SE, immediately adjacent to the diffuser, approximately 100 m northwest and southeast from Port #1 and used to assess effluent effects on benthos at the 100-m trigger distance.

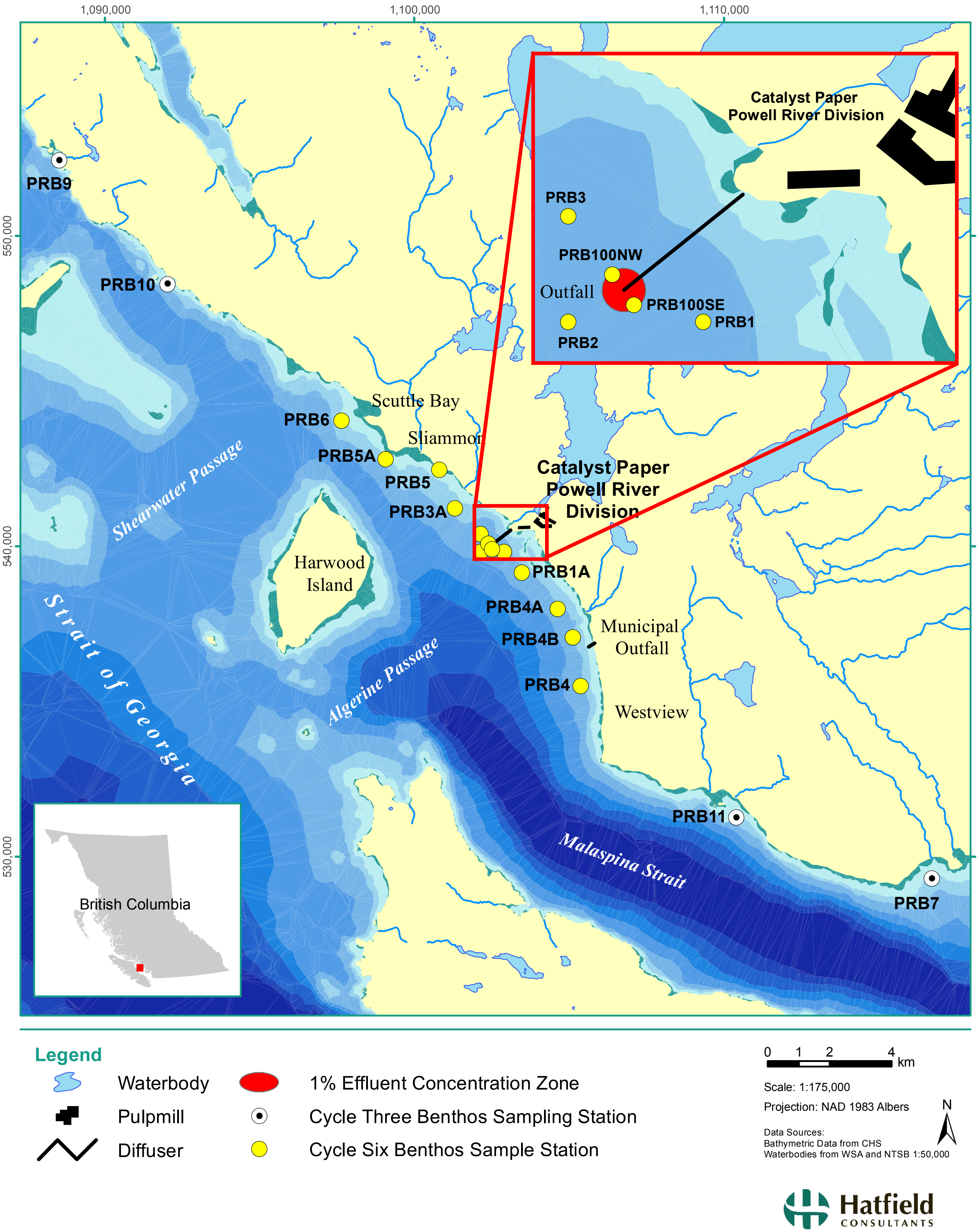
All stations were selected in consideration of known sediment transport patterns, particle size data, areas of contamination (e.g., log-booming grounds, mine tailings, sanitary shellfish closures) and current effluent dispersion patterns.

Table 4.1 summarizes the proposed sampling stations for the Powell River Cycle Six program.

Table 4.1 Location, distance and depth of stations sampled during the benthic invertebrate survey, Powell River EEM Cycle Six, March 5 to 8, 2012.

Stations	ID	Easting	Northing	Distance (m)	Depth (m)	Date Sampled (yyyy/mm/dd)
Stations on Northwest Gradient						
Scuttle Bay	PRB6	382153	5529255	7,100	35	2012/03/07
Sliammon North	PRB5A	383434	5527934	4,600	44	2012/03/07
Sliammon South	PRB5	384844	5527170	3,000	33	2012/03/07
Powell River	PRB3A	385666	5526314	1,800	40	2012/03/07
Stations Nearest Diffuser						
North of Diffuser	PRB3	387203	5525628	320	43	2012/03/06
Diffuser (NW100)	PRB100NW	386690	5525100	100	78	2012/03/07
Diffuser (SE100)	PRB100SE	386852	5524882	100	75	2012/03/07
South of Diffuser	PRB1	387678	5524652	280	41	2012/03/06
End of Diffuser	PRB2	387658	5524656	520	43	2012/03/06
Stations on Southeast Gradient						
North Westview	PRB4A	388892	5522951	2,700	61	2012/03/07
Breakwater	PRB1A	387678	5524652	1,200	38	2012/03/06
Westview WWTP	PRB4B	389359	5522066	4,000	52	2012/03/07
South Westview	PRB4	389580	5520379	5,900	61	2012/03/07

Figure 4.1 Location of benthic invertebrate sampling stations Powell River EEM Cycle Six, March 2012.



4.2.1.2 Modifications to the Benthic Invertebrate Sampling Design

There were no changes in methodology relative to the EEM Cycle Six Design Document (Hatfield 2012). However, Cycle Three coordinates for Site PRB5 placed the station in <5.0 m of water and so the station was moved seaward to a depth of ~35 m (similar to the depth observed in Cycle Three).

4.2.1.3 Sampling Procedure

Sampling Platform

Samples were collected from the MV *Lobo*, a custom-built, 7-m aluminum vessel with dual, four-stroke, 115-hp Yamaha outboard engines designed specifically for marine sediment and habitat-related work. The vessel was equipped with a hydraulic winch system, VHF radio, and all safety equipment required by Transport Canada. Station locations were determined using an on-board, differentially corrected Global Positioning System (GPS) integrated with digital nautical charts. Depth at sampling stations was recorded from the depth sounder.

Sample Collection

Sediment and benthos samples were collected using a stainless-steel, 30-cm Van Veen grab supplied by Aquametrix Research. The total surface area sampled by this dredge was 0.1 m^2 with a volume of 20 litres. Upon grab retrieval, the hinged doors were lifted and photographs of each benthic sample were collected. Small samples of sediment, to be analyzed for oxidation/reduction (redox) potential, total sulphides, total organic carbon and total nitrogen were removed by collecting two sediment volumes measuring 4 cm long by 4 cm wide by 2 cm deep from each grab sample. Following removal of the sediment samples, the grab was then opened and dumped into a large plastic tote, covered and labeled, taken to dock, and field sieved by the consulting taxonomist (Biologica Environmental Services, Appendix A2) using a stand equipped with 1 mm and 0.5-mm sieves.

Two additional sediment grabs were collected for particle size and chlorinated phenolic compounds. The top 2 cm of each grab were removed, composited, homogenized, and transferred to a 125-mL glass jar (one jar for each analysis). Chlorinated phenolics, serve as a tracer for long-term effluent exposure (historical, given its association with chlorine bleaching), particularly in the area of the mill.

Sample Sieving and Preservation

Following collection of all subsamples from each station, benthic invertebrate samples were immediately sieved onshore by Biologica Environmental Services (Biologica). The contents of the sample were placed in a washtub with 0.5-mm stainless steel mesh screen on its bottom surface and sieved by placing the screened wash-pan in a specially designed holding shelf and gently washing the samples with seawater to allow the <0.5 mm fraction to pass through the mesh sieve. During this process, larger organisms were removed and placed in station labelled vials for identification. Following sieving, each subsample was placed in a 1-L plastic jar, appropriately labelled with the station and subsample number and preserved with 10% buffered formalin. Benthic samples were taken back to the Biologica taxonomic laboratory for processing.

4.2.2 Taxonomic Analysis

Benthos samples were taken to the Biologica Environmental Services laboratory in Victoria, BC, for sorting and taxonomic identification.

Invertebrate samples were sorted to 1-mm and 0.5-mm size fractions; all invertebrates retained in the 1-mm fraction were identified to the lowest possible taxonomic detail, typically species (Appendix A2).

Two samples from Powell River (PRB5-R2 and PRB5A-R2) were selected for resorting to determine sorting efficiency. As per EC recommendations, sub-sampling was done at the marine mill level, pooling the samples collected from the Powell River pulpmill, Howe Sound pulpmill, and Port Alice pulpmill, and selecting two random samples from each mill. Biologica re-sorted these random samples following the initial spot checks that are conducted on all sampled processed in the lab to meet efficiency requirements of >90%.

The precision and accuracy of Biologica's sub-sampling techniques were verified to ensure 20% precision and accuracy was measured; results are presented in Appendix A2.

4.2.3 Supporting Environmental Measures

4.2.3.1 Water Quality

Near-bottom water quality measurements were collected at each sampling station using a YSI-85 multi-parameter probe for the following variables.

- Dissolved oxygen (mg/L);
- Temperature (ºC);
- pH; and
- Salinity (‰).

4.2.3.2 Sediment Quality

Two sediment samples were removed from each benthos replicate immediately upon collection. One sample (~30 ml) was measured immediately on board for:

- Total sulphides (mg/L); and
- Oxidation/reduction (redox) potential (Eh).

Redox potential and sulphides were analyzed in the field by Aquametrix Research using methods recommended by the BC Ministry of Environment's *Protocols for Marine Environmental Monitoring* (BCMOE 2002). Sulphide readings were taken using a ThermoOrion 290A plus pH/ion/mV meter and 9678BNWP probe; redox potential was analyzed using a VWR Symphony SP301 pH/ion/mV meter and a 9616BNWP probe by ThermoOrion.

The second sample was shipped to the ALS Environmental laboratory in Vancouver for the following analyses:

- Total organic carbon (%); and
- Total nitrogen (%).

An additional sample was taken from a separate 3rd grab and shipped to ALS for the following analyses:

- Particle size distribution; and
- Chlorinated phenolic compounds.

All containers and lids were labeled with the appropriate sample identification number. Matching sample identifications were applied to the primary data sheet for each station. At each station, depth, geographic coordinates, photographs, and observations regarding sediment characteristics will be recorded.

4.2.4 Analytical Approach

4.2.4.1 Data Handling

Data were entered into an electronic spreadsheet by the consulting taxonomist, who checked for transcription errors. Taxonomic records were organized into adults (which included "adult" and "intermediate" classifications) and juveniles for Cycle Six. Juvenile taxa were reported separately from adult taxa for all samples and stations as required.

Density

All count data were multiplied by the following density factor (DF) in order to estimate the number of organisms per m^2, as required for electronic reporting for the national database (Appendix A2):

$$DF = \frac{1\ m^2}{\text{(grab sample area – area of subsamples taken for sediment chemistry)}}$$

$$DF = \frac{1}{[0.1\ m^2(\text{grab sample area}) - 3 \times 0.0004\ m^2(\text{redox}) - 1 \times 0.0004\ m^2(\text{TOC/TN})]}$$

$$DF = 10.13$$

Individual densities were reported per replicate and station densities were calculated using the average of all replicates.

Total adult taxonomic richness (i.e., to family level and to lowest possible taxonomic level) was also calculated for each sample.

4.2.4.2 Biotic Indices

Three biotic indices were calculated to describe benthic community composition for each area, and compared among stations. These indices were calculated using average taxon density data for each station. Descriptions of each biotic index area are presented below and further described in the EEM Technical Guidance Document (Environment Canada 2010).

Evenness Index

Evenness can be quantified for each station as presented in Smith and Wilson (1996). The index takes into consideration the abundance of each taxon in proportion to total abundance, and the taxonomic richness at the station. Evenness is calculated as:

$$E = 1/\sum_{i=1}^{S}[pi]^2/S$$

where: E = Evenness;

p_i = proportion of i^{th} taxon at the station; and

S = number of taxa in the sample.

Simpson's Diversity Index

Simpson's diversity can be calculated for each station as presented in Krebs (1985). The index takes into account both the abundance patterns and the taxonomic richness of the community and determines for each taxonomic group at a station, the proportion of individuals that it contributes to the total in that station. Diversity is calculated as:

$$D = 1 - \sum_{i=1}^{s}[p_i]^2$$

where: D = Simpson's index of diversity;

S = the total number of taxa at the station; and

p_i = the proportion of the i^{th} taxon at the station.

Bray-Curtis Dissimilarity Coefficients

The Bray-Curtis dissimilarity coefficient is a distance measurement that reaches a maximum value of "1" for two sites that are entirely different and a minimum of "0" for two sites that possess identical descriptors (Bray and Curtis 1957). Bray–Curtis dissimilarity coefficients were calculated to compare the degree of similarity between individual stations and a reference median. Dissimilarity coefficients for the reference median and individual stations were calculated using SYSTAT 10 (SPSS Inc. 2000). The Bray-Curtis index is calculated as:

$$B - C = \frac{\sum_{i=1}^{n} \left| y_{i1} - y_{i2} \right|}{\sum_{i=1}^{n} \left(y_{i1} + y_{i2} \right)}$$

where: B-C = Bray-Curtis distance between sites 1 and 2;

y_{i1} = count for species i at site 1;

y_{i2} = count for species i at site 2; and

n = total number of species present at the two sites.

Given the Powell River EEM survey used a gradient design, no true reference stations were available for calculation of a reference median for comparison. Therefore, the reference median was calculated for Bray-Curtis comparisons using two furthest stations from the mill (i.e., PRB6 and PRB4).

4.2.4.3 Statistical Analysis

Analyses were conducted using Excel 2007, SYSTAT 12 (SPSS Inc. 2012) and R version 2.14.1.

Regressions

Linear regression was used to determine if significant linear relationships existed among benthic community metrics and exposure gradients. In this study, the exposure gradient was defined in two ways: as absolute distance from the pulpmill diffuser; and a carbon:nitrogen (C/N) ratio, which provides an indication of the ratio of organic matter present in sediments that was derived from terrestrial sources (such as pulpmill solids) or marine sources (Macdonald and Crecelius 1994). Supporting environmental variables also were examined against these exposure gradients using regression analysis.

Residual plots from regressions were evaluated to ensure that assumptions of the regression model were met. If data met these assumptions, regressions were conducted using $\log_{10}$-transformed variables to determine if the fit of the model improved. If the fit had improved, results for $\log_{10}$-transformed variables were reported but if that fit did not improve, results from untransformed variables were reported. If $\log_{10}$-transformed data still failed to meet assumptions of model, regressions were conducted using ranked data.

All tests were conducted at a significance level of $\alpha = 0.10$.

Determination of Effects

Results of regression analyses were used to determine whether there are effects on benthic invertebrates along the exposure gradient, where a statistical effect was defined as a statistically significant relationship between a metric and distance or a metric and an effluent exposure indicator.

The magnitude and direction of observed effects were calculated and compared to the EEM effect criterion for a biologically (rather than simply statistically) significant effect of ±2 standard deviations from the reference mean for suitable "reference" stations (i.e., the two gradient stations furthest from the mill and were also used as reference stations in Cycle Three).

In this gradient-based study, which used a regression-based rather than analysis-of-variance-based approach to assess effect, a relationship between a benthic invertebrate community metric and distance from the pulpmill diffuser with a correlation coefficient (r) of at least |0.707| was considered to be biologically significant, which was equivalent to ±2 times the standard deviation of the reference mean (Environment Canada 2010).

Correlations

Spearman's rank correlations were used to evaluate the relationships between benthic community metrics and supporting environmental variables. Correlations greater than r_s of |0.503| for n = 13 (number of stations) (α = 0.10) were indicative of statistically significant relationships. Moderate correlations were defined as those ranging from |0.50| to |0.75|. Strong correlations were defined as those ranging from |0.75| to |1.00|.

Cluster Analysis

Cluster analysis is a multivariate procedure for detecting natural groupings in data. It is based on the relative abundance of taxa from each station; taxa that are abundant tend to influence the cluster analysis more than rare taxa. The cluster analysis was conducted on Bray-Curtis dissimilarity coefficients created from abundance data for individual taxa. These Bray-Curtis dissimilarity coefficients differ from those described in the preceding section in that they include pair-wise comparisons for all stations, rather than being restricted to comparisons to the reference median.

Power Analysis

Post-hoc power analysis was conducted to verify the ability of regression analyses to detect an effect, which was defined as a relationship with a correlation coefficient (r) of at least |0.707| (Environment Canada 2010, Cohen 1988). Regression analyses were considered to have sufficient power when P≥ 0.90. Analyses were only completed for insignificant relationships to verify that the design had sufficient statistical power.

Power analysis was conducted using G*POWER (Faul and Erdfelder 1992).

4.3 RESULTS

Results of the benthic invertebrate community survey are presented below (Table 4.2 and Figure 4.2 to Figure 4.4); raw benthic data are presented in Appendix A2.

Table 4.2 Benthic invertebrate community statistics, Powell River EEM Cycle Six, March 2012.[1]

Station	Diffuser Distance (m)	Mean Density (#/m²)	Total Richness (# families)	Simpson's Diversity	Evenness	Bray-Curtis
Stations on Northwest Gradient						
PRB6	7,100	5,535	77	0.935	0.201	0.231
PRB5A	4,600	9,420	82	0.925	0.162	0.434
PRB5	3,000	8,795	68	0.907	0.158	0.381
PRB3A	1,800	9,755	63	0.935	0.245	0.420
Stations Nearest Diffuser						
PRB3	320	8,375	45	0.921	0.281	0.667
PRB100NW	100	4,755	40	0.663	0.074	0.600
PRB100SE	100	7,885	45	0.773	0.098	0.547
PRB1	280	5,315	36	0.843	0.177	0.714
PRB2	520	3,525	45	0.874	0.208	0.610
Stations on Southeast Gradient						
PRB4A	2,700	3,460	43	0.920	0.291	0.494
PRB1A	1,200	4,720	49	0.944	0.366	0.490
PRB4B	4,000	11,020	81	0.860	0.088	0.480
PRB4	5,900	4,385	61	0.894	0.155	0.259

[1] Adult organisms only (which includes intermediates).

Figure 4.2 Mean density (organisms/m²) per station, Powell River EEM Cycle Six, March 2012.

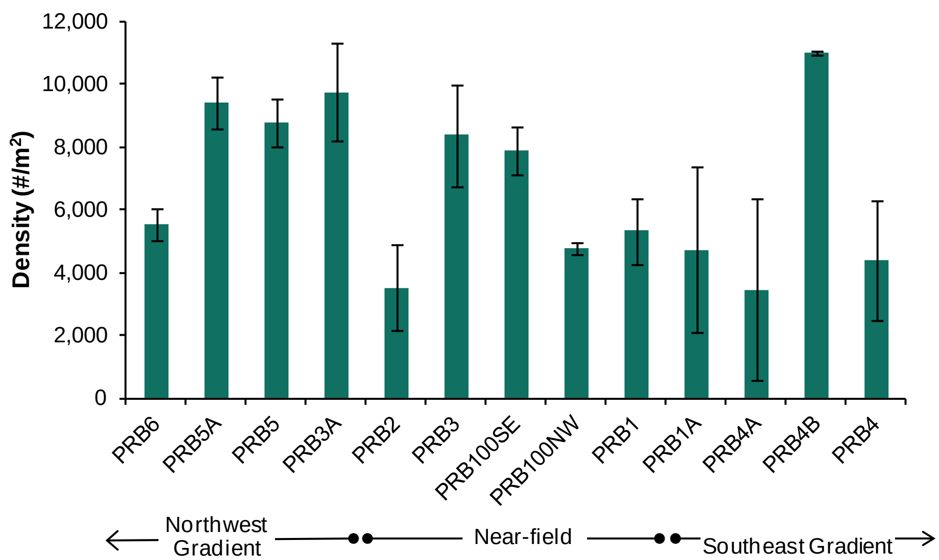
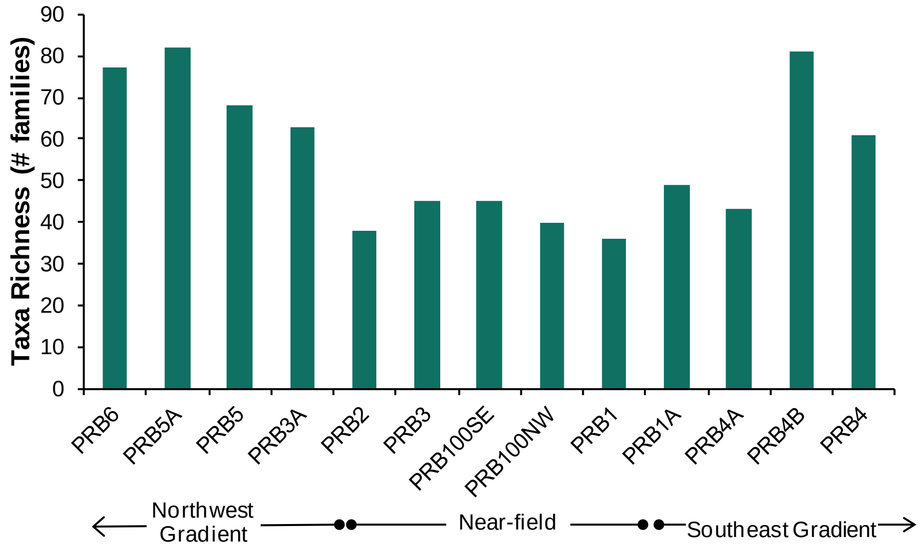


Figure 4.3 Total taxa richness per station, Powell River EEM Cycle Six, March 2012.



4.3.1 Density and Taxonomic Richness

Benthic invertebrate density (>1 mm in size) was highly variable among and within stations (Table 4.2; Appendix A2). Station densities ranged from 3,525 organisms/m^2 at PRB2 (immediately out from the diffuser), to 11,020 organisms/m^2 at PRB4B (near the municipal outfall). Within the predicted zone of 1% effluent dispersion (i.e., stations PRB100NW and PRB100SE), densities were 4,755 and 7,885 organisms/m^2, respectively. The largest difference between two replicates of the same station was observed at PRB6 where replicate densities differed by 5,770 organisms (3.2 times). In Cycle Six all stations had densities near or considerably higher than densities observed at the same station in Cycle Three. In addition, the two stations closest to the diffuser (PRB100NW and PRB100SE) had densities above the Cycle Six program median density of 5,535 organisms/m^2 (Table 4.2).

Taxa richness varied among stations, ranging from a low of 36 taxa at PRB1 to a high of 82 taxa at PRB5A, and generally increased with increased distance from the diffuser (Table 4.2). Similar to density, all stations in Cycle Six had total taxa richness near or higher than those observed at the same station in Cycle Three.

Lower densities and taxa richness of juvenile invertebrates were observed at all stations (Table 4.3) compared to adult results, with spatial patterns of density and richness similar to those observed for adult organisms.

Figure 4.4 Benthic invertebrate community evenness, Powell River EEM Cycle Six, March 2012.

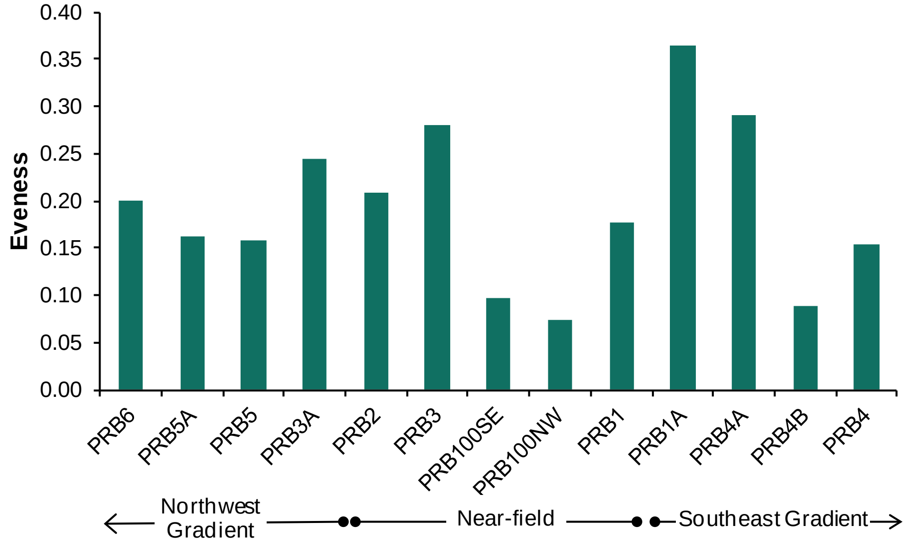


Figure 4.5 Benthic invertebrate community diversity (Simpson's index), Powell River EEM Cycle Six, March 2012.

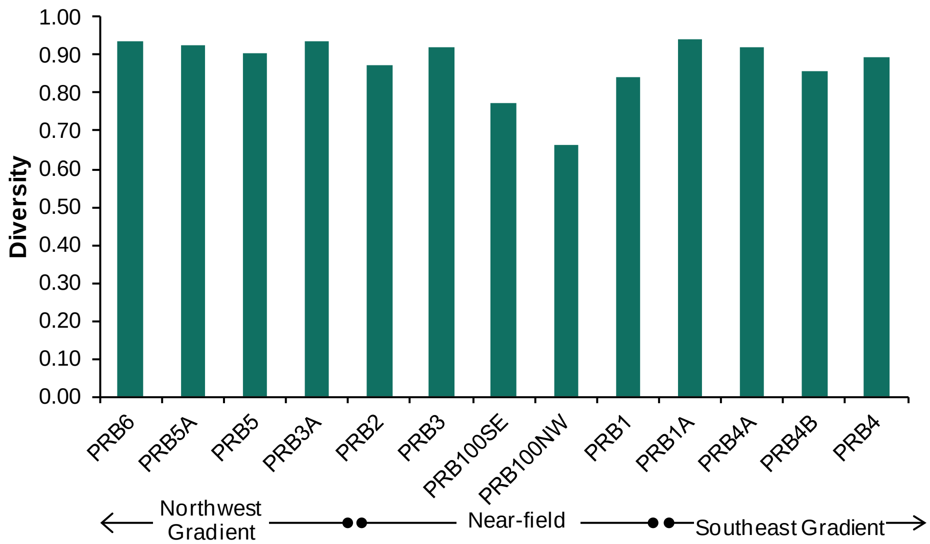
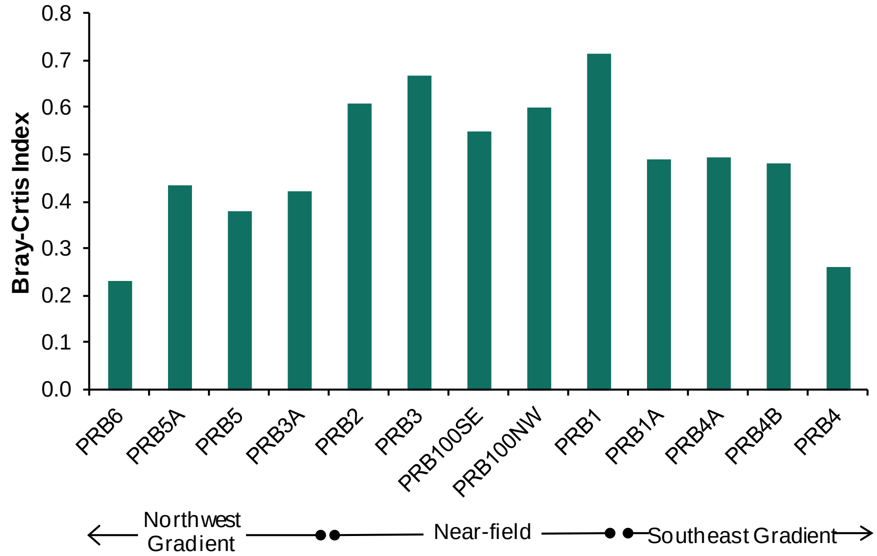


Figure 4.6 Benthic invertebrate community Bray-Curtis Index, Powell River EEM Cycle Six, March 2012.



4.3.2 Evenness Index

Evenness ranged from 0.074 at station PRB100NW to 0.366 at station PRB1A and was lowest at the two stations closest to the diffuser (Figure 4.4). Evenness was highly variable among southeast gradient stations, however; was fairly consistent along the northwest gradient.

4.3.3 Simpson's Diversity

Simpson's diversity index ranged from 0.663 at station PRB100NW to 0.944 at station PRB1A. Diversity generally increased with increased distance from the diffuser, with the two stations closest to the diffuser (PRB100NW and PRB100SE) representing the lowest diversities 0.663 and 0.733, respectively (Figure 4.5).

4.3.4 Bray-Curtis Index

Using the two furthest stations from the pulpmill as a reference median (PRB6 and PRB4), dissimilarity was highest at stations PRB3 and PRB1 (Table 4.2). Generally, increasing invertebrate community similarity was observed with increasing distance from the diffuser (Figure 4.6).

Table 4.3 Juvenile invertebrate density and taxa richness, Powell River EEM Cycle Six, March 2012.

Station	Diffuser Distance (m)	Mean density (#/m^2)	Total Richness (# families)
Stations on Northwest Gradient			
PRB6	7,100	485	27
PRB5A	4,600	1,140	32
PRB5	3,000	880	20
PRB3A	1,800	965	27
Stations Nearest Diffuser			
PRB3	320	660	9
PRB100NW	100	220	9
PRB100SE	100	595	15
PRB1	280	430	9
PRB2	520	420	10
Stations on Southeast Gradient			
PRB4A	2,700	290	16
PRB1A	1,200	500	18
PRB4B	4,000	1,325	25
PRB4	5,900	290	21

4.3.5 Community Composition

Table 4.4 presents the most abundant adult taxa for each station with taxa listed in decreasing order of density for the entire Cycle Six Program; these taxa comprised approximately 75% of the total density. In Cycle Six, the sedentary polychaete, *Mediomastus californiensis* was the most abundant taxon and comprised 14.5% of the total density across all sites. This taxon was the dominant family at all stations with the exception of stations PRB1, PRB3, PRB2 (Cycle Three near-field stations) and PRB4A and PRB6. This differed from Cycle Three results (last benthic program) where the sedentary polychaete *Prionospio lighti* was the most abundant taxon, comprising 13.8% of the total density; *Prionospio lighti* was not abundant in Cycle Six, comprising only 0.32% of the total density. In Cycle Six, historical near-field stations PRB1, PRB3 and PRB2 were dominated by *Prionospio multibranchiata*, as was observed in Cycle Three.

Polychaetes comprised the largest portion of organisms in all stations, with the exception of PRB4A, and five of the six most abundant taxonomic groups. Nineteen Sedentaria taxa and twelve Errantia taxa comprised 43.1% and 17.6% of the total abundance, respectively (Table 4.4). The three most abundant, non-polychaete, taxa were the phironidna *Phoronis psammophila*, the crustacean *Euphilomedes priducta*, and the mollusc *Astyris gausapata*, which comprised 4.7, 1.7 and 1.4% of the total density of all stations (Table 4.4). These three organisms were generally found in gradient stations further from the diffuser.

Other abundant taxa exhibited variable, yet low, proportions among stations sampled for Powell River, ranging from 0.3 to 1.7% (Table 4.4); many of these taxa were found at nearly all stations (both near-field and gradient). However, *Pholoe glabra (*Polychaeta: Errantia) was abundant at PRB1, PRB2 and PRB3 (historical near-field stations) and either found in low numbers or not present at other stations.

Table 4.4 Total and mean densities of the most abundant taxa in the Powell River EEM Cycle Six benthic invertebrate community survey (75% of total abundance), March 2012.

Group	Taxon Name	PRB6	PRB5A	PRB5	PRB3A	PRB3	PRB100NW	PRB100SE	PRB1	PRB2	PRB4A	PRB1A	PRB4B	PRB4	Total Density	Percent of Total	Cummulative Percent
		7,100 m	4,600 m	3,000 m	1,800 m	320 m	100 m	100 m	280 m	520 m	2,700 m	1,200 m	4,000 m	5,900 m			
Polychaeta Sedentaria	*Mediomastus californiensis*	**310**	**1,085**	**1,505**	**1,145**	100	**1,655**	**1,885**	150	**165**	**385**	**380**	**3,070**	**800**	12,635	14.5	14.5
Polychaeta Sedentaria	*Prionospio multibranchiata*	95	240	105	**355**	**1,420**	0	0	**1,290**	**940**	5	50	**525**	35	5,060	5.8	20.4
Polychaeta Sedentaria	*Decamastus nr. gracilis*	130	265	340	310	20	**960**	**1,030**	20	**420**	**190**	30	**545**	**310**	4,570	5.3	25.6
Phoronida	*Phoronis psammophila*	0	**380**	**1,165**	590	0	20	125	0	40	**410**	60	**1,145**	160	4,095	4.7	30.3
Polychaeta Sedentaria	*Spiochaetopterus pottsi*	**960**	335	**805**	**680**	120	0	20	60	130	5	145	180	5	3,445	4.0	34.3
Polychaeta Sedentaria	*Galathowenia oculata*	**270**	**985**	**655**	**855**	60	45	145	0	100	10	5	120	**180**	3,430	3.9	38.2
Polychaeta Errantia	*Lumbrineris californiensis*	170	365	210	200	**555**	0	0	**1,080**	100	0	**380**	160	25	3,245	3.7	42.0
Polychaeta Errantia	*Exogone lourei*	65	**730**	210	305	80	0	180	0	20	100	20	305	**375**	2,390	2.7	44.7
Polychaeta Errantia	*Pholoides asperus*	**235**	**615**	75	245	60	0	40	0	0	0	**320**	205	55	1,850	2.1	46.8
Crustacea (Arthropoda)	*Euphilomedes producta*	0	0	10	**500**	**300**	45	100	0	200	**190**	40	80	20	1,485	1.7	48.5
Polychaeta Errantia	*Pholoe glabra*	25	0	10	85	**680**	0	20	**185**	**240**	10	155	0	15	1,425	1.6	50.2
Polychaeta Errantia	*Glycera nana*	55	150	95	195	70	50	125	35	45	135	205	100	95	1,355	1.6	51.7
Mollusca (Gastropoda)	*Astyris gausapata*	130	10	**370**	70	35	40	20	100	**160**	155	45	25	25	1,185	1.4	53.1
Polychaeta Errantia	*Scoletoma luti*	0	20	145	155	50	75	**405**	40	25	105	0	105	10	1,135	1.3	54.4
Polychaeta Sedentaria	*Owenia fusiformis*	20	290	50	120	0	0	80	60	0	0	0	245	**195**	1,060	1.2	55.6
Mollusca (Bivalvia)	*Axinopsida serricata*	0	10	25	40	0	**330**	300	0	0	**235**	0	20	25	985	1.1	56.8
Arthropoda (Amphipoda)	*Orchomene pacifica*	0	0	0	20	**360**	60	295	60	120	25	0	25	20	985	1.1	57.9
Polychaeta Errantia	*Lumbrineris cruzensis*	0	0	70	25	20	**210**	290	0	0	65	0	190	105	975	1.1	59.0
Polychaeta Sedentaria	*Polycirrus californicus*	85	135	25	25	95	50	30	85	25	10	220	50	55	890	1.0	60.0
Arthropoda (Cumacea)	*Eudorellopsis longirostris*	10	180	60	260	0	60	60	0	40	25	40	60	45	840	1.0	61.0
Arthropoda (Amphipoda)	*Byblis millsi*	55	255	155	345	0	0	0	0	0	0	5	0	25	840	1.0	62.0
Nemertea (Anopla)	*Cerebratulus californiensis*	0	45	25	50	295	0	50	**205**	20	20	40	20	15	785	0.9	62.9
Polychaeta Sedentaria	*Euclymene nr. zonalis*	0	30	85	20	40	70	50	40	0	85	0	145	175	740	0.9	63.7
Polychaeta Errantia	*Typosyllis heterochaeta*	80	320	40	70	20	0	85	0	0	0	30	0	90	735	0.8	64.6
Polychaeta Sedentaria	*Prionospio jubata*	5	10	20	50	0	**185**	125	0	0	**255**	0	20	50	720	0.8	65.4
Polychaeta Errantia	*Pholoe minuta*	0	0	10	0	240	0	20	175	100	15	40	40	5	645	0.7	66.1
Polychaeta Sedentaria	Euclymeninae indet.	45	95	90	175	0	0	60	20	0	10	0	55	75	625	0.7	66.9
Polychaeta Sedentaria	*Pectinaria granulata*	80	40	45	65	200	0	5	85	20	0	45	40	0	625	0.7	67.6
Arthropoda (Amphipoda)	*Heterophoxus conlanae*	50	50	80	85	170	0	0	65	0	0	65	50	0	615	0.7	68.3
Polychaeta Errantia	*Pionosyllis uraga*	75	40	35	5	20	0	20	40	0	0	**250**	80	20	585	0.7	69.0
Polychaeta Errantia	Dorvilleidae indet.	0	0	0	0	**480**	0	0	0	0	0	20	40	0	540	0.6	69.6
Polychaeta Sedentaria	*Barantolla nr. americana*	5	0	10	30	345	0	75	60	0	0	5	0	0	530	0.6	70.2
Polychaeta Sedentaria	*Prionospio steenstrupi*	0	0	10	40	145	0	0	**265**	20	5	20	0	0	505	0.6	70.8
Polychaeta Sedentaria	*Mediomastus sp.*	0	0	0	0	0	0	**490**	0	0	0	0	0	0	490	0.6	71.3
Polychaeta Sedentaria	*Petaloproctus tenuis borealis*	**175**	210	5	55	0	0	0	0	0	0	0	20	15	480	0.6	71.9
Polychaeta Sedentaria	*Pista wui*	0	35	0	45	0	20	60	5	0	5	**220**	40	25	455	0.5	72.4
Arthropoda (Amphipoda)	*Heterophoxus ellisi*	0	0	40	135	70	25	120	0	5	5	0	0	30	430	0.5	72.9
Polychaeta Sedentaria	*Spio cirrifera*	25	60	40	90	0	0	0	20	0	0	65	85	40	425	0.5	73.4
Arthropoda (Amphipoda)	*Metaphoxus frequens*	5	25	50	130	20	40	60	0	0	5	0	60	20	415	0.5	73.9
Polychaeta Sedentaria	*Mesochaetopterus taylori*	55	5	150	180	0	0	0	10	0	0	0	0	0	400	0.5	74.3
Polychaeta Errantia	*Gyptis lobatus*	0	0	0	10	200	0	0	140	0	0	40	0	0	390	0.4	74.8
Polychaeta Sedentaria	*Phyllochaetopterus prolifica*	0	5	10	40	0	0	0	0	0	0	0	**335**	0	390	0.4	75.2

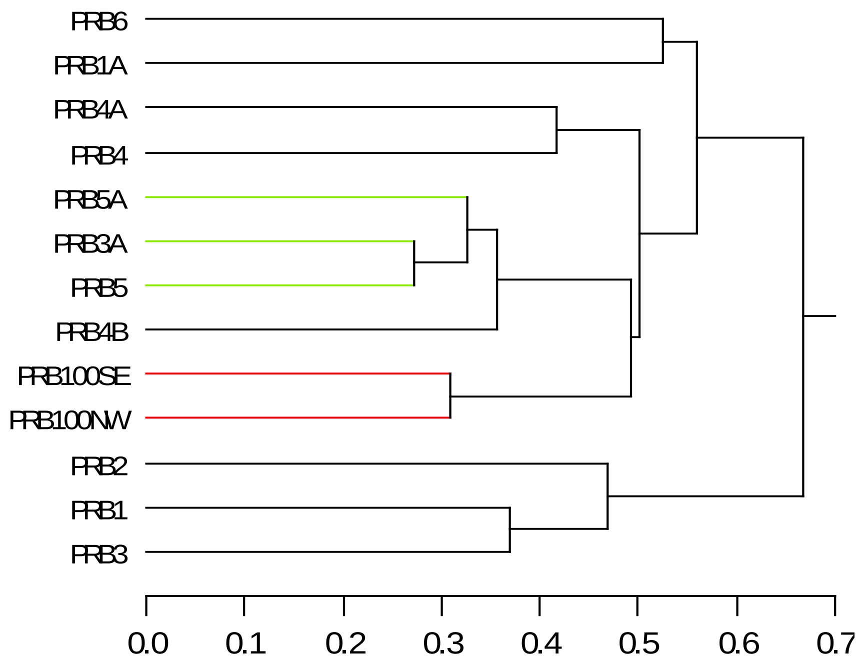
Bold = Top five most abundant taxa from each station.

4.3.5.1 Cluster Analysis

A dendrogram clustering stations together according to their densities and taxa was calculated using the Bray-Curtis dissimilarity index (Figure 4.7). There were two major clusters with a relatively clear distinction between stations northwest and southeast of the diffuser.

The three most impacted stations, with respect to sediment conditions indicative of the historic fibre mat (PRB1, PRB2 and PRB4), clustered separately from the rest of the stations; these stations were also the closest stations to the diffuser during Cycle Three. Stations PRB100NW and PRB100WSE, the stations closest to the diffuser in Cycle Six, clustered with gradient stations due to similarities in density and tax richness. Stations in the northwest gradient formed another distinct sub-cluster with the exception of PRB6. Stations in the southeast gradient did not group together based on gradient direction. Distances between individual stations ranged from approximately 0.27 to 0.68.

Figure 4.7 Dendrogram describing similarities in benthic community composition, Powell River EEM Cycle Six, March 2012.



4.3.6 Statistical Analyses

4.3.6.1 Regression Analyses

A summary of the relationships between benthic invertebrate metrics and absolute distance from the diffuser and C/N ratio are provided in Table 4.5 and Table 4.6. Scatter plots of each regression are presented in Appendix A4.

No significant relationship was observed between absolute distance from the pulpmill diffuser and density or evenness (Table 4.5). A significant relationship was observed between absolute distance and taxa richness (p=0.000), diversity (p=0.061) and between absolute distance and the Bray-Curtis index (p=0.000).

When the pulpmill exposure gradient was defined using the C/N ratio, an indicator of terrestrial organic inputs and related to absolute distance from the diffuser (Table 4.10), a significant relationship was observed for taxa richness and the Bray-Curtis index (Table 4.6).

The EEM effects criterion was defined as a biologically significant relationship with a correlation coefficient (r) of at least |0.707|, which is equivalent to ±2SD of the reference mean (Environment Canada 2010). Based on this criterion, taxa richness and the Bray-Curtis index are the only metrics that show a gradient effect with increasing distance from the diffuser (Table 4.5); as well as an effect gradient based on C/N ratio (Table 4.6).

4.3.6.2 Power Analyses

The statistical power of the gradient regressions was 0.96, above the recommended level of P=0.90, indicating sufficient power to detect the target effect size for this survey (Appendix A4).

Table 4.5 Relationships between benthic invertebrate metrics and absolute distance from the pulpmill diffuser, Powell River EEM Cycle Six, March 2012.

Effect Endpoint	p-value for F-test[2]	Regression Equation[1]	r	r^2	Effect?
Density	0.746	DENS=6422+109DIST	0.095	0.009	No
Taxa Richness	**0.000**	**RICH = 42.110 + 5.711 DIST**	**0.780**	**0.609**	**Yes**
Evenness	0.711	EVEN = 0.203 - 0.004 DIST	-0.114	0.013	No
Diversity[4]	**0.061**	**Rank DIV = 3.317 + 0.526 Rank DIST**	**0.529**	**0.28**	**No**
Bray-Curtis[3]	**0.000**	**Log BRAY = -0.453 - 0.130 DIST**	**0.904**	**0.818**	**Yes**

[1] DENS = density; RICH = taxa richness; EVEN = evenness; DIV = diversity; B-C = Bray-Curtis index.

[2] Significant result (p ≤ 0.10); significant values are in **bold**. Patterns are provided for significant values only.

[3] Data were log-transformed.

[4] Data were rank-transformed.

r = Pearson's correlation coefficient (parametric correlations).

r^2 = coefficient of determination.

Table 4.6 Relationships between benthic invertebrate metrics and C/N ratio, Powell River EEM Cycle Six EEM, March 2012.

Effect Endpoint	p-value for F-test[2]	Regression Equation[1]	r	r^2	Effect ?
Density[3]	0.23	DENS= 7642.28 - 22.400 C/N	-0.263	0.069	No
Taxa Richness	**0.002**	**Rank RICH = 12.365-0.766 Rank C/N**	**-0.767**	**0.589**	**Yes**
Evenness	0.879	EVEN = 0.158 +0.001 C/N	0.288	0.083	No
Diversity[3]	0.358	Rank DIV = 8.923- Rank 0.274 C/N	-0.266	0.071	No
Bray-Curtis	**0.001**	**Rank BRAY= 1.346 + Rank 0.808 C/N**	**0.809**	**0.654**	**Yes**

[1] DENS = density; RICH = taxa richness; EVEN = evenness; DIV = diversity; B-C = Bray-Curtis index.

[2] Significant result ($p \leq 0.10$); significant values are in **bold**. Patterns are provided for significant values only.

[3] Data were log-transformed.

[4] Data were rank-transformed.

r = Pearson's correlation coefficient (parametric correlations).

r^2 = coefficient of determination.

4.3.7 QA/QC and Verifications

All QA/QC reports are presented in Appendix A2. Sorting efficiency ranged from 90.8% to 98.2% for three sets of samples (three stations), with an average sorting efficiency of 94.1%, which passed the required >90% efficiency.

QA/QC results for the accuracy of the splitting technique showed a sub-sampling error ranging from 1.4 to 19.4% across the three marine mills (two stations from each of the three mills for a total of 6 stations), with an average sub-sampling error of 9.0%, which is within the 20% error allowed. Of the two randomly selected samples from Powell River, average sub-sampling error was 4.3%.

Verifications of the reference collection, conducted by Columbia Science, are also presented in Appendix A2. Out of a total of 130 samples in the reference collection for combined EEM Cycle Six marine mill programs (i.e., Port Alice, Howe Sound and Powell River mills), 108 organisms were in agreement; 18 organisms were confirmed to a higher taxonomic level (often to Genus); and one organism was in disagreement to the initial taxonomy. Three organisms were recorded as microscopic and/or fragile and could not be verified by Columbia Science.

4.4 SUPPORTING ENVIRONMENTAL VARIABLES

4.4.1 Water Quality

In situ water samples were taken at near-bottom depths (~2 m off the bottom) at each station.

Table 4.7 presents water variables measured in the field during the benthic invertebrate survey, taken at near-bottom depths.

Temperatures for all stations were relatively similar ranging from 7.1ºC at PRB4B to 7.9 ºC at PRB3. Little variation was also observed in dissolved oxygen (DO) concentrations and pH, ranging from 8.14 to 9.51 mg/L and 7.4 to 7.7, respectively. DO and pH did not appear to correlate with distance from the diffuser. Corrosion of the pH probe on the last day of the program prevented the measurement of pH at stations PRB100SE, PRB4A, PRB4B and PRB4. Additionally, as the YSI probe used during the field program calculates salinity based on pH (amongst other variables), salinity could not be recorded at the same stations. Where salinity could be recorded it was similar between stations ranging from 24.4% at PRB3 to 26.8% at PRB100NW (Table 4.7). Trends in water quality measurements across stations were similar to Cycle Three with the exception of salinity; on average salinity measurements were 4% lower in Cycle Six than Cycle Three.

Table 4.7 Near-bottom water quality at stations sampled for the Powell River EEM Cycle Six benthic invertebrate survey, March 2012.

Station	Sample Depth (m)	DO (mg/L)	Temp (°C)	pH	Salinity (%)
Stations on Northwest Gradient					
PRB6	33	9.29	7.29	7.7[1]	24.56
PRB5A	42	8.90	7.24	7.7	24.62
PRB5	31	8.96	7.26	7.6	24.3
PRB3A	38	9.79	7.09	7.4[1]	24.45
Stations Nearest Diffuser					
PRB3	41	ns	7.90	7.6	24.37
PRB100NW	60	9.51	7.13	7.5[1]	26.82
PRB100SE	60	8.71	7.30	ns	ns
PRB1	39	8.81	7.22	7.6	24.66
PRB2	41	8.36	7.27	7.5	24.57
Stations on Southeast Gradient					
PRB4A	59	9.06	7.14	ns	ns
PRB1A	36	8.14	7.28	7.7	24.65
PRB4B	50	9.12	7.10	ns	ns
PRB4	59	9.20	7.10	ns	ns

[1] Sample was brought to the surface and verified using a hand-held Hanna pen.

4.4.2 Sediment Quality

Sediment samples were collected from one benthic sub-sample at each station at the same depths as the benthic samples and analyzed for particle size, total organic carbon, total nitrogen, chlorinated phenolics, redox potential and total sulphides. Results of the sediment quality survey are presented below; raw benthic data are presented in Appendix A3.

4.4.2.1 Particle Size and Moisture Content

Particle size distributions of composited sediment collected at stations near Powell River are presented in Figure 4.8. Photographs of representative sediment samples are presented in Figure 4.9 to Figure 4.12. Sediments at all stations were comprised predominantly of sand (60.4% at PRB1 to 94.4% at PRB6). The proportion of silt was generally low (<15%) at all stations with the exception of PRB1 (24.5%) and PRB2 (21.6%). The proportion of clay was also low at all sites with the exception of PRB1A (22.9%). Gravel was low at all stations with the highest proportion found at PRB2 (5.78%). In general, harder substrates with increased gravel content were observed in the field at stations furthest from the diffuser. This was evident during sample collection by the grab apparently bouncing on the bottom and by increased gravel content observed in partial grabs. However, partial grabs were rejected due to insufficient sample size, often due to larger substrates preventing closure of the grab.

Substrate composition was generally coarser in Cycle Six relative to Cycle Three (Hatfield 2004). However, samples from many stations in Cycle Three could not be fully analyzed for particle size due to high amounts of organic material (e.g., wood fibre, charcoal organic debris, etc.), which is an indicator of anthropogenic related effects. Organic debris was not as prevalent during Cycle Six and was only observed at station PRB2. In addition, all sediment samples collected in Cycle Six contained sufficient substrate for full particle size analysis.

Figure 4.8 Particle size distribution of sediments, Powell River EEM Cycle Six, March 2012.

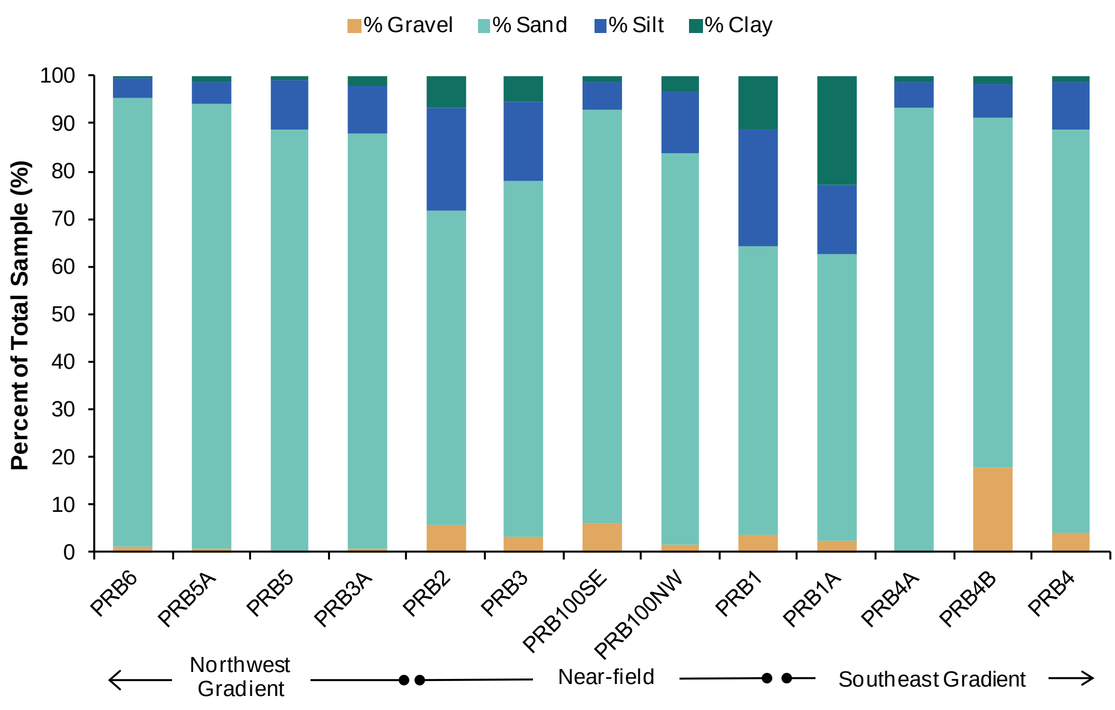


Figure 4.9 Substrate at PRB1 (note wood fibre in sediment), Powell River EEM, March 2012.

Figure 4.10 Substrate at PRB100SE (note sand and silt composition), Powell River EEM, March 2012.

Figure 4.11 Substrate at PRB4 (note silt and finer sand composition), Powell River EEM, March 2012.

Figure 4.12 Substrate at PRB6 (note sand substrate and polychaete casings), Powell River EEM, March 2012.

4.4.2.2 Total Organic Carbon, Total Nitrogen and C/N Ratio

Mean total organic carbon (TOC), total nitrogen (TN) and carbon:nitrogen (C/N) ratios at each station are presented in Table 4.8; raw data for each replicate grab are presented in Appendix A3.

TOC content in sediments was highest at five stations closest to the diffuser; however, TOC content at station PRB100SE was comparatively low and more representative of gradient stations (Table 4.8). TOC values within these five stations ranged from 3.5 to 29.5%. TOC content decreased rapidly in the remaining gradient stations ranging from 0.31% at PRB6 (furthest station from the diffuser) to 2.17% at station PRB1A (Table 4.8). Since Cycle Three, TOC content has continually decreased at stations closest to the diffuser and has remained low at all others (Figure 4.9).

TN content in sediments followed similar patterns as TOC; samples containing the highest TOC also exhibited the highest TN. TN ranged from 0.08 to 0.33% at sites closest to the mill and from 0.03 to 0.04% and the remaining gradient stations (Figure 4.8).

C/N ratios for stations within the historical near-field area ranged from 41.86 to 91.66 with the remaining gradient stations ranging from 11.73 to 29.26 (Table 4.9 and Figure 4.8). All stations exhibited high C/N ratios relative to expected background concentrations of near six for marine mills, suggesting terrestrial carbon sources are present in sediments (Macdonald et al. 1991), especially in the vicinity of the diffuser where C/N ratios were in excess of 41. Evidence of the historical fibre mat near the Powell River diffuser remains even though TOC content continues to decrease (Figure 4.8).

Table 4.8 Mean organic carbon and nitrogen concentrations, C/N ratio, and oxidative-state variables in sediments, Powell River Cycle Six, March 2012.

Stations	ID	Total Organic Carbon (%)	Total Nitrogen (%)	C/N Ratio	Redox Potential (mV)	Total Sulphides (µmol)
Stations on Northwest Gradient						
Scuttle Bay	PRB6	0.31	0.03	11.73	1.6	-325
Sliammon North	PRB5A	0.52	0.03	16.77	12	-381
Sliammon South	PRB5	0.98	0.04	26.00	8.33	-366
Powell River	PRB3A	1.19	0.04	29.26	8.29	-280
Station out from Diffuser						
North of Diffuser	PRB3	17.10	0.19	90.69	68	-296
Diffuser (NW100)	PRB100NW	12.00	0.29	41.86	58	-278
Diffuser (SE100)	PRB100SE	3.50	0.08	45.23	58	-340
South of Diffuser	PRB1	29.50	0.32	91.66	193	-392
End of Diffuser	PRB2	29.30	0.33	88.37	864	-391
Stations on Southeast Gradient						
North Westview	PRB4A	0.53	0.03	16.94	24	-360
Breakwater	PRB1A	2.17	0.04	61.13	150	-405
Westview WWTP	PRB4B	0.49	0.03	15.81	13	-285
South Westview	PRB4	0.49	0.03	18.30	10.18	-341

Figure 4.13 Mean organic carbon, total nitrogen and C/N ratios in sediments, Powell River EEM Cycle Six, March 2012.

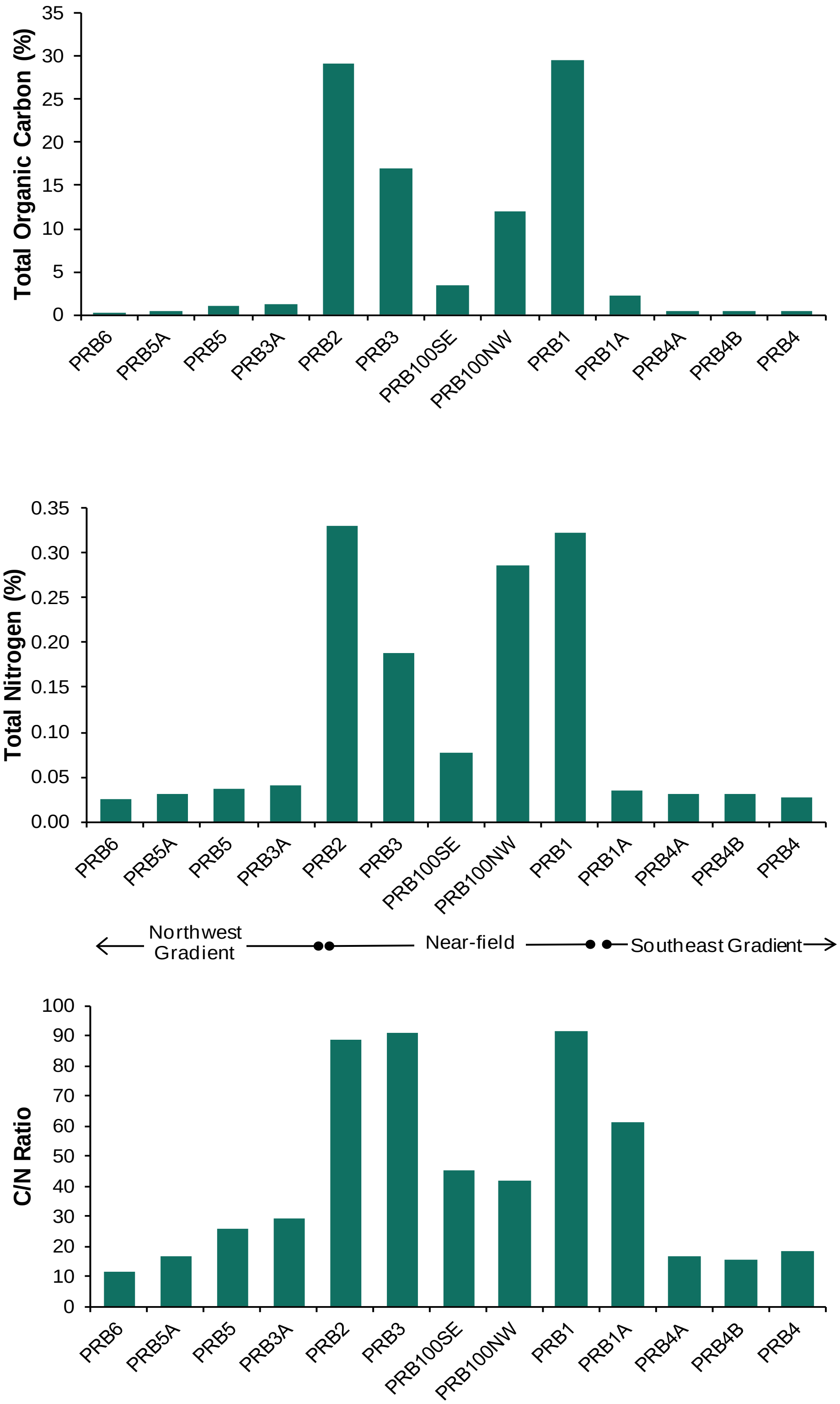
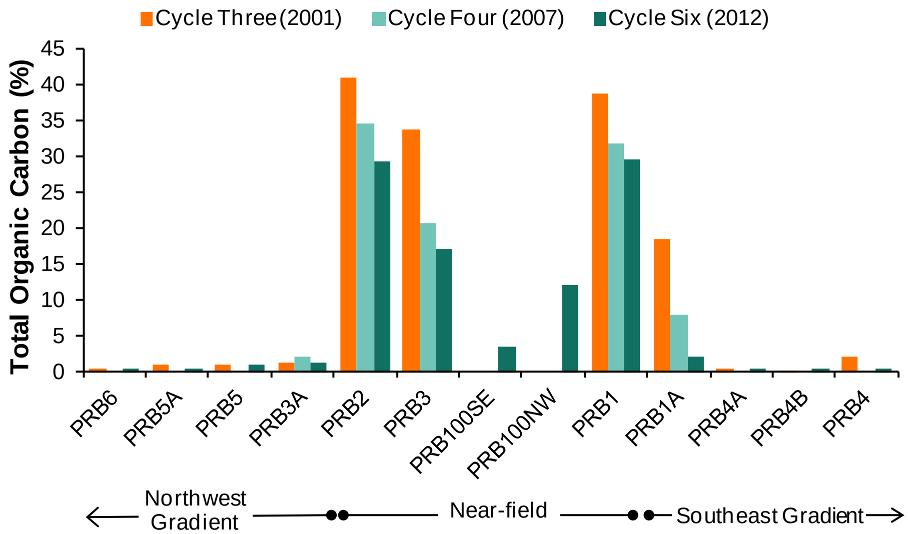


Figure 4.14 Percent total organic carbon in sediments, Powell River EEM Cycle Three, Cycle Four and Cycle Six.



4.4.2.3 Oxidative State

Redox potential was highly negative (i.e., indicative of reducing conditions) at all stations in Cycle Six, ranging from -277 mV at station PRB100NW to -405 mV at station PRB1A (Table 4.9 and Figure 4.10). This was consistent with Cycle Four results, although conditions have become more reducing at all stations (Figure 4.11). In addition, several stations in Cycle Three (both in near-field and far-field areas) exhibited positive redox values (i.e., indicative of oxidative conditions); however, have since transitioned to reducing environments (Figure 4.11).

Total sulphide (TS) values were generally highest in sites closest to the diffuser with the highest value (864 µmol) recorded at station PRB2 (Figure 4.10). With the exception of station PRB2, TS has decreased at all stations compared to Cycle Three and Four, with stations closest to the mill decreasing considerably (Figure 4.11).

Figure 4.15 Total sulphides and mean sediment redox potential in sediments, Powell River EEM Cycle Six, March 2012.

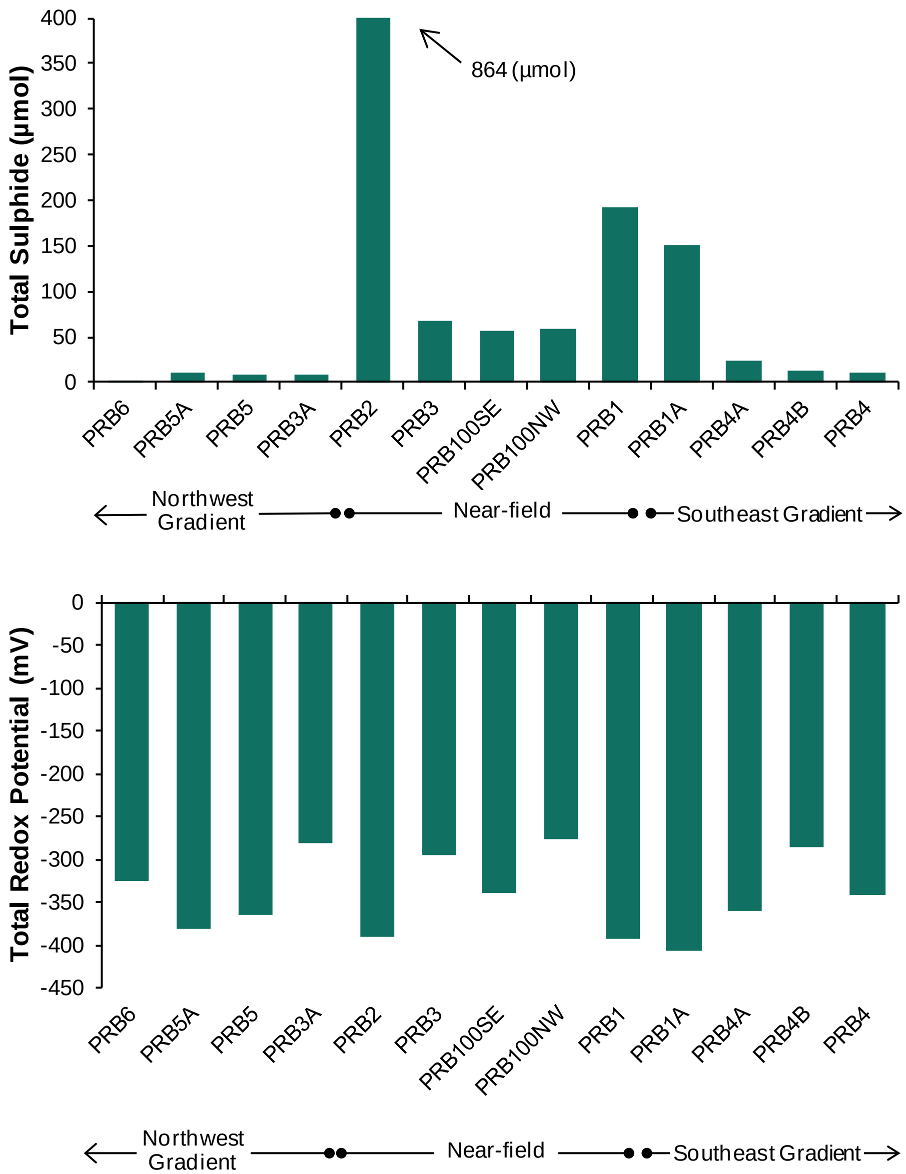
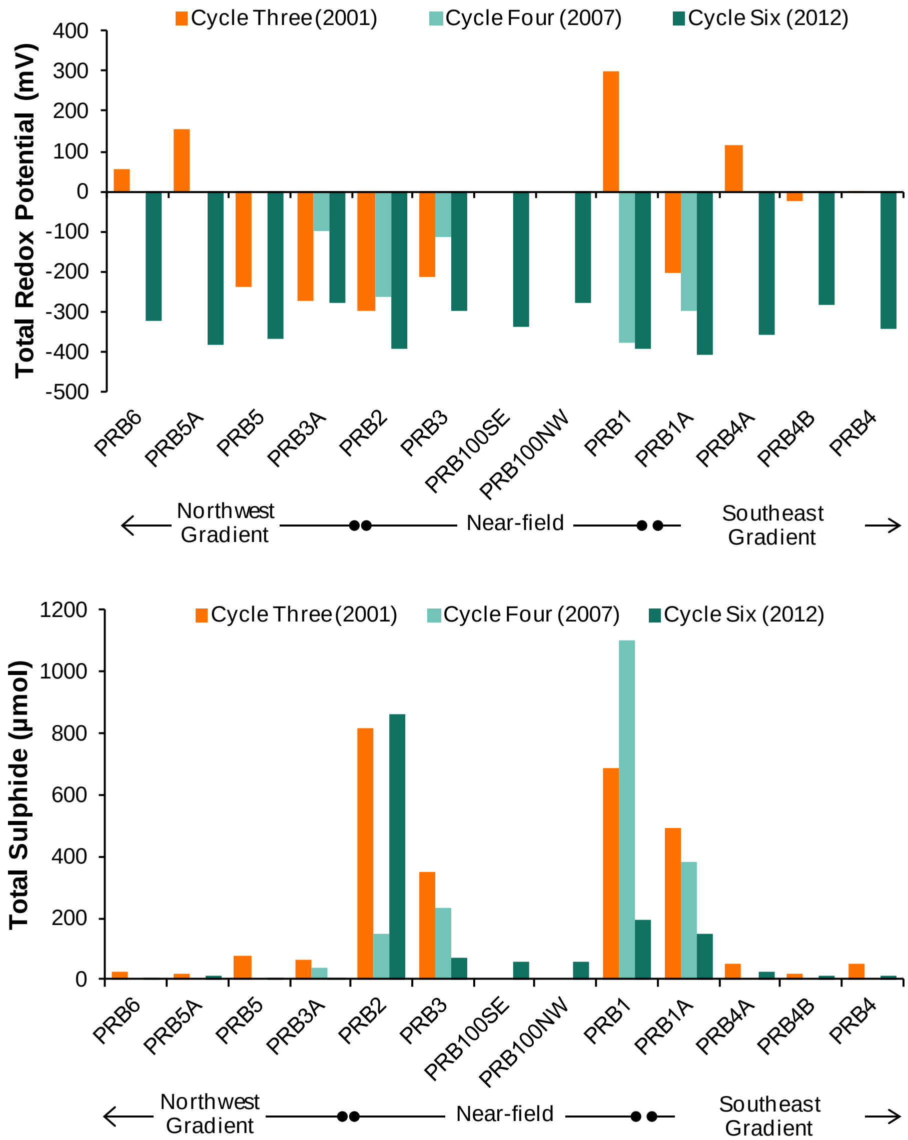


Figure 4.16 Mean sediment redox potential and total sulphides in sediments, Powell River EEM Cycle Three, Cycle Four, and Cycle Six.



4.4.2.4 Chlorinated Phenolic Compounds

Table 4.10 presents concentrations of chlorinated phenolic compounds in composited sediments collected from benthic invertebrate stations in March 2012. Eight stations, including the two stations closest to the diffuser, were below detection limits for all chlorinated phenolic compounds while the remaining stations ranged from 0.002 mg/kg at station PRB1A to 0.507 mg/kg at station PRB3 (Table 4.10). All stations within the historical near-field area had detectable concentrations, with the exception of PRB3A. The only compound detected outside the historical near-field area was pentachlorophenol (0.0209 mg/kg at station PRB5) which has been associated historically with either chlorinated pulpmill effluent or its historical use as a wood preservative. All stations have shown a decrease in total chlorinated phenolic compounds since Cycle Three, with the exception of PRB3 (Figure 4.12). Station PRB3 has had the highest total concentration since Cycle Two, mainly attributed to relatively high concentrations of catechols and guaicols (Figure 4.12 and Table 4.10).

Figure 4.17 Summary of total chlorinated phenolic concentrations in sediments, Powell River EEM Cycle One (1997) to Cycle Six (2012).

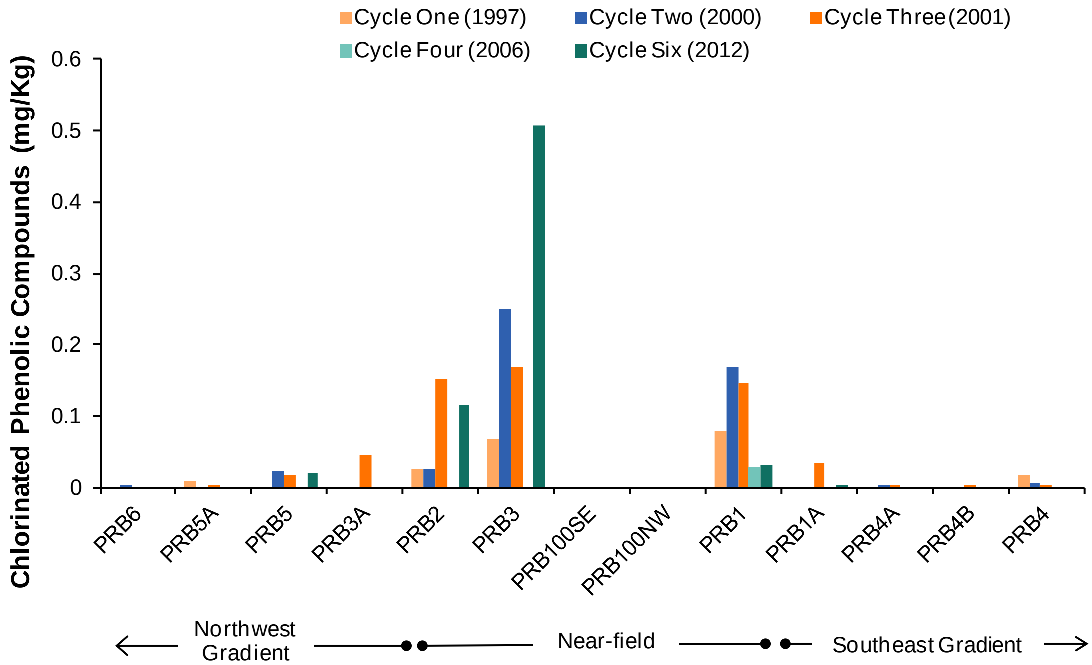


Table 4.9 Chlorinated phenolic compounds in sediments (mg/kg dry weight), Powell River EEM Cycle Six, March 2012.

Parameter	PRB100SE 100 SE of Diffuser	PRB100NW 100 NW of Diffuser	PRB1 South of Diffuser	PRB3 North of Diffuser	PRB2 End of Diffuser	PRB1A Break-water	PRB3A Powell River	PRB4A North Westview	PRB5 Sliammon South	PRB4B Westview WWTP	PRB5A Sliammon North	PRB4 South Westview	PRB6 Scuttle Bay
Pentachlorophenol	<0.0080	<0.0080	<0.050	<0.10	<0.035	<0.0080	<0.015	<0.0020	**0.0209**	<0.0040	<0.0040	<0.0040	<0.0020
Tetrachlorocatechol	<0.0050	<0.015	<0.040	**0.138**	**0.0663**	<0.015	<0.015	<0.0050	<0.0080	<0.0050	<0.0050	<0.0050	<0.0050
Tetrachloroguaiacol	<0.0050	<0.0050	<0.030	**0.358**	**0.0351**	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
2,3,4,5-Tetrachlorophenol	<0.0020	<0.0020	<0.0070	<0.020	<0.010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,3,4,6-Tetrachlorophenol	<0.0020	<0.0020	**0.0140**	<0.040	<0.015	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,3,5,6-Tetrachlorophenol	<0.0020	<0.0020	<0.0020	<0.020	<0.0030	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
3,4,5-Trichlorocatechol	<0.0050	<0.0090	<0.030	<0.070	<0.040	<0.015	<0.0070	<0.0050	<0.0060	<0.0050	<0.0050	<0.0050	<0.0050
3,4,5-Trichloroguaiacol	<0.0050	<0.0050	<0.0090	<0.020	<0.015	<0.015	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
2,3,4-Trichlorophenol	<0.0020	<0.0020	<0.0020	<0.0090	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,3,5-Trichlorophenol	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,3,6-Trichlorophenol	<0.0020	<0.0020	<0.0050	<0.0030	<0.0030	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,4,5-Trichlorophenol	<0.0020	<0.0020	<0.0040	<0.0050	<0.0060	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
2,4,6-Trichlorophenol	<0.0020	<0.0020	**0.0161**	**0.0112**	**0.0136**	**0.0020**	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
STATION TOTAL [1]	***ND***	***ND***	***0.030***	***0.507***	***0.115***	***0.002***	***ND***	***ND***	***0.021***	***ND***	***ND***	***ND***	***ND***
Cycle Four Total	*ns*	*ns*	*0.030*	*ND*	*ND*	*ND*	*ND*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Cycle Three Total	*ns*	*ns*	*0.145*	*0.169*	*0.151*	*0.033*	*0.046*	*0.001*	*0.017*	*0.001*	*0.003*	*0.004*	*0.000*
Cycle Two Total [2]	*ns*	*ns*	*0.169*	*0.249*	*0.026*	*ns*	*ns*	*0.004*	*0.022*	*ns*	*ns*	*0.006*	*0.001*
Cycle One Total [3]	*ns*	*ns*	*0.078*	*0.069*	*0.027*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.009*	*0.018*	*ns*

[1] Values greater than the detection limit (0.001 mg/dry kg) **appear in bold**. Non-detect values considered as "0" in summation.

[2] Data from Hatfield Consultants Ltd. 2000.

[3] Data from Hatfield Consultants Ltd. 1997.

[4] Data from Hatfield Consultants Ltd. 2001.

ns = not sampled; ND = not detected.

4.4.3 Statistical Assessment of Supporting Data

Based on regression analyses, total organic carbon, C/N ratio, total sulphides, and %-clay exhibited significant correlations with distance from the pulpmill diffuser (p-values ≤0.10; Table 4.10). TOC and %-clay data were log-transformed while C/N and total sulphides data were rank-transformed in order to meet the assumptions of a linear regression model. Generally, a decreasing trend was observed in concentration of each significantly related environmental variable with distance from the diffuser.

Remaining supporting environmental variables showed insignificant relationships with absolute distance. Data for these variables were transformed to best-fit; regression equations are presented in Table 4.10.

Table 4.10 Relationships between supporting environmental variables and absolute distance from the pulpmill diffuser, Powell River EEM Cycle Six, March 2012.

Effect Endpoint	p-value (F-test)[1]	Regression Equation[1]	Correlation Coefficients	
			r	r^2
TOC[2]	**0.000**	**Rank TOC = 13.267 - 0.895 Rank DIST**	**0.896**	**0.895545**
Total nitrogen[2]	0.000	Rank TN = 12.785 - 0.826 Rank DIST	0.447	0.2
C/N	**0.001**	**Rank C/N = 12.727-0.818 Rank DIST**	**0.817**	**0.668**
Total sulphides[2]	**0.005**	**Rank SULPH = 12.072 - 0.725 Rank DIST**	**0.723**	**0.523**
Redox potential	0.880	REDOX = -343.621 + 0.87 DIST	0.045	0.002
Chlorinated phenolics	0.256	Log CHLOR = -5.862 - 0.558 Log DIST	0.339	0.115
% clay	**0.023**	**Rank % clay = 11.358 - 0.623 Rank DIST**	**0.621**	**0.386**
% Silt	**0.022**	**Rank % silt = 11.377 - 0.625 Rank DIST**	**0.625**	**0.391**
% Sand	**0.065**	**Rank % sand = 3.317 + 0.526 Rank DIST**	**0.526**	**0.277**
% Gravel	0.338	Rank % gravel = 9.025 - 0.289 Rank DIST	-0.288	0.083

[1] Significant results ($p \leq 0.10$) in **bold**.
[2] Data were log-transformed.
[3] Data were rank-transformed.
r = Pearson's correlation coefficient (parametric); r^2 = coefficient of determination.

Correlations between benthic metrics and supporting environmental variables are presented in Table 4.11; significant correlations (r ≥ |0.484|) are discussed below.

Based on Spearman's rank correlations, mean adult density and the Bray-Curtis dissimilarity index were moderately correlated with C/N ratio (Table 4.11). Taxa richness and Simpson's diversity were moderately and strongly correlated with oxidative-state variables indicative of non-reducing environments (i.e., positively correlated with redox potential and negatively correlated with total sulphides). Mean adult density and taxa richness were strongly correlated with sand but negatively correlated with silt and clay. Total sulphides and chlorinated phenolics were moderately and strongly correlated with the Bray-Curtis dissimilarity index (i.e., dissimilarity between stations was correlated with reducing characteristics of sediments).

Simpson's diversity was negatively correlated with total organic carbon and total nitrogen, whereas the Bray-Curtis index was positively correlated with these variables. These results indicate that the most dissimilar stations to the reference stations with respect to benthic invertebrate communities were found in environments with high organic matter and nutrients.

Table 4.11 Spearman's rank correlations (r_s) between benthic community metrics and supporting environmental variables, Powell River Cycle Six, March 2012.

Variable	Distance	Depth	Density	Richness	Evenness	Simpson's Diversity	Bray-Curtis
Distance	-	-0.315	0.167	**0.77**	0.028	**0.531**	**-0.845**
TOC	**0.625**	-0.210	0.338	**0.577**	0.058	0.381	**-0.619**
TN	0.449	-0.128	0.369	0.421	0.020	0.224	-0.426
C/N Ratio	**0.575**	-0.070	0.258	**0.509**	-0.047	0.278	**-0.571**
% Gravel	-0.217	**0.532**	0.118	-0.022	-0.333	-0.281	-0.077
% Sand	-0.237	-0.227	**-0.530**	**-0.550**	0.430	0.050	0.445
% Silt	0.363	-0.03	0.487	**0.511**	-0.289	0.056	-0.464
% Clay	0.410	0.060	**0.648**	**0.713**	-0.332	0.144	**-0.544**
Dissolved oxygen	0.343	0.100	0.280	0.308	-0.277	0.106	-0.49
Temperature	-0.242	-0.236	-0.104	-0.124	0.300	0.134	0.264
Salinity	**-0.500**	**0.527**	**-0.550**	-0.433	-0.276	-0.426	0.433
Total sulphides	**-0.724**	0.223	-0.456	**-0.77**	0.187	-0.422	**0.901**
Redox	-0.036	0.339	0.412	0.204	-0.399	-0.122	-0.159
Total Chlorophenols	-0.376	-0.452	-0.150	-0.456	0.425	-0.010	**0.56**

Bolded values represent significant correlations where $r_s \geq |0.0.484|$ for n=12.

Moderate Correlations: $|0.5|<r_s<|0.75|$; Strong Correlations: $r_s>|0.75|$.

4.5 DISCUSSION

4.5.1 Comparisons with Previous Cycles

Mean invertebrate density was higher in Cycle Six than in previous, comparable cycles, with the exception of stations PRB2, PRB1A, and PRB4, where slight decreases in density were observed between Cycle Three and Cycle Six (Table 4.12). In Cycle Six, stations within the historical near-field area had invertebrate densities greater than or similar to those observed in the far-field areas of Cycle Three and considerably greater densities than all stations in Cycle Two.

Benthic community data from Cycle One are not presented in Table 4.12 as sampling methodologies and benthic processing and enumeration techniques were not comparable to subsequent cycles. Generally, all Cycle One stations in the vicinity of Powell River exhibited lower densities relative to the reference area (Qualicum Beach). Within exposed stations, mean density at near-field stations was slightly lower relative to far-field and far-far-field stations (Hatfield 1995).

Taxa richness has varied over time, with many stations experiencing decreasing richness between Cycles Two and Three followed by slight increases at most stations in Cycle Six (Table 4.12). Stations PRB4A and PRB4 experienced considerable decreases in taxa richness over time; however, generally increased in mean density. The most notable change in taxa richness between cycles was observed at stations near the Powell River WWTP (PRB4A, PRB4B and PRB4). Taxa richness at stations north and south of the municipal outfall decreased considerably between Cycle Three and Six; however, the station closest to the outfall (PRB4B) experienced the largest increase in taxa richness between cycles increasing by 46 families between Cycle Three and Cycle Six (Table 4.12).

Table 4.12 Mean density and richness of benthic invertebrate communities in Malaspina Straight, Powell River EEM Cycles Two (1999), Three (2001), and Six (2012).

Station	Station Name	Mean Density (N/m^2)			Taxa Richness (# families)		
		Cycle Two	Cycle Three	Cycle Six	Cycle Two	Cycle Three	Cycle Six
Stations on Northwest Gradient							
PRB6	Scuttle Bay	2,926	3,468	5,535	76	65	77
PRB5A	Sliammon North	NS	2,876	9,420	NS	74	82
PRB5	Sliammon South	2,922	2,649	8,795	88	63	68
PRB3A	Powell River	NS	4,300	9,755	NS	89	63
Stations Nearest Diffuser							
PRB3	North of diffuser	1,830	5,890	8,375	71	47	45
PRB100NW	100 m northwest	NS	NS	4,755	NS	NS	40
PRB100SE	100 m southeast	NS	NS	7,885	NS	NS	45
PRB1	South of diffuser	777	1,405	5,315	59	32	36
PRB2	End of diffuser	1,670	4,455	3,525	64	44	45
Stations on Southeast Gradient							
PRB4A	North westview	2,587	2,829	3,460	81	69	43
PRB1A	Breakwater	NS	9,526	4,720	NS	51	49
PRB4B	Westview WWTP	NS	1,166	11,020	NS	35	81
PRB4	South Westview	2,017	4,629	4,385	80	79	61

NS = not sampled.

A noticeable difference in the community composition was also observed between Cycle Three and Cycle Six, especially at the species level (Section 4.3.5). Given the long time frame between benthic field studies (11 years) and the nature of the species present, this was not unexpected (T. Macdonald, Biologica Environmental Services Pers. comm. 2013). Many of the dominant species present in both Cycle Three and Cycle Six were opportunistic/”boom-and-bust” types of species that can have highly fluctuating densities (T. Macdonald, Biologica Environmental Services Pers. comm. 2013). *Eupholomedes producta*, highly abundant in the furthest northwest station of Cycle Three (PRB9), is referred to as a “suprabenthic organisms” and often has clustered abundance. In addition, there were 106 new taxa (i.e., new species or higher order organisms) identified in Cycle Six, a large increase in the overall number taxa in the area. Many of these were epifaunal taxa (e.g., hyroids, sponges, ascians and polychaetes) that inhabit harder, sandy substrates more common beyond the extent of the historical fibre mat.

4.5.2 Sediment Quality and Degree of Impact

The Pulp and Paper EEM Technical Guidance Document (Environment Canada 2010) provided guidelines for classifying impacted sediments (Table 4.13). Based on these criteria, sediment quality at stations along Malaspina Straight was classified according to percent TOC, redox potential and sulphide concentrations (Table 4.14). Data from all stations indicated grossly impacted redox potential (i.e., sediment at all stations was highly reducing) and normal grades for total sulphides at all stations with the exception of PRB2, which was classified as Low impact (Table 4.14). Percent TOC at sites further from the diffuser (PRB6, PRB5A, PRB5, PRB4, PRB4B, PRB4A, and PRB1A) indicated a normal to low impact while remaining sites near the diffuser varied from moderate to grossly (PRB1) impacted (Table 4.14).

Table 4.13 Environment Canada criteria for classifying impacts of organic carbon concentrations and oxidative state in marine sediments (Environment Canada 2010).

Degree of Impact	% TOC	Redox Potential (mV)	Sulphides (µmol)
Normal	Normal (0 to 0.5%)	> 100	< 300
Low impact or enrichment	Slight increase (0.5 to 5%)	0 to 100	300 to 1,300
Moderate to high impact	Moderate increase (5 to 20%)	-100 to 0	1,300 to 6,000
Gross impact	High TOC (>20%)	< -100	> 6,000

Table 4.14 Evaluation of sediment variables at each station based on Environment Canada impact criteria, Powell River EEM Cycles Two, Three, Four, and Six.

Station	Total Organic Carbon				Redox Potential[1]				Total Sulphides[1]			
	Cycle Two	Cycle Three	Cycle Four	Cycle Six	Cycle Two[2]	Cycle Three	Cycle Four	Cycle Six	Cycle Two[2]	Cycle Three	Cycle Four	Cycle Six
PRB1	Gross	Gross	Gross	Gross	Gross	Normal	Gross	Gross	Moderate	Low	Low	Normal
PRB1A	ns	Moderate	Normal	Low	ns	Gross	Gross	Gross	ns	Low	Low	Normal
PRB2	High	Gross	Gross	Gross	High	Gross	Gross	Gross	Low	Low	Normal	Low
PRB3	High	Gross	Gross	Moderate	Gross	Gross	Gross	Gross	Moderate	Low	Normal	Normal
PRB3A	ns	Low	Low	Low	ns	Gross	Moderate	Gross	ns	Normal	Normal	Normal
PRB4	Moderate	Low	ns	Normal	High	Moderate	ns	Gross	Moderate	Normal	ns	Normal
PRN4A	Low	Low	ns	Low	Moderate	Normal	ns	Gross	ns	Normal	ns	Normal
PRB4B	ns	Normal	ns	Normal	ns	Moderate	ns	Gross	ns	Normal	ns	Normal
PRB5	ns	Low	ns	Low	Low	Gross	ns	Gross	Low	Normal	ns	Normal
PRB5A	ns	Low	ns	Low	ns	Normal	ns	Gross	ns	Normal	ns	Normal
PRB6	Normal	Normal	ns	Normal	Moderate	Low	ns	Gross	Normal	Normal	ns	Normal
PRB100NW	ns	ns	ns	Moderate	ns	ns	ns	Gross	ns	ns	ns	Normal
PRB100SE	ns	ns	ns	Moderate	ns	ns	ns	Gross	ns	ns	ns	Normal

[1] Redox potential and total sulphides were not measured in Cycle one.

[2] Sediment samples analyzed by a different laboratory than cycles Four and Five.

ns = not sampled.

At all stations, a general improvement in sediment quality has been observed over time, with the exception of redox potential, although concerns were raised in Cycle Six regarding the change in redox sample analyses personnel. The degree of organic enrichment in sediments, indicated by TOC impacts, has remained similar or shown some improvement across cycles. Improvements in sulphide concentrations in Cycle Six indicate that sediment quality has reached "normal" conditions at all sites, with the exception of PRB2, and with respect to sulphides, has recovered from effects of historical pulpmill discharges. The oxidative-state remains grossly impacted at stations closest to the diffuser (within the historical near field area) and, despite observed improvements between Cycle Two and Cycle Three, indicated deterioration in the oxidative-state (i.e., becoming more negative) at all far-field sites in Cycle Six. Redox potential and total sulphides in sediments were analyzed by different personal, compared to previous cycles, which may have confounded the comparisons across cycles.

4.5.3 Effects Along the Exposure Gradient

Stations closest to Powell River diffuser continue to show significant effects that exceed the CES for benthic invertebrate communities (Section 4.3.6.1); this effect diminishes with increasing distance from the diffuser (i.e., increasing distance from the historical fibre mat). In Cycle Six, this was observed in taxa richness and the Bray-Curtis Index (Table 4.15). The direction of these effects (expressed as a positive correlation in the r value) indicates that taxa richness and the Bray-Curtis index significantly increase with increasing distance from the diffuser. Closer to the mill, communities become less similar and are dominated by fewer taxa (i.e., invertebrate families).

A spatially condensed study design, with more stations near the diffuser and fewer distant (far-field) stations, likely contributed to the significant effects observed in Cycle Six and not observed in Cycles Two and Three.

Table 4.15 Summary of benthic invertebrate endpoint analyses, Powell River EEM Cycle Six.

Effect Endpoint	Effect?	Direction	Magnitude
Density	Yes	Increases with distance	|r|=0.780
Taxa Richness	No	-	-
Evenness	No	-	-
Diversity	No	-	-
Bray-Curtis	Yes	Increasingly different with distance	|r|=0.904

Stations PRB1, PRB3 and PRB2 (within the Cycle Three near-field area) continue to be dominated by deposit-feeding species that are commonly found in organic enriched and or polluted areas such municipal and industrial outfalls (Musale and Desai 2011; Simboura and Zenetos 2002; Eleftheriou and Basford 1989). These species include the polychaetes, *Prionospio multibranchiata*., *Lumbrineris sp*. and *Pholoe s*., which prefer sediments comprised of silts and clays that allow for easy burrowing (Simboura and Zenetos 2002). These fine sediments occur in higher proportion at stations closer to the diffuser.

Gradient stations further from the diffuser as well as the two stations closest to the diffuser (PRB100SE and PRB100NW) were dominated by a deposit-feeding polychaete *Mediomastus californiensis*; which is often found in remediated areas with improving sediment oxygen concentrations and finer sandy sediments (Gallagher and Keay 1998; Flint and Kalke 1986). This species has also been observed to out-compete more pollution tolerant species such as *Capitella capitata* when pollution loads decline (Swartz et al. 1986). Gradient stations were also dominated by an opportunistic species of phoronid *Phoronis psammophila;* which is a filter-feeding species of horseshoe worm that prefers sandy substrates with minimal silt content (Simboura and Zenetos 2002).

Stations PRB100SE and PRB100NW, sampled approximately 100 m north and south of the diffuser and for the first time in Cycle Six, were more closely related to stations further from the diffuser; this was observed in terms of organic enrichment and oxidative state as well as biotic indices. These stations are within the current 1% dilution zone, as identified in Hatfield (2010b), and are representative of current conditions near the diffuser. Relatively high abundance of *Axinopsida serricata,* a small free-burrowing deposit feeding bivalve, was observed at these stations. Several studies have found that *Axinopsida serricata* was one of the most abundant species of benthic invertebrate in areas were organic enrichment was declining (Stull et al. 1986 and Swartz et al. 1986). A possible explanation for the sediment characteristics at these two stations might be related to historical dispersion patterns at the outfall or wood-chip barging/log-boom activities. These activities are not permitted in the immediate vicinity of the diffuser possibly decreasing their effect on sediments at stations PRB100SE and PRB100NW.

Sediments close to the diffuser continue to exhibit high TOC, increased sulphides and a negative oxidative state that appear to be mill-related. Given large improvements in effluent quality, in terms of significant decreases in discharged volumes of BOD and TSS, and the consistent declines in TOC in sediments over time, the cause of the effect is clearly historical (i.e., a result of the historical fibre mat, defined in Hatfield [2007]).

4.5.3.1 Conclusions

Based on the results of the Cycle Six EEM benthic invertebrate survey and supporting sediment and water quality surveys, the following conclusions are made:

- Benthic invertebrate taxa richness and the Bray-Curtis dissimilarity index exhibited significant spatial trends along the absolute distance exposure gradient and with the C/N ratio. Taxa richness and the Bray-Curtis index generally increased with increasing distance from the diffuser, while taxa richness decreased and the Bray-Curtis index increased with increasing C/N ratio;
- No effects were observed on invertebrate density, Simpson's diversity or evenness along the distance exposure gradient or the C/N ratio;

- While an overall improvement in the condition of sediments is evident from Cycle One to Cycle Six, sediments closest to the diffuser and within Cycle Three near-field area continue to exhibit organic enrichment and more anoxic conditions relative to far-field stations;
- Overall, benthic conditions near the Powell River pulpmill improved relative to previous cycles, evident in the general increase in invertebrate densities at nearly all sites and the large increase in total taxa richness. In addition, the increase in total taxa richness was largely associated with an increase in the number of epifaunal taxa that inhabit "harder" sandy substrates indicative of improving sediment conditions and reference type areas;
- Concentrations of pulpmill-specific contaminants in sediment (i.e., chlorinated organic compounds) continue to decline; and
- Given the improving state of the sediment quality near the Powell River Pulpmill between Cycle Three and Cycle Six, it is evident that the anoxic conditions and enrichment in the area surrounding the pulpmill diffuser are from historical pulpmill discharges and effects on benthos were likely not from current mill discharges.

5.0 CONCLUSIONS

Based on the results of the Powell River EEM Cycle Six program, the following conclusion can be made.

5.1 SUBLETHAL TOXICITY OF EFFLUENT

Effects on echinoderm fertilization were observed at a mean effluent concentration of 64.4% (IC25); and algal reproduction was affected at a mean effluent concentration of 4.9% (IC25).

The sublethal toxicity of effluent discharged from the Powell River pulpmill was similar to, or slightly greater than that observed in recent EEM cycles. Sublethal toxicity testing results indicate that Powell River effluent may influence the receiving environment in a zone up to 19 m for invertebrate fertilization, and 24.7 m for algal reproduction.

5.2 BENTHIC COMMUNITIES AND SUPPORTING ENVIRONMENTAL VARIABLES

Benthic invertebrate taxa richness and the Bray-Curtis dissimilarity index exhibited significant spatial trends, greater than the CES, along the absolute distance exposure gradient and with the C/N ratio. Taxa richness and the Bray-Curtis index generally increased with increasing distance from the diffuser, while taxa richness decreased and the Bray-Curtis index increased with increasing C/N ratio. A spatially condensed study design, with more stations near the diffuser and fewer distant (far-field) stations, likely contributed to the observation of these significant effects in Cycle Six and not in Cycles Two and Three.

Overall, benthic conditions near the Powell River pulpmill improved relative to previous cycles, evident in the general increase in invertebrate densities at nearly all sites and the large increase in total taxa richness. While benthic invertebrate communities within the historical near-field area continue to be dominated by species indicative human induced organic enrichment, the extent of this impact has decreased over time.

While an overall improvement in the condition of sediments is evident from Cycle One to Cycle Six, sediments closest to the diffuser and within Cycle Three near-field area continue to exhibit organic enrichment and more anoxic conditions relative to far-field stations. Given large improvements in effluent quality, in terms of significant decreases in discharged volumes of BOD and TSS, and the consistent declines in TOC in sediments over time, the cause of the effect is clearly historical.

6.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

HATFIELD CONSULTANTS:

Approved by: ______________________ April 2, 2013

Colin Schwindt — Date
Project Manager

Approved by: ______________________ April 2, 2013

Martin Davies — Date
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8.0 GLOSSARY

Acute	With reference to toxicity tests with fish, usually means an effect that happens within four to seven days, or an exposure of that duration. An acute effect could be mild or sublethal, if it were rapid.
BOD	Biochemical oxygen demand. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. Usually conducted as a 5-day test (i.e., BOD_5).
CL	Confidence limits. A set of possible values within which the true value will lie with a specified level of probability.
Colour	True colour of water is the colour of a filtered water sample (and thus with turbidity removed), and results from materials which are dissolved in the water. These materials include natural mineral components such as iron and calcium carbonate, as well as dissolved organic matter such as humic acids, tannin, and lignin. Organic and inorganic compounds from industrial or agricultural uses may also add colour to water. As with turbidity, colour hinders the transmission of light through water, and thus "regulates" biological processes within the body of water.
Concentration Units	

Concentration Units	Abbreviation	Units
Parts per million	ppm	mg/kg or µg/g or mg/L
Parts per billion	ppb	µg/kg or ng/g or µg/L
Parts per trillion	ppt	ng/kg or pg/g or ng/L
Parts per quadrillion	ppq	pg/kg or fg/g or pg/L

Conductivity	A numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence and relative concentrations, and on the temperature of measurement.
Dioxins/Furans	Polychlorinated dibenzo-para-dioxins (PCDDs) and dibenzofurans (PCDFs) are often simply called dioxins, although they are two separate groups of substances with similar effects. There are 210 different compounds, of which 17 are the most toxic.

EC*p*	A point estimate of the concentration of test material that causes a specified percentage effective toxicity (sublethal or lethal). In most instances, the EC*p* is statistically derived by analysis of an observed biological response (e.g., incidence of nonviable embryos or reduced hatching success) for various test concentrations after a fixed period of exposure. EC25 is used for the rainbow trout sublethal toxicity test.
IC*p*	A point estimate of the concentration of test material that causes a specified percentage impairment in a quantitative biological test which measures a change in rate, such as reproduction, growth, or respiration.
Intertidal	The area of the marine shoreline that is only covered with water a portion of the time. Three intertidal zones typically are identified: upper (which is out of water most of the time); mid (which is in or out of water roughly equal amounts of time); and lower (which is underwater most of the time). Each zone supports a unique assemblage of biological communities.
LC_{50}	Median lethal concentration. The concentration of a substance that is estimated to kill half of a group of organisms. The duration of exposure must be specified (e.g., 96-hour LC_{50}).
Macroinvertebrates	Those invertebrate (without backbone) animals that are visible to the eye and retained by a sieve with 500 µm mesh openings for freshwater, or 1,000 µm mesh openings for marine surveys (EEM methods).
MOE	Ministry of Environment.
PEP	Provincial Emergency Program.
Plume	The main pathway for dispersal of effluent within the receiving waters, prior to its complete mixing.
Reference Toxicant	A chemical of quantified toxicity to test organisms, used to gauge the fitness, health, and sensitivity of a batch of test organisms.
SD	Standard deviation.
SE	Standard error.
Secondary Treatment	A stage of purification of a liquid waste in which micro-organisms decompose organic substances in the waste. In the process, the micro-organisms use oxygen. Oxygen usually is supplied by mechanical aeration and/or large surface area of treatment ponds (lagoons). Most secondary treatment also reduces toxicity.

Sublethal	A concentration or level that would not cause death. An effect that is not directly lethal.
T_4CDD	2,3,7,8-tetrachlorodibenzo-para-dioxin, the most toxic dioxin.
TEQ	Toxic Equivalents.
TSS	Total suspended solids (TSS) is a measurement of the oven dry weight of particles of matter suspended in the water which can be filtered through a standard filter paper with pore size of 0.45 micrometres.
v/v	volume/volume - used to define dilution ratios for two liquids.

APPENDICES

Appendix A1

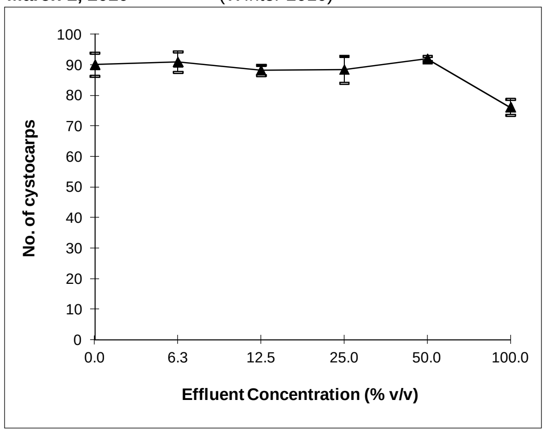
Sublethal Toxicity Testing Results and Calculations

Table A1-1 Catalyst Paper, Powell River Division, Sublethal Effluent Toxicity Test Results, Cycle Six.

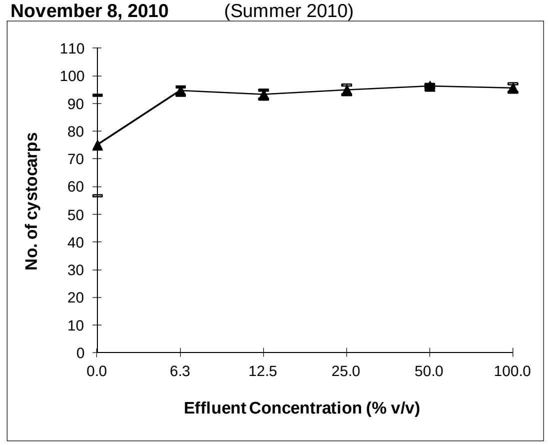
Testing Period	Project Number	Effluent Description	Collection Date	Consultant / Laboratory	Species Tested	Test type	Flag LC50%				Flag EC25 or IC25%				Comments
		(final, cooling, etc.)	yyyymmdd			S=Survival, G=Growth, R=Reproduction	> for greater than 100%	LC50 %	LC50 Lower 95% cl	LC50 Upper 95% cl	> for greater than 100%	EC25 or IC25 %	EC25 or IC25 Lower 95% cl	EC25 or IC25 Upper 95% cl	
Winter 2010	pp1053	Outfall #1	20100302	Cantest	Strongylocentrotus purpuratus	R					>	100			
Winter 2010	pp1053	Outfall #1	20100302	Saskatchewan Research Council	Champia parvula	R						26.6	9.5	44.9	
Summer 2010	pp1053	Outfall #1	20101108	Maxxam Analytics	Strongylocentrotus purpuratus	R					>	100			
Summer 2010	pp1053	Outfall #1	20101108	Aquatox Testing & Consulting Inc.	Champia parvula	R						43.3	42.7	44.2	
Winter 2011	pp1053	Outfall #1	20110502	Maxxam Analytics	Strongylocentrotus purpuratus	R					>	100			
Winter 2011	pp1053	Outfall #1	20110502	Aquatox Testing & Consulting Inc.	Champia parvula	R						9.41	6.49	11.1	
Summer 2011	pp1053	Outfall #1	20111031	Nautilus Environmental	Strongylocentrotus purpuratus	R						39.2	34.1	47.0	
Summer 2011	pp1053	Outfall #1	20110926	Aquatox Testing & Consulting Inc.	Champia parvula	R						1.57	1.25	1.85	
Winter 2012	pp1053	Outfall #1	20120416	Nautilus Environmental	Strongylocentrotus purpuratus	R						52.5	49.8	54.9	
Winter 2012	pp1053	Outfall #1	20120319	Aquatox Testing & Consulting Inc.	Champia parvula	R						1.32	0.79	1.41	
Summer 2012	pp1053	Outfall #1	20121022	Nautilus Environmental	Strongylocentrotus purpuratus	R						34.8	28.4	42.6	
Summer 2012	pp1053	Outfall #1	20121022	Aquatox Testing & Consulting Inc.	Champia parvula	R						0.59	0.14	1.07	

Table A1-2 Mean (± SD) number of echinoderm eggs fertilized when exposed to final effluent and control water, Catalyst Paper, Powell River Division, EEM Cycle Six.

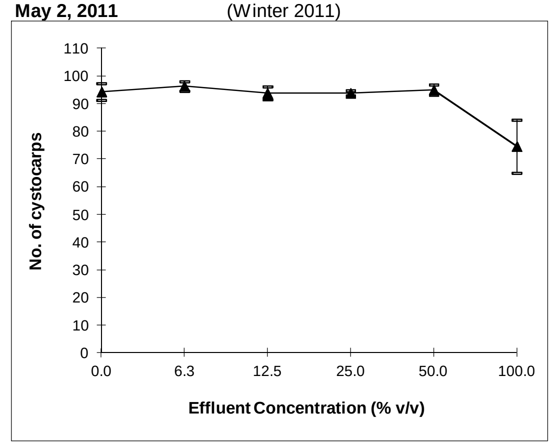
March 2, 2010 (Winter 2010)



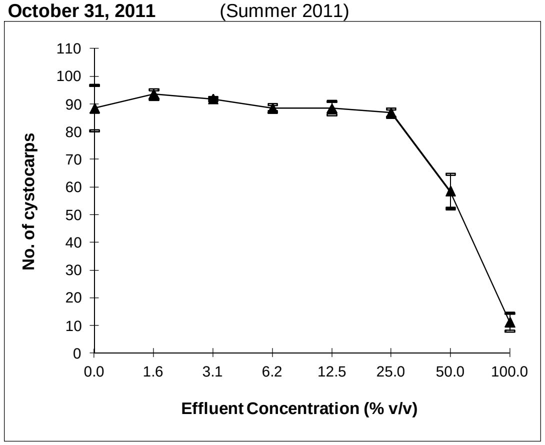
November 8, 2010 (Summer 2010)



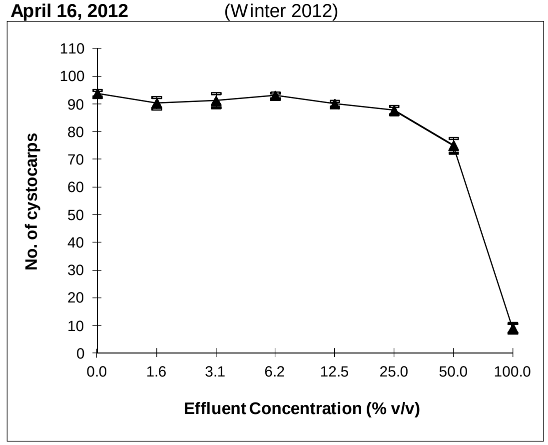
May 2, 2011 (Winter 2011)



October 31, 2011 (Summer 2011)



April 16, 2012 (Winter 2012)



October 22, 2012 (Summer 2012)

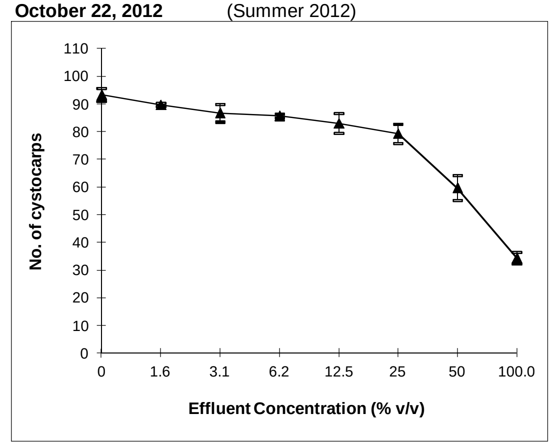
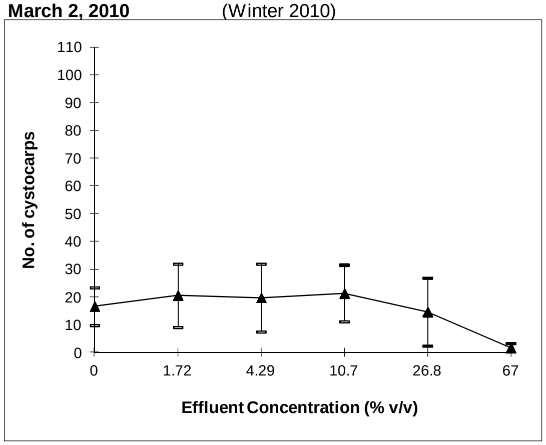
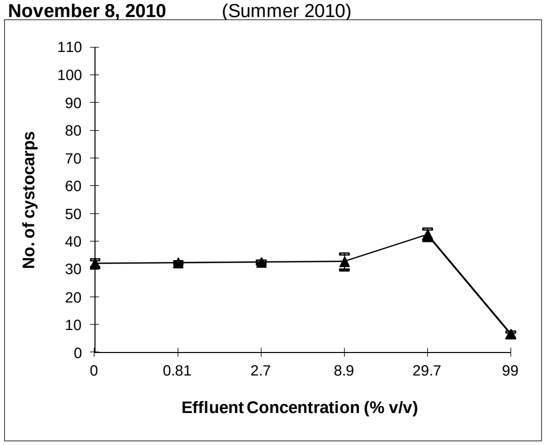


Table A1-3 Mean (± SD) number of cystocarps produced by an alga (*Champia parvula*) exposed to final effluent and control water, Catalyst Paper, Powell River Division, EEM Cycle Six.

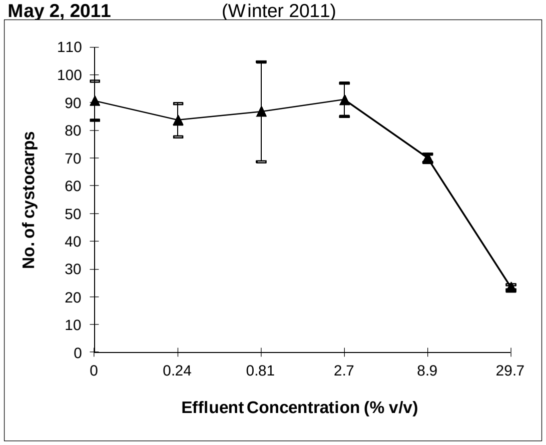
March 2, 2010 (Winter 2010)



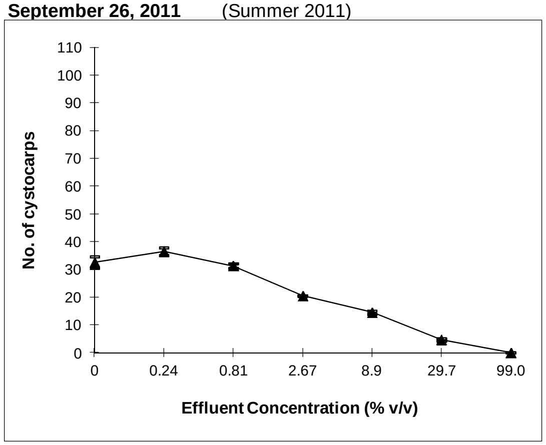
November 8, 2010 (Summer 2010)



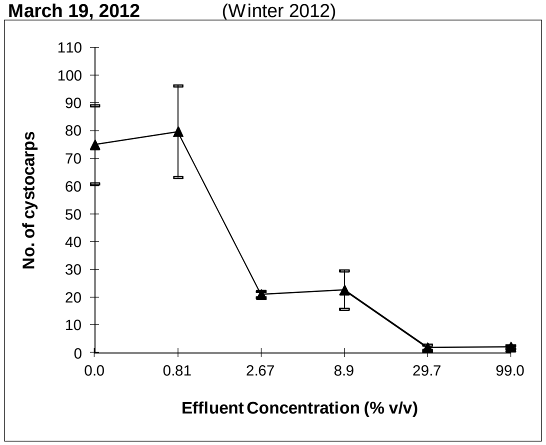
May 2, 2011 (Winter 2011)



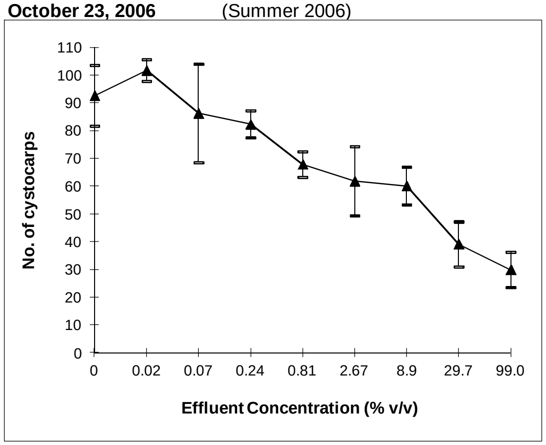
September 26, 2011 (Summer 2011)



March 19, 2012 (Winter 2012)



October 23, 2006 (Summer 2006)



Appendix A2

Benthic Invertebrate Data and QA/QC reports

Biologica
Environmental Services Ltd.
Marine & Freshwater Taxonomy

Powell River EEM 2012 QA/QC Report - Sorting Efficiency
Prepared for Hatfield Consultants

Sorting efficiency calculated only for re-sorted samples.
Calculation for % efficiency: [(total count – (spot check and re-sort) / total count] x 100%

Quality Control:
16 of 26 samples were spotchecked.
Samples for QC re-sorts were selected non-randomly based on results of spot checks.

Re-sorted 7 of 26 samples for a re-sort rate of 26.9%
Estimated sorting efficiency from QC re-sorts: 92.6%

Quality Assurance:
QA samples were randomly selected from all 26 samples.

Re-sorted 3 of 26 samples for a re-sort rate of 11.5%
Estimated sorting effiecincy from QA re-sorts: 94.1% (See table below)

This table is generated using preliminary count data (total number of organisms before identification).

Sample	Fraction	Initial Count	# Recovered on spot check	# Recovered QA Resort	Total Count	% Efficiency after QA
PRB3-R1	Whole	53	1	0	54	98.2%
	1/4a	266	1	11	278	95.7%
PRB4B-R1	Whole	165		10	175	94.3%
	1/4a	295		30	325	90.8%
PRB5A-R1	Whole	807		75	882	91.5%
					Average	**94.1%**

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www.biologica.bc.ca info@biologica.bc.ca

Table A2-1 Bethic invertebrate densities (#N/m^2) from each replicate at each station, Powell River EEM Cycle 6, March 2012.

Phylum	Order	Taxon	PRB1 Rep 1		PRB1 Rep 2		PRB1A Rep 1		PRB1A Rep 2		PRB2 Rep 1		PRB2 Rep 2		PRB3 Rep 1		PRB3 Rep 2		PRB3A Rep 1		PRB3A Rep 2		PRB4 Rep 1		PRB4 Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Porifera			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Desmacellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Clathrinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Velellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Halisarcidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mycalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hymedesmiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Myxillidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Suberitidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
		Sycettidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tetillidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cnidaria			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrozoa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gymnoblastea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0
		Hydroida indet.	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bougainvilliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
		Campanulariidae	0	0	0	0	90	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
		Campanulinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lafoeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Olindiasidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
		Pandeidae	0	0	40	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0
	Anthozoa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Actinaria indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
		Actiniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cerianthidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Edwardsiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Platyhelminthes			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Platyhelminthes indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anopla sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nemertea indet.	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	20	0	20	0	10	0	0
		Amphiporidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Carinomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Emplectonematidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
		Lineidae	210	80	200	80	0	0	80	10	40	40	0	0	170	40	420	40	80	150	40	0	10	0	30	10
		Prosorhochmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tetrastemmatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tubulanidae	0	0	0	0	40	0	170	0	0	0	0	0	0	0	0	0	90	0	50	40	30	10	10	10
Annelida			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polychaeta Errantia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dorvilleidae	0	80	0	50	80	0	0	0	40	0	0	0	1050	360	280	40	0	0	0	0	10	0	0	0
		Euphrosinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Glyceridae	50	0	20	0	140	0	270	0	40	0	50	0	120	0	20	0	160	0	230	40	60	0	130	0
		Goniadidae	0	0	0	0	0	0	0	0	0	0	20	0	0	0	10	0	0	0	40	0	40	20	10	10
		Hesionidae	40	0	0	0	50	0	40	0	0	0	200	0	200	0	290	0	0	0	0	0	0	0	0	0
		187 Gyptis lobatus	0	0	280	0	40	0	40	0	0	0	0	0	0	0	400	0	20	0	0	0	0	0	0	0
		Histriobdellidae	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0
		Lacydoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
		Lumbrineridae	1340	0	900	0	540	0	300	0	40	0	210	0	970	0	280	40	430	0	530	0	200	0	80	0
		Nephtyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	10	0	10	0
		Nereididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
		Oenonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0
		Onuphidae	40	0	40	0	0	0	20	0	0	0	10	0	0	0	0	0	0	0	10	0	20	0	30	0
		Pholoidae	0	0	0	0	400	270	240	50	0	0	0	0	0	0	120	80	410	30	80	0	80	20	30	10
		Phyllodocidae	10	0	10	0	50	0	10	0	0	0	40	0	10	0	40	0	50	0	20	0	100	10	0	0
		Polynoidae	90	0	120	0	160	0	100	0	40	0	40	0	0	0	60	0	40	0	10	0	90	10	10	0
		Sigalionidae	310	0	410	200	380	20	10	0	200	0	480	280	1160	0	680	0	80	10	130	0	50	10	10	0
		Sphaerodoridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Syllidae	230	0	0	0	510	60	180	0	0	0	80	40	540	40	250	40	730	70	340	40	810	40	210	0

Table A2-1 Bethic invertebrate densities (#N/m^2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB1		PRB1		PRB1A		PRB1A		PRB2		PRB2		PRB3		PRB3		PRB3A		PRB3A		PRB4		PRB4	
			Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
	Polychaeta		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedentaria	Ampharetidae	0	0	0	0	120	0	40	0	0	0	0	0	0	0	0	0	0	50	100	40	20	0	10	20
		Apistobranchidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0
		Capitellidae	260	10	240	0	420	0	410	0	200	40	1010	80	410	120	520	120	890	0	2120	0	1700	120	580	40
		Chaetopteridae	90	0	50	0	90	0	210	0	180	0	80	0	200	0	40	0	1020	0	710	0	10	0	0	0
		251 Phyllochaetopterus pottsi	0	0	40	0	0	0	0	0	40	0	0	0	0	0	0	0	60	0	50	0	0	0	0	0
		Cirratulidae	40	40	0	40	200	50	150	0	0	0	0	0	130	0	160	0	120	10	10	0	110	10	70	10
		Flabelligeridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Magelonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	140	40	30	0	0	0
		Maldanidae	80	0	40	0	80	90	120	80	0	0	0	40	80	0	40	0	390	100	400	120	470	50	270	50
		Opheliidae	0	0	0	0	0	0	0	0	80	0	0	0	50	0	130	0	0	0	0	0	0	0	0	0
		Orbiniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	10	0	10	0
		Oweniidae	0	0	120	0	0	0	10	0	80	0	120	0	40	0	80	0	580	0	1390	0	480	40	380	20
		Paraonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	240	0	120	0	50	0
		Pectinariidae	20	0	150	0	90	0	0	0	0	0	40	0	60	0	340	0	70	0	60	0	0	0	0	0
		Sabellariidae	0	0	0	0	0	10	40	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
		Sabellidae	0	0	0	0	90	40	0	0	0	0	0	0	0	0	0	0	90	0	130	0	30	0	30	0
		Scalibregmatidae	0	0	0	0	0	10	40	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	20	0
		Serpulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Spionidae	1510	0	1840	0	130	0	240	20	760	0	1160	0	2640	0	610	0	410	10	670	0	290	10	20	0
		Spirorbidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Terebellidae	120	0	60	40	850	40	360	60	0	40	50	80	180	80	20	160	300	20	90	250	100	10	100	10
		Trichobranchidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	20	0	10	0
	Oligochaeta		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Enchytraeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echiura			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Echiuridae	0	0	80	0	0	0	0	0	10	0	0	0	10	0	0	0	0	0	0	0	20	0	10	0
Sipuncula			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Golfingiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Mollusca			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gastropoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Doridacea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gastropoda indet.	0	0	0	160	0	0	0	0	0	0	0	80	0	0	80	0	0	40	0	120	0	0	0	0
		Aglajidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cerithiopsidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Columbellidae	40	0	160	40	0	0	90	0	280	40	40	0	50	0	20	0	60	0	80	0	30	0	20	0
		Conidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	10	0	0	0
		Cylichnidae	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	20	0	0	0	20	0	20	0
		Epitoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Eulimidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nassariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Naticidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pyramidellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
		Rissoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Trochidae	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
		Turridae	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bivalvia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bivalvia indet.	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	20	0	0	0	0	0	0
		Astartidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cardiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hiatellidae	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
		Lasaeidae	40	0	120	0	0	0	0	0	0	0	0	0	80	0	210	0	0	0	0	0	0	0	20	0
		Lucinidae	0	0	10	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	10	0	0
		Lyonsiidae	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	40	40	0	0	0	0
		Mytilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0
		Nuculanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
		Nuculidae	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0
		Pectinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
		Solemyidae	0	0	40	0	0	0	0	0	0	0	40	0	0	0	40	0	0	0	0	0	0	0	0	0
		Tellinidae	0	0	0	0	40	0	0	0	40	0	0	0	0	0	0	0	70	80	40	40	20	10	10	40
		Thyasirisae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	0	40	0	100	0	60	0
		Veneridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0
		Yoldiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A2-1 Bethic invertebrate densities (#N/m^2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB1 Rep 1		PRB1 Rep 2		PRB1A Rep 1		PRB1A Rep 2		PRB2 Rep 1		PRB2 Rep 2		PRB3 Rep 1		PRB3 Rep 2		PRB3A Rep 1		PRB3A Rep 2		PRB4 Rep 1		PRB4 Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Anthropoda			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Copepoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cyclopoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	10	0	10	0
	Ostracoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cylindroleberididae	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
		Philomedidae	0	0	160	0	0	0	80	0	280	0	120	0	600	0	360	0	320	0	680	0	30	0	10	0
	Cirripedia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pollicipedidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptostraca		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nebaliidae	0	0	80	0	0	0	0	0	40	0	80	0	0	0	0	0	0	0	0	0	0	0	10	0
	Cumacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Diastylidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Leuconidae	0	0	0	0	240	0	40	0	40	0	40	0	0	0	0	0	360	0	160	0	30	0	60	0
		Nannastacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
	Tanaidacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anarthruridae	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	60	0	50	0	0	0	0	0
		Paratanaidae	0	0	0	0	0	0	0	0	0	0	0	0	120	0	160	0	0	0	130	0	10	0	0	0
		Pseudotanaidae	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Isopoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anthuridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
		Gnathiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	0	20	0
		Limnoriidae	40	0	220	0	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paramunnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gammaridea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ampeliscidae	0	0	0	0	10	0	10	0	0	0	0	0	40	0	0	0	180	0	640	0	70	0	30	0
		Aoridae	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0
		Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dexaminidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	20	0	40	0	0	0	0	0
		Isaeidae	0	0	0	0	0	0	40	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lysianassidae	80	0	160	0	0	0	90	0	130	40	200	0	250	0	640	0	10	20	60	0	90	0	30	0
		Melphidippidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Melitidae	0	0	10	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	10	0	0	0	0	0
		Oedicerotidae	0	0	0	0	0	0	40	0	40	0	0	0	0	0	120	0	60	0	160	0	60	0	40	0
		Pardaliscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
		Phoxocephalidae	90	0	40	0	380	0	10	0	10	0	0	0	380	80	140	40	260	0	440	0	180	0	80	0
		Pleustidae	0	0	40	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0
		Synopiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	10	0	0	0
	Decapoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Crangonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hippolytidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Majidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pinnotheridae	40	0	50	0	0	0	10	0	10	0	0	0	50	0	60	0	0	0	0	0	10	0	0	0
Phoronida			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phoronidae	40	0	40	0	0	0	130	0	0	0	80	0	0	0	0	0	590	270	590	0	180	30	140	90
Brachiopoda			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cancellothyrididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entoprocta			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Barentsiidae	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0
Bryozoa			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bryozoa indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Alcyonidiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bugulidae	0	0	0	0	50	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Calloporidae	0	0	0	0	0	0	80	0	40	0	0	0	10	0	10	0	10	0	0	0	30	0	10	0
		Candidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
		Cellariidae	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chapperiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Crisiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Escharellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hippothoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lichenoporidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phylactellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tubuliporidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Vesiculariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0

Table A2-1 Bethic invertebrate densities (#N/m^2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB1 Rep 1		PRB1 Rep 2		PRB1A Rep 1		PRB1A Rep 2		PRB2 Rep 1		PRB2 Rep 2		PRB3 Rep 1		PRB3 Rep 2		PRB3A Rep 1		PRB3A Rep 2		PRB4 Rep 1		PRB4 Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Echinodermata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ophiuroidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ophiuroidea indet.	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	20	0	40	0	80	0	30
		Amphiuridae	0	0	10	40	10	0	10	40	10	0	0	0	20	40	0	0	10	0	10	0	0	0	10	0
		Ophiuridae	0	0	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
	Holothuroidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dendrochirotida indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chirodotidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cucumariidae	0	0	0	0	10	40	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
		Phyllophoridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
		Synaptidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	10	0
	Echinoidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Strongylocentrotidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urochordata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ascidacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Didemnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Molgulidae	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pyuridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Styelidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemichordata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Harrimaniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total Density	**4810**	**210**	**5820**	**650**	**5540**	**670**	**3900**	**330**	**2750**	**200**	**4300**	**640**	**9920**	**760**	**6830**	**560**	**8400**	**990**	**11110**	**940**	**5990**	**510**	**2780**	**350**
		Number of Taxa	**23**	**4**	**33**	**8**	**32**	**11**	**40**	**10**	**26**	**5**	**25**	**7**	**35**	**7**	**35**	**8**	**46**	**20**	**52**	**15**	**51**	**19**	**49**	**13**
				-1010				1640				-1550				3090				-2710				#REF!		

Table A2-1 Bethic invertebrate densities (#N/m2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd).

Phylum	Order	Taxon	PRB4A Rep 1 Adult	PRB4A Rep 1 Juvenile	PRB4A Rep 2 Adult	PRB4A Rep 2 Juvenile	PRB4B Rep 1 Adult	PRB4B Rep 1 Juvenile	PRB4B Rep 2 Adult	PRB4B Rep 2 Juvenile	PRB5 Rep 1 Adult	PRB5 Rep 1 Juvenile	PRB5 Rep 2 Adult	PRB5 Rep 2 Juvenile	PRB5A Rep 1 Adult	PRB5A Rep 1 Juvenile	PRB5A Rep 2 Adult	PRB5A Rep 2 Juvenile	PRB6 Rep 1 Adult	PRB6 Rep 1 Juvenile	PRB6 Rep 2 Adult	PRB6 Rep 2 Juvenile	PRB100SE Rep 1 Adult	PRB100SE Rep 1 Juvenile	PRB100SE Rep 2 Adult	PRB100SE Rep 2 Juvenile	PRB100NW Rep 1 Adult	PRB100NW Rep 1 Juvenile	PRB100NW Rep 2 Adult	PRB100NW Rep 2 Juvenile
Porifera			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Desmacellidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Clathrinidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Velellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Halisarcidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Mycalidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hymedesmiidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0
		Myxillidae	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Suberitidae	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0	0	0	0	0	0	0
		Sycettidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tetillidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0
Cnidaria			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrozoa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gymnoblastea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Hydroida indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bougainvilliidae	10	0	0	0	0	0	0	0	0	0	20	0	0	0	40	0	0	0	200	0	0	0	0	0	0	0	10	0
		Campanulariidae	0	0	0	0	50	0	80	0	40	0	0	0	40	0	0	0	0	0	110	0	0	0	0	0	0	0	0	0
		Campanulinidae	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	410	0	0	0	0	0	0	0	0	0
		Lafoeidae	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0	0	0	0	0
		Olindiasidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pandeidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Anthozoa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Actinaria indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	40	0	0	0	0	0	0	0	0
		Actiniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Cerianthidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
		Edwardsiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Platyhelminthes			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Platyhelminthes indet.	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anopla sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Nemertea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amphiporidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0
		Carinomidae	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Emplectonematidae	0	0	0	0	0	0	40	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
		Lineidae	0	10	40	0	40	0	40	0	50	80	0	120	80	10	60	0	20	0	0	20	20	0	80	40	0	0	0	40
		Prosorhochmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0
		Tetrastemmatidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tubulanidae	30	0	0	0	40	200	0	0	50	0	10	20	20	20	40	80	0	10	0	0	80	0	40	0	0	0	10	40
Annelida			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polychaeta Errantia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dorvilleidae	0	0	0	0	200	40	0	0	10	0	30	0	90	10	100	0	20	10	130	40	10	0	0	0	0	0	40	0
		Euphrosinidae	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Glyceridae	70	0	200	0	60	0	140	0	70	0	120	20	100	10	200	0	70	0	40	0	120	0	130	0	30	0	70	0
		Goniadidae	10	10	30	0	0	0	0	0	10	0	40	0	10	0	40	0	20	0	0	0	140	0	40	0	0	0	110	0
		Hesionidae	0	0	0	0	40	0	0	0	0	0	0	0	20	0	40	0	10	0	0	0	0	0	0	0	0	0	0	0
		187 Gyptis lobatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Histriobdellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
		Lacydoniidae	0	0	0	0	80	0	40	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lumbrineridae	200	0	150	0	390	0	570	0	540	0	310	0	410	0	380	80	170	0	210	40	480	0	920	0	310	0	260	0
		Nephtyidae	0	0	0	0	0	0	10	0	20	0	10	0	20	0	30	0	10	0	30	0	0	0	0	0	0	0	0	0
		Nereididae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	100	0	10	0	0	0	0	0	10	0
		Oenonidae	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Onuphidae	0	10	0	10	70	0	20	0	70	0	80	0	60	10	10	0	20	0	50	0	40	0	0	0	0	0	40	0
		Pholoidae	0	0	0	0	290	50	120	0	0	0	150	0	130	10	1100	190	40	20	430	30	0	0	80	0	0	0	0	0
		Phyllodocidae	10	0	0	0	80	0	40	0	90	0	90	0	40	0	90	0	10	0	100	0	10	0	80	0	0	0	0	0
		Polynoidae	10	0	20	0	10	0	230	0	40	0	90	10	70	0	90	0	10	0	50	0	20	0	70	0	0	0	10	0
		Sigalionidae	10	0	70	0	40	40	40	0	40	0	40	0	0	0	60	0	20	0	50	0	40	0	120	0	80	40	0	0
		Sphaerodoridae	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Syllidae	60	0	150	0	770	210	400	10	230	10	590	0	620	20	1940	0	310	40	540	40	120	0	490	0	40	0	0	0

Table A2-1 Bethic invertebrate densities (#N/m2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB4A		PRB4A		PRB4B		PRB4B		PRB5		PRB5		PRB5A		PRB5A		PRB6		PRB6		PRB100SE		PRB100SE		PRB100NW		PRB100NW	
			Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2		Rep 1		Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
	Polychaeta Sedentaria		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ampharetidae	10	20	60	30	40	80	0	40	0	0	40	60	60	40	90	0	50	10	80	0	80	0	80	80	80	80	50	0
		Apistobranchidae	10	0	0	0	40	0	40	0	0	0	20	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Capitellidae	610	40	620	50	3700	240	3740	120	1690	50	2100	60	560	60	2150	40	430	40	470	40	4080	0	3120	80	1250	0	4140	80
		Chaetopteridae	0	0	10	0	240	0	120	0	950	0	970	0	200	0	480	0	280	10	1750	0	0	0	40	0	0	0	0	0
		251 Phyllochaetopterus pottsi	0	0	0	0	390	0	280	0	40	0	20	0	10	0	0	0	0	0	610	0	0	0	0	0	0	0	0	0
		Cirratulidae	20	0	50	0	330	50	150	40	130	0	80	0	110	40	300	90	90	30	80	0	50	0	50	0	0	0	0	0
		Flabelligeridae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	90	0	10	0	0	0	0	0	0	0	0	0	0	0
		Magelonidae	0	0	0	0	0	0	60	0	140	0	100	0	60	0	90	0	20	0	10	0	0	0	0	0	0	0	0	0
		Maldanidae	130	20	190	20	490	0	560	40	180	0	470	120	440	70	540	60	80	50	590	80	70	120	270	240	70	0	150	40
		Opheliidae	0	0	0	0	0	0	10	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Orbiniidae	0	0	60	0	0	0	0	0	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oweniidae	10	0	10	0	160	0	650	120	600	0	810	20	1170	10	1400	0	220	20	360	40	240	0	330	0	40	0	50	0
		Paraonidae	50	0	120	0	120	0	80	0	130	0	20	0	150	0	80	0	60	0	0	0	40	0	0	0	0	0	0	0
		Pectinariidae	0	0	0	0	0	0	80	0	0	0	90	0	40	10	40	0	40	0	120	0	80	0	10	40	60	0	0	0
		Sabellariidae	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Sabellidae	20	10	40	0	150	40	40	0	0	0	40	0	40	10	10	40	50	10	0	0	0	0	40	40	0	0	40	0
		Scalibregmatidae	10	0	30	0	0	40	10	0	0	0	30	0	10	0	10	0	0	0	10	0	30	0	20	0	0	0	10	0
		Serpulidae	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Spionidae	140	0	440	10	1140	0	200	40	230	0	140	20	190	0	520	10	150	0	100	10	90	0	210	0	180	0	390	0
		Spirorbidae	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Terebellidae	80	10	130	160	320	70	150	130	40	0	160	20	140	50	510	40	160	10	150	20	80	10	150	120	120	0	220	0
		Trichobranchidae	0	0	0	10	10	0	0	0	40	0	20	20	20	0	60	0	10	0	0	0	20	0	40	0	0	0	0	0
	Oligochaeta		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Enchytraeidae	0	0	0	0	120	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echiura			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Echiuridae	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	10	0
Sipuncula			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Golfingiidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mollusca			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gastropoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Doridacea indet.	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gastropoda indet.	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	40	0	0	40	0	0	0	0	0	0	40	0	0
		Aglajidae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cerithiopsidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
		Columbellidae	210	0	100	0	50	0	0	0	320	0	420	0	20	0	0	0	10	0	250	0	40	0	0	0	80	0	0	0
		Conidae	0	0	0	0	0	0	40	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cylichnidae	20	0	20	0	0	0	0	0	90	0	40	0	40	10	40	0	0	0	0	0	40	0	40	0	0	0	10	0
		Epitoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
		Eulimidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0
		Nassariidae	0	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Naticidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
		Pyramidellidae	0	0	0	0	10	0	40	0	0	0	50	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rissoidae	0	0	0	0	0	0	0	0	0	0	100	0	20	0	0	0	10	0	120	0	0	0	0	0	0	0	0	0
		Trochidae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0
		Turridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bivalvia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bivalvia indet.	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	40	40	40	0	0	40	0
		Astartidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Cardiidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hiatellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lasaeidae	10	0	0	0	0	0	0	0	40	0	0	0	0	0	50	0	0	0	80	0	0	0	0	0	0	0	20	40
		Lucinidae	0	10	0	0	10	0	0	0	40	40	10	20	0	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0
		Lyonsiidae	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mytilidae	10	0	10	0	0	0	0	0	0	0	60	0	30	0	0	0	10	0	60	20	0	0	0	0	0	0	0	0
		Nuculanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nuculidae	0	0	0	0	40	0	0	0	0	0	70	0	20	0	0	0	0	0	40	0	0	0	0	0	0	0	40	0
		Pectinidae	0	0	0	0	0	90	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0
		Solemyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tellinidae	0	40	10	30	10	40	40	80	40	0	20	60	20	30	10	40	0	0	0	0	40	80	40	0	0	0	30	0
		Thyasirisae	210	0	480	0	0	0	280	0	10	0	60	0	70	0	0	0	10	0	0	0	400	0	200	0	320	0	340	0
		Veneridae	0	0	10	0	0	0	0	0	0	0	20	0	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Yoldiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0

Table A2-1 Bethic invertebrate densities (#N/m2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB4A Rep 1		PRB4A Rep 2		PRB4B Rep 1		PRB4B Rep 2		PRB5 Rep 1		PRB5 Rep 2		PRB5A Rep 1		PRB5A Rep 2		PRB6 Rep 1		PRB6 Rep 2		PRB100SE Rep 1		PRB100SE Rep 2		PRB100NW Rep 1		PRB100NW Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Anthropoda			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Copepoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cyclopoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ostracoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cylindroleberididae	0	0	30	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Philomedidae	170	0	210	0	0	0	160	0	40	0	20	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0	90	0
	Cirripedia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pollicipedidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptostraca		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nebaliidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cumacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Diastylidae	0	0	0	0	0	0	0	0	0	0	0	0	20	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
		Leuconidae	20	0	30	0	40	0	120	0	40	0	80	0	80	0	280	0	20	0	0	0	80	0	160	0	0	0	120	0
		Nannastacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tanaidacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anarthruridae	0	0	20	0	40	0	40	0	80	0	60	0	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Paratanaidae	0	0	0	0	0	0	130	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	80	0	0	0	40	0
		Pseudotanaidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Isopoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anthuridae	0	0	0	0	0	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gnathiidae	0	0	0	0	0	0	0	0	0	0	0	0	20	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
		Limnoriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paramunnidae	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gammaridea indet.	0	0	0	0	0	30	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ampeliscidae	0	0	30	0	110	0	60	0	190	0	170	0	400	10	230	80	30	0	130	40	0	0	50	0	0	40	0	0
		Aoridae	0	0	0	0	40	0	40	0	0	0	0	0	40	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Corophiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
		Dexaminidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Isaeidae	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lysianassidae	40	0	70	0	0	0	90	0	40	0	10	0	40	0	0	0	10	0	20	0	420	0	310	0	50	0	90	0
		Melphidippidae	0	0	0	0	0	0	10	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Melitidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Oedicerotidae	0	0	70	0	10	0	10	0	120	0	10	0	20	0	10	0	10	0	0	0	210	0	40	0	0	0	0	0
		Pardaliscidae	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phoxocephalidae	100	0	250	0	50	0	180	0	200	0	280	0	190	0	140	0	80	0	70	0	320	0	250	0	0	0	130	0
		Pleustidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0
		Synopiidae	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Decapoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Crangonidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hippolytidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Majidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
		Pinnotheridae	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoronida			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phoronidae	370	10	450	30	830	330	1460	280	810	160	1520	660	350	70	410	540	0	10	0	0	120	80	130	0	0	0	40	0
Brachiopoda			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cancellothyrididae	0	0	0	0	10	10	0	0	0	0	0	0	140	140	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Entoprocta			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Barentsiidae	0	0	0	0	0	0	0	0	0	0	20	0	20	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Bryozoa			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bryozoa indet.	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Alcyonidiidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0
		Bugulidae	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0
		Calloporidae	0	0	20	0	50	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0
		Candidae	0	0	0	0	60	0	0	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cellariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chapperiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Crisiidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Escharellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Hippothoidae	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lichenoporidae	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phylactellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Tubuliporidae	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Vesiculariidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A2-1 Bethic invertebrate densities (#N/m2) from each replicate at each station, Powell River EEM Cycle 6, March 2012 (Cont'd.).

Phylum	Order	Taxon	PRB4A Rep 1		PRB4A Rep 2		PRB4B Rep 1		PRB4B Rep 2		PRB5 Rep 1		PRB5 Rep 2		PRB5A Rep 1		PRB5A Rep 2		PRB6 Rep 1		PRB6 Rep 2		PRB100SE Rep 1		PRB100SE Rep 2		PRB100NW Rep 1		PRB100NW Rep 2	
			Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Echinodermata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ophiuroidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ophiuroidea indet.	0	0	0	0	0	40	0	40	0	0	0	60	0	20	0	40	0	0	0	0	0	0	0	40	0	0	0	0
		Amphiuridae	0	0	0	10	0	0	0	0	40	0	10	0	10	10	0	0	0	0	0	40	0	0	0	10	0	0	0	0
		Ophiuridae	0	0	0	0	0	10	0	0	70	80	0	0	20	10	40	60	0	0	20	0	0	0	10	0	0	0	0	0
	Holothuroidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dendrochirotida indet.	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	80	0	0	0	80	0	40	0	0	0	0	0	0
		Chirodotidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	10	0	0	0	0	0	0	0	10	0
		Cucumariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
		Phyllophoridae	0	0	0	0	0	40	10	0	0	0	0	0	30	30	0	0	0	0	0	0	0	40	0	40	0	0	0	0
		Synaptidae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	20	0	10	0	10	0	0	0	0	0	0	0	0	0
	Echinoidea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Strongylocentrotidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Urochordata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ascidacea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Didemnidae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Molgulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pyuridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
		Styelidae	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	20	0	0	10	10	0	0	0	0	0	0	0	0
Hemichordata			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Harrimaniidae	0	0	0	0	0	0	40	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total Density	**2670**	**210**	**4250**	**370**	**11220**	**1670**	**10820**	**980**	**7720**	**430**	**9870**	**1330**	**6780**	**740**	**12060**	**1540**	**2650**	**270**	**8420**	**700**	**7950**	**410**	**7820**	**780**	**2840**	**200**	**6670**	**240**
		Number of Taxa	**31**	**12**	**37**	**11**	**63**	**21**	**49**	**12**	**47**	**7**	**58**	**17**	**70**	**27**	**52**	**18**	**44**	**13**	**60**	**21**	**36**	**7**	**37**	**12**	**17**	**4**	**33**	**5**
				-1580				400				-2150				-5280				-5770				130				-3830		

2012 Cycle Six Reference Collection for Marine Mills (Howe Sound, Port Alice and Powell River)
Prepared by Biologica Environmental Services LTD., Verified by Columbia Science

Region	grpcode	famcode	Locatecode	Taxon	Substitutions/Corrections/Notes	Taxonomic Comments (Biologica)	Comments (Columbia Science)
HS	MOSC	0646	2E-04	*Gadila tolmiei*			*Agree*
HS	ANOL	1136	1E-03	Tubificoid Naididae indet.	Suggest Naididae indet		Agree
HS	MOGA	0558	2E-03	*Haminoea vesicula*			*Agree*
HS	PLTY	0128	1E-02	*Notoplana* spp.			*Agree*
HS	BRYO	0970	2E-02	*Alderina* sp.	on *Astyris gausapata* reference		Did not find in vial
HS	MOGA	0516	2E-02	*Astyris gausapata*			*Agree*
HS	NTEA	0152	1E-01	*Oerstedia dorsalis*	*Nice specimen*		*Agree*
HS	MOBI	0392	2E-01	*Parvalucina tenuisculpta*	*Spelling is Parvilucina*		*Agree*
HS	POER	0202	1B-02	*Bipalponephtys cornuta*		Name change from *Nephtys cornuta*	*Agree*
HS	POER	0206	1B-03	*Drilonereis longa*			*Agree*
HS	POER	0214	1B-04	*Eteone californica*	*No posterior-based ID on mid dorsal cirri*		*Agree*
HS	POER	0228	1B-05	*Exogone dwisula*	*Damaged specimen but probably was E. dwisula*		*Exogone sp*
HS	POER	0220	1B-06	*Gattyana treadwelli*			*Agree*
HS	POER	0180	1B-07	*Glycera nana*			*Agree*
HS	POER	0182	1B-08	*Glycinde armigera*			*Agree*
HS	POER	0208	1B-09	*Onuphis iridescens*			*Agree*
HS	POER	0212	1B-10	*Pholoides asperus*			*Agree*
HS	POER	0186	1C-01	*Podarkeopsis perkinsi*			*Agree*
HS	POER	0204	1C-02	*Nereis procera*			*Agree*
HS	POER	0224	1C-03	*Pholoe glabra*			*Agree*
HS	POSE	0242	1C-04	*Ampharete* nr. *acutifrons*			*Agree*
HS	POSE	0248	1C-05	*Barantolla* nr. *americana*	*1st 6 setigers with capillary notosetae*		*Agree*
HS	POSE	0260	1C-06	*Brada sachalina*			*Agree*
HS	POSE	0272	1C-07	*Leitoscoloplos pugettensis*	*no subpodial lobes*		*Agree*
HS	POSE	0274	1C-08	*Myriochele olgae*	*small specimen somewhat damaged*		*Myriochele sp.*
HS	POSE	0270	1C-09	*Ophelina acuminata*			*Agree*
HS	POSE	0280	1C-10	*Pectinaria californiensis*			*Agree*
HS	POSE	0250	1D-01	*Phyllochaetopterus limicolus*	Family correction to 0250 (Chaetopteridae); Name correction from *P. pottsi* .		*Agree*
HS	POSE	0250	1D-02	*Spiochaetopterus pottsi*	*Spiochaetopterus costarum Cmplx*	Synonym of *Spiochaetoperus costarum* complex (SCAMIT 2012).	*Agree*
HS	POSE	0312	1D-03	*Sternaspis* nr. *fossor*			*Agree*
HS	POSE	0318	1D-04	*Trochochaeta multisetosa*			*Agree*
HS	POSE	0299	1D-05	*Jasmineira pacifica*			*Agree*
HS	BRAC	0952	1D-06	*Terebratulina unguicula*			*Agree*
HS	BRYO	1016	1D-07	*Bowerbankia gracilis*			*Agree*
HS	BRYO	0972	1D-08	*Caberea ellisi*	*long barbed vibracula*		*Agree*
HS	BRYO	0968	1D-09	*Caulibugula californica*	*very small fragment*		*Bugulidae indet.*
HS	CNHY	0090	1D-10	*Clytia cylindrica*	*Clytia* sp. (no *C. cylindrica* present in HS)	Synonym of *C. gracilis*	Agree
HS	CHAC	0673	2B-01	Halacaridae indet.			Agree
HS	CHPY	0666	2B-02	*Nymphon pixellae*			*Agree*
HS	CRAM	0770	2B-03	*Aoroides exilis*			*Agree*
HS	CRAM	0798	2B-04	*Eusirus columbianus*	*eye faded in preservative*		*Agree*
HS	CRAM	0829	2B-05	*Megamoera dentata*			*Agree*
HS	CRAM	0862	2B-06	*Syrrhoe longifrons*			*Agree*
HS	CRAM	0826	2B-07	*Orchomene minutus*		Synonym of *Orchomenella minuta*	*Agree*
HS	CRCU	0698	2B-08	*Vaunthompsonia pacifica*			*Agree*
HS	CRIS	0744	2B-09	*Limnoria lignorum*			*Agree*
HS	CRTA	0713	2B-10	*Typhlotanais williamsae*	*fits description but really tiny specimen--did not dissect mouthparts*		*Agree*
HS	CRTA	0712	2C-01	*Leptochelia savignyi*			*Agree*
HS	MOBI	0394	2D-10	*Lyonsia californica*			*Agree*
HS	CNHY	0104	2F-10	*Monobrachium parasitum*		on *Axinopsida serricata*	*Agree*
HS	ECHO	1092	E-01	*Chiridota albatrossii*			*Agree*
HS	BRYO	0990	O-03	*Celleporella hyalina*			*Agree*
HS	ENTO	0958	O-03	*Barentsia hildegardae*	*Could not confirm species*	Distinct from *Barentsia discreta* in Kozloff (Lights Manual)	*Barentsia sp.*
			)-03	*Also Bowerbankia gracilis and Clytia sp. in vial*			
PA	MOBI	0384	2E-10	*Rochefortia tumida*	*Synonym of Mysella tumida*	Synonym of *Kurtiella tumida*	*Agree*
PA	MOBI	0418	2E-09	*Pandora bilirata*			*Agree*
PA	MOBI	0412	2E-08	*Nuculana minuta*			*Agree*
PA	MOBI	0356	2E-07	*Cyclocardia* sp.	*Probably C. ventricosa but very tiny*		*Agree*
PA	MOBI	0420	2E-06	*Chlamys* sp.			*Agree*
PA	MOGA	0512	2E-05	*Bittium munitum*	*Some confusion in literature if Bittium or Lirobittium*		*Agree*
PA	CNHY	0088	1A-01	*Garveia groenlandica*	*Could not take to species*	Synonym of *Rhizorhagium roseum*	*Bougainvillidae indet.*
PA	HEMI	1126	1A-02	*Saccoglossus* sp.			*Agree*
PA	URAS	1132	1A-03	*Ascidia* sp.	This one took a long time!		Agree
PA	SIPN	0330	1A-04	*Nephasoma diaphanes*			*Agree*
PA	POSE	0298	1A-05	*Idanthyrsus saxicavus*	*Synonym Idanthyrsus ornamentatus thoracic palae not widened distally*		*Agree*
PA	PHOR	0950	1A-06	*Phoronis psammophila*	*Could not take to species*		*Phoronis sp.*

Region	grpcode	famcode	Locatecode	Taxon	Substitutions/Corrections/Notes	Taxonomic Comments (Biologica)	Comments (Columbia Science)
PA	POSE	0300	1A-07	*Megalomma splendida*			*Agree*
PA	POSE	0276	1A-08	*Aricidea antennata*			*Agree*
PA	POER	0188	1A-09	*Gyptis* sp.	*Damaged anterior fragment*		*Agree*
PA	POER	0226	1A-10	*Sphaerodoropsis sphaerulifer*			*Agree*
PA	POSE	0264	1B-01	*Magelona longicornis*	*Vial locator is 1B-01*		*Agree*
PA	CROS	0674	2C-02	*Bathyleberis* sp.			*Agree*
PA	CRLE	0694	2C-03	*Nebalia* sp.	*This genus is undergoing taxonomic review/revision*		*Agree*
PA	CRCU	0700	2C-04	*Diastylis umatillensis*			*Agree*
PA	CRTA	0708	2C-05	*Scoloura phillipsi*		Synonym of *Akanthophoreus phillipsi*	*Agree*
PA	CRIS	0736	2C-06	*Gnathia productatridens*	*Debated between G. trilobata and G. productatridens but agree with the latter*		*Agree*
PA	CRIS	0756	2C-07	*Gnorimospaeroma oregonense*	*Correct spelling is Gnorimosphaeroma*		*Agree*
PA	CRIS	0740	2C-08	*Ianiropsis kincaidi*			*Agree*
PA	CRIS	0750	2C-09	*Pleurogonium* sp.	Substituted *Munnogonium* sp.		*A with Munnogonium sp.*
PA	CRAM	0810	2C-10	*Photis lacia*			*Agree*
PA	ECOP	1058	2F-07	*Amphioplus strongyloplax*			*Agree*
PA	CRDE	0932	C-01	*Pinnixa occidentalis* complex			*Agree*
PR	ANOL	1133	1E-10	*Grania* sp.			*Agree*
PR	POSE	0244	1E-09	*Apistobranchus tullbergi*			*Agree*
PR	BRYO	0962	1E-08	*Alcyonidium polyoum*	*Colony fragment too small*		*Ctenostomata indet.*
PR	PORI	0020	1E-07	*Mycale* sp.	*Fragment too small to dissolve and have any left*		*Peocilosclerida indet.*
PR	BRYO	0987	1E-06	*Haywardipora rugosa*	*Not confident of species*	New species in Santa Barbara Taxonomic Atlas	*Haywardipora sp.*
PR	PORI	0022	1E-05	*Myxilla incrustans*	*features match Light's*		*Accept*
PR	URAS	1124	1E-05	*Styela gibbsii*	*Difficult but fits Styela*		*Styela sp.*
PR	CNHY	0105	1E-04	*Amphinema dinema*	*See notes*	*Perigonimus serpens* is a junior synonym	*Accept*
PR	MOGA	0542	2F-03	*Epitonium* sp.	*Vial locator is 2F-03*		*Agree*
PR	BRYO	0984	1F-01	*Crisia pugeti*	*Circular aperture*		*Agree*
PR	POER	0178	1F-02	*Euphrosine bicirrata*	*Very cool!*		*Agree*
PR	POSE	0311	1F-03	*Circeis armoricana*	*Dissected specimen could not reconstruct*		*Spirorbidae indet.*
PR	BRYO	0991	1F-04	*Disporella* sp.	*Fits description in Osburn*		*Agree*
PR	PORI	0034	1F-05	*Prosuberites* sp.	*Using Lee et al.--could not take to species*		*Hadromerida indet.*
PR	NTEA	0142	1F-06	*Carinoma mutabilis*			*Agree*
PR	BRYO	0980	1F-07	*Chaperiopsis patula*			*Agree*
PR	PORI	0038	1F-08	*Craniella spinosa*	*Could not take to species*		*Craniella sp.*
PR	CNHY	0092	1F-09	*Calycella syringa*	Spelling corrected from *Calycera syringa*		*Agree using Santa Barbara key*
PR	URAS	1115	1F-10	*Didemnum albidum*	*Fits description in Van Name especially spicules*		*Agree*
PR	PORI	0019	2A-01	*Halisarca sacra*	*Fits description in Lee et al. and Kozloff--no skeleton, fibres, spicules*		*Agree*
PR	BRYO	1002	2A-02	*Lagenicella punctulata*	*Keys to this in Light's*		*Agree*
PR	NTEA	0140	2A-03	*Amphiporus* sp.	*Ocelli*		*Agree*
PR	POER	0194	2A-04	*Lacydonia* sp.	*Good call*		*Agree*
PR	CNAN	0040	2A-05	*Epiactis* sp.	*Confirm to Actiniaria although seems to fit Epiactis sp.*		*Actiniaria indet.*
PR	PORI	0010	2A-06	*Clathrina* spp.			*Did not find*
PR	PORI	0021	2A-06	*Hymedesmia* sp.			*Demospongiae indet.*
PR	PORI	0035	2A-06	*Sycon* spp.	*Lee et al. Thought it could be Leucandra sp. but fits Sycon better*		*Agree*
PR	PORI	0009	2A-07	*Biemna rhadia*	*Biemna* sp. (no *B. rhadia* in PR) did not see sigmas		*Demospongiae indet.*
PR	BRYO	0974	2A-08	*Cellaria diffusa*	*Van Name and Osburn*		*Agree*
PR	CNHY	0101	2A-09	*Lafoea gracillima*	*Think this is another example of Calycella sp.*	Synonym of *Lafoea dumosa*	*Disagree*
PR	URAS	1116	2A-10	Mogulidae indet.	Branched tentacles		Agree
PR	CRAM	0848	2D-02	*Kamptopleustes coquillus*	*Vial locator 2D-02*		*Agree*
PR	CRDE	0898	2D-01	*Eualus herdmani*			*Agree*
PR	CRDE	0908	2D-03	Majidae indet.			Agree
PR	CRAM	0828	2D-04	*Melaphisana bola*	*Correct spelling is Melphisana fits description in Santa Barbara key*		*Agree*
PR	CRDE	0884	2D-05	*Metacrangon munita*			*Agree*
PR	CRAM	0788	2D-06	*Monocorophium sp.*	*Damaged specimen-cannot go further*		*Agree*
PR	CRCI	0693	2D-07	*Pollicipes polymerus*	*Fits description in Light's attached Demospongiaeas well*		*Agree*
PR	CRTA	0714	2D-08	*Pseudotanais sp.*			*Agree*
PR	CRAM	0838	2D-09	*Rhynohalicella halona*			*Agree*
PR	MOGA	0544	2F-01	*Balcis columbiana*	*I think Vitreolina is still correct*	Synonym of *Vitreolina columbiana*	*Agree*
PR	MOGA	0514	2F-02	*Cerithiopsis* sp.	*Damaged specimen but fits description*		*Agree*
PR	MOGA	0584	2F-04	*Euspira pallida*			*Agree*
PR	MOGA	0488	2F-05	*Melanochlamys diomedea*	*Spent time to be sure was not a Gastropteron*		*Agree*
PR	MOGA	0634	2F-06	Turridae indet.	Substituted *Oenopta* sp.	Family now revised to Mangeliidae.	Agree Oenopota sp.
PR	ECEC	1086	2F-08	*Strongylocentrotus* sp.	*Little guy*		*Agree*
PR	MOBI	0352	2F-09	*Astarte* sp.	Biologica added for internal QC		Agree
PR	PORI	0015	O-01	*Hymeniacidon* sp.	*Agree through couplet 61 in Kozloff but this is a small fragment*		*Demospongiae indet.*
PR	URAS	1122	O-02	*Halocynthia igaboja*	*Vial locator is 0-02*		*Agree*

Biologica

Environmental Services Ltd.
Marine & Freshwater Taxonomy

Sub-Sampling Accuracy Report- Marine Benthos, EEM 2012

Prepared for Hatfield Consultants, Inc.

Powell River 2012

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
PRB5-R2					
1	560	1120	-16	-1.4	1.4
2	576	1152	16	1.4	1.4
Total remaining	0				
Total in sample	**1136**	**Mean Absolute sub-sampling error (%)**			**1.4**
(actual total count)				**Min % error**	**1.4**
				Max % error	**1.4**
Correction Factor: 2					

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
PRB5A-R2					
1	340	1360	146	12.0	12
2	290	1160	-54	-4.4	4.4
3	273	1092	-122	-10.0	10
4	311	1244	30	2.5	2.5
Total remaining	0				
Total in sample	**1214**	**Mean Absolute sub-sampling error (%)**			**7.2**
(actual total count)				**Min % error**	**2.5**
				Max % error	**12**
Correction Factor: 4					

Average subsampling error (%) for Powell River (n=2 samples): 4.3

Universal average subsampling error (%) for all mills (n=6 samples): 9.0

Howe Sound 2012

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
HSB8-R3					
1	60	240	-44	-15.5	15.5
2	71	284	0	0.0	0
3	74	296	12	4.2	4.2
4	79	316	32	11.3	11.3
Total remaining	0				
Total in sample	**284**		**Mean Absolute sub-sampling error (%)**		**7.8**
(actual total count)				**Min % error**	**0**
				Max % error	**15.5**
Correction Factor: 4					

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
HSB10A-R1					
1	163	326	53	19.4	19.4
2	110	220	-53	-19.4	19.4
Total remaining	0				
Total in sample	**273**		**Mean Absolute sub-sampling error (%)**		**19.4**
(actual total count)				**Min % error**	**19.4**
				Max % error	**19.4**
Correction Factor: 2					

Average subsampling error (%) for Howe Sound (n=2 samples) : 13.6

Average subsampling error (%) for all mills (n=6 samples): 9.0

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Environmental Services Ltd.
Marine & Freshwater Taxonomy

Port Alice 2012

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
N1B1A-1					
1	257	514	58	12.7	12.7
2	199	398	-58	-12.7	12.7
Total remaining	0				
Total in sample	**456**		**Mean absolute sub-sampling error (%)**		**12.7**
(actual total count)				**Min % error**	**12.7**
				Max % error	**12.7**
Correction Factor: 2					

Sub-sample #	Number Inverts [counted]	Predicted #	Predicted - Actual	% Difference from Actual	Absolute Difference
N1B3A-3					
1	149	596	42	7.6	7.6
2	134	536	-18	-3.2	3.2
3	128	512	-42	-7.6	7.6
4	143	572	18	3.2	3.2
Total remaining	0				
Total in sample	**554**		**Mean absolute sub-sampling error (%)**		**5.4**
(actual total count)				**Min % error**	**3.2**
				Max % error	**7.6**
Correction Factor: 4					

Average subsampling error (%) for Port Alice (n=2 samples): 9.1

Average subsampling error (%) for all mills (n=6 samples): 9.0

Appendix A3

Sediment Chemistry

HATFIELD CONSULTANTS
ATTN: Colin Schwindt
200 - 850 Harbourside Drive
North Vancouver BC V7P 0A3

Date Received: 09-MAR-12
Report Date: 26-APR-12 18:16 (MT)
Version: FINAL

Client Phone: 604-926-3261

Certificate of Analysis

Lab Work Order #: L1122355

Project P.O. #: NOT SUBMITTED
Job Reference: PR1629
C of C Numbers:
Legal Site Desc:

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1122355-1	L1122355-2	L1122355-3	L1122355-4	L1122355-5
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	07-MAR-12	07-MAR-12	07-MAR-12	07-MAR-12	07-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB6	PRB6 R1	PRB6 R2	PRB5A	PRB5A R1
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	22.4			29.0	
Particle Size	% Gravel (>2mm) (%)	1.03			0.68	
	% Sand (2.0mm - 0.063mm) (%)	94.4			93.4	
	% Silt (0.063mm - 4um) (%)	4.02			4.75	
	% Clay (<4um) (%)	0.59			1.18	
Anions and Nutrients	Total Nitrogen by LECO (%)		0.030	0.022		0.028
Organic / Inorganic Carbon	Total Organic Carbon (%)		0.39	0.22		0.44
Phenolics	Pentachlorophenol (mg/kg)	<0.0020			<0.0040 DLM	
	Tetrachlorocatechol (mg/kg)	<0.0050			<0.0050	
	Tetrachloroguaiacol (mg/kg)	<0.0050			<0.0050	
	2,3,4,5-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,4,6-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,5,6-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	3,4,5-Trichlorocatechol (mg/kg)	<0.0050			<0.0050	
	3,4,5-Trichloroguaiacol (mg/kg)	<0.0050			<0.0050	
	2,3,4-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,5-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,6-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,4,5-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,4,6-Trichlorophenol (mg/kg)	<0.0020			<0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L1122355-6	L1122355-7	L1122355-8	L1122355-9	L1122355-10
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	07-MAR-12	07-MAR-12	07-MAR-12	07-MAR-12	06-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB5A R2	PRB3A	PRB3A R1	PRB3A R2	PRB3
SOIL						
Physical Tests	Moisture (%)		40.3			81.5
Particle Size	% Gravel (>2mm) (%)		0.72			3.35
	% Sand (2.0mm - 0.063mm) (%)		87.0			74.6
	% Silt (0.063mm - 4um) (%)		10.2			16.6
	% Clay (<4um) (%)		2.09			5.47
Anions and Nutrients	Total Nitrogen by LECO (%)	0.034		0.041	0.040	
Organic / Inorganic Carbon	Total Organic Carbon (%)	0.60		1.17	1.20	
Phenolics	Pentachlorophenol (mg/kg)		<0.015 DLM			<0.10 DLM
	Tetrachlorocatechol (mg/kg)		<0.015 DLB			0.138
	Tetrachloroguaiacol (mg/kg)		<0.0050			0.358
	2,3,4,5-Tetrachlorophenol (mg/kg)		<0.0020			<0.020 DLM
	2,3,4,6-Tetrachlorophenol (mg/kg)		<0.0020			<0.040 DLM
	2,3,5,6-Tetrachlorophenol (mg/kg)		<0.0020			<0.020 DLM
	3,4,5-Trichlorocatechol (mg/kg)		<0.0070 DLM			<0.070 DLM
	3,4,5-Trichloroguaiacol (mg/kg)		<0.0050			<0.020 DLM
	2,3,4-Trichlorophenol (mg/kg)		<0.0020			<0.0090 DLM
	2,3,5-Trichlorophenol (mg/kg)		<0.0020			<0.0020
	2,3,6-Trichlorophenol (mg/kg)		<0.0020			<0.0030 DLM
	2,4,5-Trichlorophenol (mg/kg)		<0.0020			<0.0050 DLM
	2,4,6-Trichlorophenol (mg/kg)		<0.0020			0.0112

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample ID / Description / Sampled Date / Sampled Time / Client ID		L1122355-11 SEDIMENT 06-MAR-12 12:00 PRB3 R1	L1122355-12 SEDIMENT 06-MAR-12 12:00 PRB3 R2	L1122355-13 SEDIMENT 06-MAR-12 12:00 PRB2	L1122355-14 SEDIMENT 06-MAR-12 12:00 PRB2 R1	L1122355-15 SEDIMENT 06-MAR-12 12:00 PRB2 R2
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)			80.8		
Particle Size	% Gravel (>2mm) (%)			5.78		
	% Sand (2.0mm - 0.063mm) (%)			65.8		
	% Silt (0.063mm - 4um) (%)			21.6		
	% Clay (<4um) (%)			6.85		
Anions and Nutrients	Total Nitrogen by LECO (%)	0.226	0.150		0.313	0.349
Organic / Inorganic Carbon	Total Organic Carbon (%)	21.8	12.3		29.2	29.3
Phenolics	Pentachlorophenol (mg/kg)			<0.035 DLM		
	Tetrachlorocatechol (mg/kg)			0.0663		
	Tetrachloroguaiacol (mg/kg)			0.0351		
	2,3,4,5-Tetrachlorophenol (mg/kg)			<0.010 DLM		
	2,3,4,6-Tetrachlorophenol (mg/kg)			<0.015 DLM		
	2,3,5,6-Tetrachlorophenol (mg/kg)			<0.0030 DLM		
	3,4,5-Trichlorocatechol (mg/kg)			<0.040 DLM		
	3,4,5-Trichloroguaiacol (mg/kg)			<0.015 DLM		
	2,3,4-Trichlorophenol (mg/kg)			<0.0020		
	2,3,5-Trichlorophenol (mg/kg)			<0.0020		
	2,3,6-Trichlorophenol (mg/kg)			<0.0030 DLM		
	2,4,5-Trichlorophenol (mg/kg)			<0.0060 DLM		
	2,4,6-Trichlorophenol (mg/kg)			0.0136		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1122355-16	L1122355-17	L1122355-18	L1122355-19	L1122355-20
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	06-MAR-12	06-MAR-12	06-MAR-12	06-MAR-12	06-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB1	PRB1 R1	PRB1 R2	PRB1A	PRB1A R1
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	84.7			41.1	
Particle Size	% Gravel (>2mm) (%)	3.90			2.55	
	% Sand (2.0mm - 0.063mm) (%)	60.4			59.9	
	% Silt (0.063mm - 4um) (%)	24.5			14.7	
	% Clay (<4um) (%)	11.2			22.9	
Anions and Nutrients	Total Nitrogen by LECO (%)		0.303	0.341		0.046
Organic / Inorganic Carbon	Total Organic Carbon (%)		26.9	32.1		3.04
Phenolics	Pentachlorophenol (mg/kg)	<0.050 DLM			<0.0080 DLM	
	Tetrachlorocatechol (mg/kg)	<0.040 DLB			<0.015 DLB	
	Tetrachloroguaiacol (mg/kg)	<0.030 DLB			<0.0050	
	2,3,4,5-Tetrachlorophenol (mg/kg)	<0.0070 DLB			<0.0020	
	2,3,4,6-Tetrachlorophenol (mg/kg)	0.0140			<0.0020	
	2,3,5,6-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	3,4,5-Trichlorocatechol (mg/kg)	<0.030 DLM			<0.015 DLM	
	3,4,5-Trichloroguaiacol (mg/kg)	<0.0090 DLM			<0.015 DLM	
	2,3,4-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,5-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,6-Trichlorophenol (mg/kg)	<0.0050 DLM			<0.0020	
	2,4,5-Trichlorophenol (mg/kg)	<0.0040 DLM			<0.0020	
	2,4,6-Trichlorophenol (mg/kg)	0.0161			0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1122355-21	L1122355-22	L1122355-23	L1122355-24	L1122355-25
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	06-MAR-12	08-MAR-12	08-MAR-12	08-MAR-12	08-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB1A R2	PRB4A	PRB4A R1	PRB4A R2	PRB4B
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)		28.8			26.1
Particle Size	% Gravel (>2mm) (%)		<0.10			18.0
	% Sand (2.0mm - 0.063mm) (%)		93.4			73.2
	% Silt (0.063mm - 4um) (%)		5.40			7.26
	% Clay (<4um) (%)		1.22			1.49
Anions and Nutrients	Total Nitrogen by LECO (%)	0.025		0.028	0.034	
Organic / Inorganic Carbon	Total Organic Carbon (%)	1.30		0.48	0.57	
Phenolics	Pentachlorophenol (mg/kg)		<0.0020			DLM <0.0040
	Tetrachlorocatechol (mg/kg)		<0.0050			<0.0050
	Tetrachloroguaiacol (mg/kg)		<0.0050			<0.0050
	2,3,4,5-Tetrachlorophenol (mg/kg)		<0.0020			<0.0020
	2,3,4,6-Tetrachlorophenol (mg/kg)		<0.0020			<0.0020
	2,3,5,6-Tetrachlorophenol (mg/kg)		<0.0020			<0.0020
	3,4,5-Trichlorocatechol (mg/kg)		<0.0050			<0.0050
	3,4,5-Trichloroguaiacol (mg/kg)		<0.0050			<0.0050
	2,3,4-Trichlorophenol (mg/kg)		<0.0020			<0.0020
	2,3,5-Trichlorophenol (mg/kg)		<0.0020			<0.0020
	2,3,6-Trichlorophenol (mg/kg)		<0.0020			<0.0020
	2,4,5-Trichlorophenol (mg/kg)		<0.0020			<0.0020
	2,4,6-Trichlorophenol (mg/kg)		<0.0020			<0.0020

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1122355-26	L1122355-27	L1122355-28	L1122355-29	L1122355-30
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	08-MAR-12	08-MAR-12	07-MAR-12	07-MAR-12	07-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB4B R1	PRB4B R2	PRB100NW	PRB100NW R1	PRB100NW R2
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)			53.5		
Particle Size	% Gravel (>2mm) (%)			1.59		
	% Sand (2.0mm - 0.063mm) (%)			82.0		
	% Silt (0.063mm - 4um) (%)			13.1		
	% Clay (<4um) (%)			3.31		
Anions and Nutrients	Total Nitrogen by LECO (%)	0.031	0.031		0.402	0.172
Organic / Inorganic Carbon	Total Organic Carbon (%)	0.49	0.49		17.2	6.83
Phenolics	Pentachlorophenol (mg/kg)			<0.0080 DLM		
	Tetrachlorocatechol (mg/kg)			<0.015 DLB		
	Tetrachloroguaiacol (mg/kg)			<0.0050		
	2,3,4,5-Tetrachlorophenol (mg/kg)			<0.0020		
	2,3,4,6-Tetrachlorophenol (mg/kg)			<0.0020		
	2,3,5,6-Tetrachlorophenol (mg/kg)			<0.0020		
	3,4,5-Trichlorocatechol (mg/kg)			<0.0090 DLM		
	3,4,5-Trichloroguaiacol (mg/kg)			<0.0050		
	2,3,4-Trichlorophenol (mg/kg)			<0.0020		
	2,3,5-Trichlorophenol (mg/kg)			<0.0020		
	2,3,6-Trichlorophenol (mg/kg)			<0.0020		
	2,4,5-Trichlorophenol (mg/kg)			<0.0020		
	2,4,6-Trichlorophenol (mg/kg)			<0.0020		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1122355-31	L1122355-32	L1122355-33	L1122355-34	L1122355-35
	Description	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
	Sampled Date	08-MAR-12	08-MAR-12	08-MAR-12	08-MAR-12	08-MAR-12
	Sampled Time	12:00	12:00	12:00	12:00	12:00
	Client ID	PRB100SE	PRB100SE R1	PRB100SE R2	PRB4	PRB4 R1
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	34.7			29.1	
Particle Size	% Gravel (>2mm) (%)	6.28			3.98	
	% Sand (2.0mm - 0.063mm) (%)	86.4			84.9	
	% Silt (0.063mm - 4um) (%)	5.94			9.79	
	% Clay (<4um) (%)	1.34			1.35	
Anions and Nutrients	Total Nitrogen by LECO (%)		0.084	0.069		0.030
Organic / Inorganic Carbon	Total Organic Carbon (%)		3.22	3.70		0.67
Phenolics	Pentachlorophenol (mg/kg)	<0.0080 DLM			<0.0040 DLM	
	Tetrachlorocatechol (mg/kg)	<0.0050			<0.0050	
	Tetrachloroguaiacol (mg/kg)	<0.0050			<0.0050	
	2,3,4,5-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,4,6-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,5,6-Tetrachlorophenol (mg/kg)	<0.0020			<0.0020	
	3,4,5-Trichlorocatechol (mg/kg)	<0.0050			<0.0050	
	3,4,5-Trichloroguaiacol (mg/kg)	<0.0050			<0.0050	
	2,3,4-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,5-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,3,6-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,4,5-Trichlorophenol (mg/kg)	<0.0020			<0.0020	
	2,4,6-Trichlorophenol (mg/kg)	<0.0020			<0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1122355-36 SEDIMENT 08-MAR-12 12:00 PRB4 R2	L1122355-37 SEDIMENT 07-MAR-12 12:00 PRB5	L1122355-38 SEDIMENT 07-MAR-12 12:00 PRB5 R1	L1122355-39 SEDIMENT 07-MAR-12 12:00 PRB5 R2	
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)		36.9			
Particle Size	% Gravel (>2mm) (%)		<0.10			
	% Sand (2.0mm - 0.063mm) (%)		88.7			
	% Silt (0.063mm - 4um) (%)		10.2			
	% Clay (<4um) (%)		1.15			
Anions and Nutrients	Total Nitrogen by LECO (%)	0.023		0.033	0.042	
Organic / Inorganic Carbon	Total Organic Carbon (%)	0.30		0.79	1.16	
Phenolics	Pentachlorophenol (mg/kg)		0.0209			
	Tetrachlorocatechol (mg/kg)		DLB <0.0080			
	Tetrachloroguaiacol (mg/kg)		<0.0050			
	2,3,4,5-Tetrachlorophenol (mg/kg)		<0.0020			
	2,3,4,6-Tetrachlorophenol (mg/kg)		<0.0020			
	2,3,5,6-Tetrachlorophenol (mg/kg)		<0.0020			
	3,4,5-Trichlorocatechol (mg/kg)		DLM <0.0060			
	3,4,5-Trichloroguaiacol (mg/kg)		<0.0050			
	2,3,4-Trichlorophenol (mg/kg)		<0.0020			
	2,3,5-Trichlorophenol (mg/kg)		<0.0020			
	2,3,6-Trichlorophenol (mg/kg)		<0.0020			
	2,4,5-Trichlorophenol (mg/kg)		<0.0020			
	2,4,6-Trichlorophenol (mg/kg)		<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Method Blank	Tetrachlorocatechol	MB-LOR	L1122355-1, -19, -22, -25, -28, -31, -34, -37, -4, -7
Method Blank	Pentachlorophenol	MB-LOR	L1122355-10, -13, -16

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLB	Detection limit was raised due to detection of analyte at comparable level in Method Blank.
DLM	Detection Limit Adjusted For Sample Matrix Effects
MB-LOR	Method Blank exceeds ALS DQO. LORs adjusted for samples with positive hits below 5 times blank level. Please contact ALS if re-analysis is required.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
C-TOT-ORG-LECO-SK	Soil	Organic Carbon by combustion method	SSSA (1996) p. 973

Total Organic Carbon (C-TOT-ORG-LECO-SK, C-TOT-ORG-SK)

Total C and inorganic C are determined on separate samples. The total C is determined by combustion and thermal conductivity detection, while inorganic C is determined by weight lass after addition of hydrochloric acid. Organic C is calculated by the difference between these two determinations.

Reference for Total C:
Nelson, D.W. and Sommers, L.E. 1996. Total Carbon, organic carbon and organic matter. P. 961-1010 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

Reference for Inorganic C:
Loeppert, R.H. and Suarez, D.L. 1996. Gravimetric Method for Loss of Carbon Dioxide. P. 455-456 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

ALS Test Code	Matrix	Test Description	Method Reference**
CP-LL-P&P-SE-MS-VA	Soil	CP-P&P-SE-MS-VA	EPA METHODS 3500B, 8041 & 8270C

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3500B, 8041 & 8270C, published by the United States Environmental Protection Agency (EPA). A sediment/soil sub-sample is extracted with basic methanol or acidified acetone. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS) and/or electron capture detection (GC/ECD).

ALS Test Code	Matrix	Test Description	Method Reference**
MOISTURE-VA	Soil	Moisture content	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

ALS Test Code	Matrix	Test Description	Method Reference**
N-TOT-LECO-SK	Soil	Total Nitrogen by combustion method	SSSA (1996) P. 973-974

The sample is ignited in a combustion analyzer where nitrogen in the reduced nitrous oxide gas is determined using a thermal conductivity detector.

ALS Test Code	Matrix	Test Description	Method Reference**
PSA-PIPET+GRAVEL-SK	Soil	Particle size - Sieve and Pipette	SSIR-51 METHOD 3.2.1

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA

Chain of Custody Numbers:

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

10- 115183

ALS Environmental

ustody / Analytical Request Form
da Toll Free: 1 800 668 9878
www.alsglobal.com

Page ___ of ___

Report To	Colin Schwindt
Company:	HATFIELD Consultants
Contact:	
Address:	850 Harbourside drive
Phone:	604 926 3261 Fax:

Distribution
Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: cschwindt@hatfieldgroup.com
Email 2:

Service Request: (Rush subject to availability - Contact ALS to confirm TAT)
- ✓ Regular (Standard Turnaround Times - Business Days)
- Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
- Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
- Same Day or Weekend Emergency - Contact ALS to confirm TAT

Invoice To Same as Report ? (circle) (Yes) or No (if No, provide details)
Copy of Invoice with Report? (circle) (Yes) or No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: PR1629
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only): L1122355
ALS Contact: Brent Mack
Sampler: CS / ST

Analysis Request (Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	TOC	Total Nitrogen	Chloro Phenolics	Particle Size	Number of Containers
	PRB6	March 7	12:00	sediment	✓	✓	✓	✓	4
	PRB5A	March 7	12:00	↓	✓	✓	✓	✓	↓
	PRB5	March 7	12:00	↓	✓	✓	✓	✓	↓
	PRB3A	March 7	12:00	↓	✓	✓	✓	✓	↓
	PRB3	March 6	12:00	↓	✓	✓	✓	✓	↓
	PRB2	March 6	12:00	↓	✓	✓	✓	✓	↓
	PRB1	March 6	12:00	↓	✓	✓	✓	✓	↓
	PRB1A	March 6	12:00	↓	✓	✓	✓	✓	↓
	PRB4A	March 8	12:00	↓	✓	✓	✓	✓	↓
	PRB4B	March 8	12:00	↓	✓	✓	✓	✓	↓
	PRB100NW	March 7	12:00	↓	✓	✓	✓	✓	↓
	PRB100SE	March 8	12:00	↓	✓	✓	✓	✓	↓
	PRB4	↓	↓	↓	✓	✓	✓	✓	↓

Special Instructions / Regulations / Hazardous Details

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

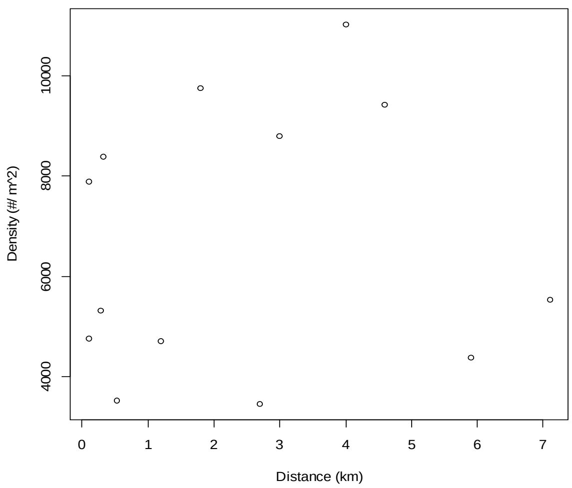
By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

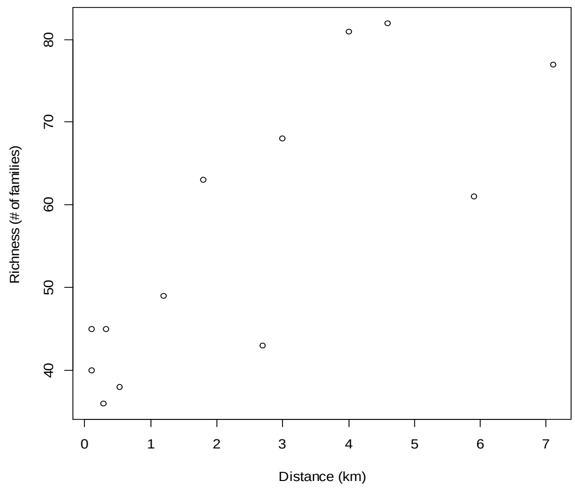
SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Colin Schwindt	Date: March 9	Time: 8:15	Received by: Britt	Date: Mar. 9	Time: 8:11	Temperature: 4.9 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

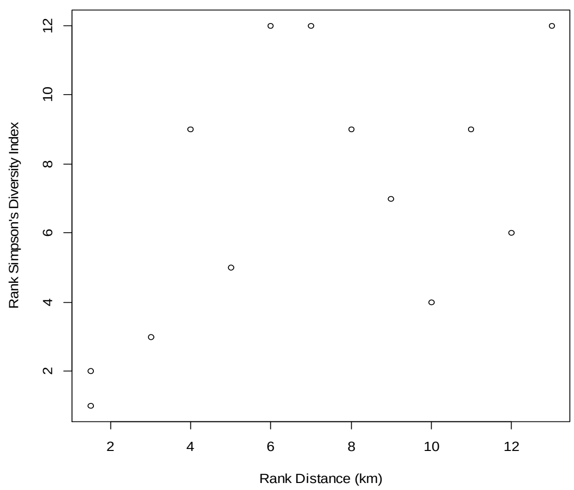
Appendix A4

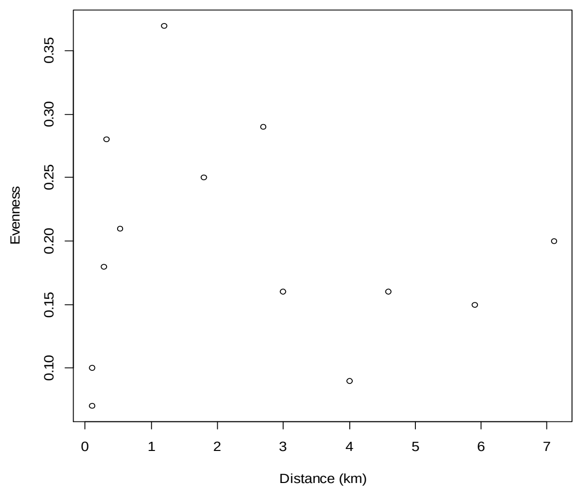
Scatter Plots of Benthic Invertebrate Statistical Analysis

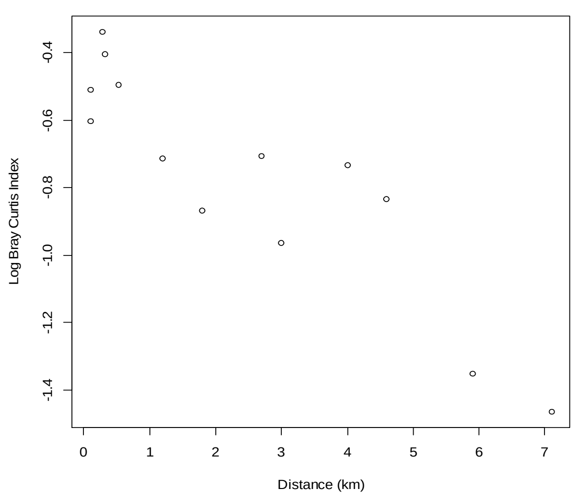
Powell River Cycle Six (2012) Benthic Invertebrate Scatter Plots by Distance











Powell River Cycle Six (2012) Benthic Invertebrate Scatter Plots by C:N

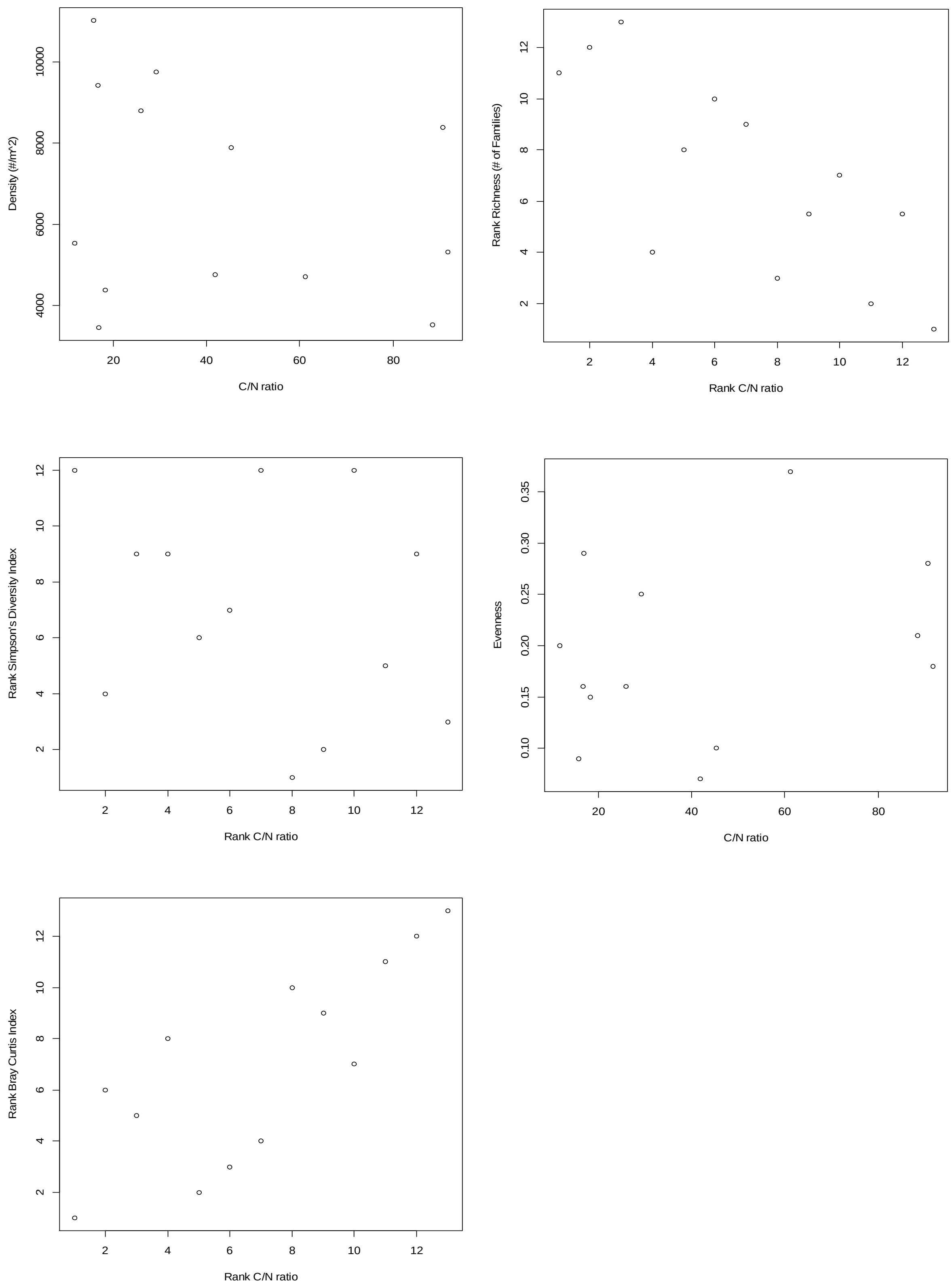


Table A4-3 Output from power analyses of regressions to detect an "effect" (r=|0.707|) on benthic invertebrates using n=13 stations along the effluent exposure gradient; Powell River Cycle Six, March 2012.

t tests - Correlation		
Analysis:	Post hoc: Compute achieved power	
Input:	Tail(s)	= Two
	Effect size |ρ|	= 0.707
	α err prob	= 0.1
	Total sample size	= 13
Output:	Noncentrality parameter δ	= 3.6045
	Critical t	= 1.7959
	Df	= 11
	Power (1-β err prob)	= 0.9578